# SCREENING FOR RESISTANCE TO *Meloidogyne incognita* (KOFOID AND WHITE) CHITWOOD IN *Aeschynomene* AND *Desmodium* SPP. AND HERBICIDE EFFECTS ON *Aeschynomene americana* L.

BY

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Root-knot nematodes (*Meloidogyne* spp.) are endemic in Florida. In Part 1 of this study, a rapid and simple greenhouse technique for screening large numbers of lines for resistance to *Meloidogyne incognita* (Kofoid and White) Chitwood was evaluated on 29 lines from five species of *Aeschynomene* and two species of *Desmodium*. The lines were grown in *M. incognita* infested and non-infested field plots, and were identified as resistant or susceptible on the basis of nematode reproduction and effect on dry matter yields. These variables were highly correlated to visual gall scores. Visual gall scores from lines grown in the greenhouse in *M. incognita* infested soil were poorly correlated with root

and shoot biomass, vigor, and degree of nodulation but did correctly identify the resistance or susceptibility of 27 of the 29 lines. This indicates that the initial screening of Aeschynomene and Desmodium lines for resistance to M. incognita can be conducted in the greenhouse. The lines were grown in the greenhouse in Meloidogyne arenaria (Neal) Chitwood infested soil, and lines appearing to be resistant were identified.

Some herbicide-nematode combinations are more detrimental to plant growth than the additive effects of each. In Part 2, a commercial source of Florida Common American jointvetch (Aeschynomene americana L.), thought to be resistant to M. incognita, and a susceptible plant introduction of A. americana were grown in a M. incognita infested field. Methyl bromide treated plots were used to assess the effects of the herbicides Trifluralin, Ethalfluralin, and Paraquat on A. americana and non-fumigated plots to assess the effects of the herbicides on M. incognita. The latter effects could not be determined because weed competition was so severe and soil populations of M. incognita so variable. Dry matter yields were significantly higher in Trifluralin treated subplots than in Paraquat treated subplots. There were no significant herbicide effects on degree of nodulation, nitrogenase activity, percent stand, or percent dry matter. Each source of Florida Common American jointvetch may require screening for resistance to Meloidogyne spp. because the source used exhibited galling symptoms in non-fumigated plots.

# INTRODUCTION

The primary goal of the Florida grassland research program is to find the most economical way to supply enough quality forage to attain an 80 to 85% calf crop and produce calves of 500 or more pounds at nine months of age. One of the stated objectives to accomplish this is to determine the best legume(s) to use in improving established bahiagrass (Paspulum notatum Flugge) pastures (Anonymous, 1978).

Breeding for disease and pest resistance is a paramount consideration in a forage legume program because chemical control measures are becoming uneconomical and the forage legume will probably be grown on the same site for several years which encourages disease and pest buildup. Root-knot nematodes (Meloidogyne spp.) are endemic in Florida and, according to Lamberti (1979), the southern root-knot nematode [Meloidogyne incognita (Kofoid and White) Chitwood] is the most important of the Meloidogyne complex in subtropical climates because of its widespread distribution, wide host range, and effect on overall yield reduction.

To keep a breeding program within manageable limits, a plant breeder must continually evaluate and discard unpromising material as soon as possible and routinely screen new germplasm for desirable characteristics. One

approach to screening forage legumes for resistance to the southern root-knot nematode involves planting these legumes in fields thought to be infested with the nematode. Subsequent evaluations, including visual observations of plant growth, examination of the roots for galling symptoms, or yield measurements may be conducted to assess the effects of the nematode on the plant. Visual evaluations are usually for characteristics such as vigor and stand. Equating plant appearance to the effects of the nematode is speculative, as nematode effects may be exacerbated by or confused with the effects of other plant pests, plant diseases, variation in soil conditions, or by the nature of the genetic material under consideration. Root galling symptoms, however, are more direct indicators of the effect of the nematode on the plant. Field infestations of nematodes are rarely uniform and a plant that may appear to be unaffected by nematodes may in fact be an escape.

Replicated yield trials are often conducted in fields thought to be infested with nematodes in order to assess the effects of the nematodes on the plant. Replicated yield trials are costly in terms of the labor and space they require. For maximum efficiency, only the most promising lines should enter these costly trials. As a consequence, yield trials are rarely conducted on material that has not been previously selected by the plant breeder. To aid in this selection process, a reliable and cost-efficient means

is needed to initially screen relatively large numbers of forage genotypes for resistance to the southern root-knot nematode. This preliminary process must be relatively simple and be highly correlated to the effects of the nematode on the plant under field conditions. Yield trials are often treated with herbicides because herbicides are considered cost-efficient when compared with the alternative of hand-weeding. Because yield trials are a test of the breeder's earlier selection efforts, more information concerning the effects of specific herbicides on the plant by nematode interaction is needed in order for the breeder to choose a herbicide that will not confound the results of his costly yield trials.

The objectives of this research were (1) to evaluate the use of a greenhouse procedure as a preliminary means of screening lines of Aeschynomene and Desmodium spp. for resistance to the southern root-knot nematode, (2) to compare greenhouse results with the effects of the nematode on these same lines in the field, and (3) to evaluate the effects of certain selected herbicides on the nematode by legume interaction under field conditions.

## REVIEW OF LITERATURE

The 1967-68 losses in the U. S. in grass and legume hay due to nematodes were estimated at $118,767,300.00 (Feldmesser, 1971). Root-knot nematodes are a major group of plant-pathogenic nematodes affecting crop production and rank among the top five major plant pathogens because of their worldwide distribution, extensive host range, and involvement with fungi and bacteria in disease complexes. The most widespread and most important agronomic species are M. incognita, Meloidogyne javanica (Treub) Chitwood, Meloidogyne hapla Chitwood, and Meloidogyne arenaria (Neal) Chitwood, in that order (Lamberti, 1979). Sasser (1979b) reported that the estimated losses in the tropics (defined for convenience as the area between the Tropic of Cancer and the Tropic of Capricorn) due to Meloidogyne spp. averaged 12.69% for all major crops. He considered these estimates conservative and stated ". . . the direct losses each year are hundreds or thousands of times greater than the amounts which will be expended . . . for research on means for alleviation of damage caused by nematodes [Meloidogyne spp.] . . ." (1979b, p. 366). In Florida, Dickson (1973) estimated that M. arenaria cost peanut (Arachis hypogea L.) producers 1.6 million dollars in 1972.

The southern root-knot nematode complex is made up of at least four races based on the parasitism of host differentials. The races of M. incognita are distributed throughout the world and are morphologically indistinguishable (Sasser, 1979a).

The life cycles of Meloidogyne spp. are similar and can be generalized. Second stage larvae hatch from eggs which may be free in the soil or embedded in a gelantinous matrix which may adhere to the root tissue of the host plant. These larvae migrate to and invade new root tips in the zone of intense meristematic activity. They penetrate the cortex, establish themselves with their anterior in contact with the vascular cylinder and, in susceptible hosts, induce the formation of giant cells upon which they feed. Galls generally form at this stage. During their development, the larvae undergo three moults. The mature females secrete a gelatinous matrix in which they lay 500-1,000 or more eggs. The number of generations per year is highly variable and is influenced by factors such as nematode species, soil temperature, soil moisture, soil nutrient status, and host species. Almost all eggs hatch under optimum conditions but there is always a variable proportion of eggs that remain alive with their development arrested at an early stage. Many of these dormant eggs are resistant to environmental stress and nematicides (Guiran and Ritter, 1979).

Breeding for resistance to the southern root-knot nematode is important because eradication on a large scale

basis is economically impractical and control through crop rotation has limited effectiveness because the nematode is polyphagous (Agrios, 1969). Further, it has been observed that resistance in low value crops such as forages often produces yields equal to those obtained with soil fumigants (Good, 1972; Netscher and Manhoussin, 1973). The movement to low energy technology agriculture coupled with the manufacturing restrictions placed on soil fumigants containing 1,2-dibromo-3-chloropropane has placed additional emphasis on breeding for resistance to nematodes in general (Fassuliotis, 1979). Some efforts in breeding for resistance to M. incognita have been spectacular as was the case with 'NC 95' tobacco (Nicotiana tabacum L.) which saved growers millions of dollars (Moore, Jones, and Gwynn, 1962). Relative to Meloidogyne spp., most breeding efforts have been directed toward the southern root-knot nematode. Over 235 cultivars in 15 major crop species, including forage legumes, have been selected or developed for resistance to M. incognita. The notable exceptions from this list are vegetable cultivars from Cucumis and Cucurbita spp. and eggplant (Solanum melongena L.). In the latter cases, resistance is either non-existent or in a sexually incompatible form (Fassuliotus and Rau, 1963; Birat, 1966; Fassuliotis, 1979).

Generally, root-knot nematode larvae invade the roots of both susceptible and resistant plants. Resistance is usually expressed by larvae that fail to develop into

reproductive adults (Webster, 1975). According to Fassuliotis and Dukes (1972), galling does not necessarily indicate nematode development. Such lack of nematode development may be of little value if the galling still causes crop loss. A plant breeder is concerned with breeding plants that can withstand nematode attack and yield as well as plants not attached by the nematode (Fassuliotis, 1979).

Nematologists usually advocate using some index that includes nematode reproduction when screening for resistance to M. incognita (Fassuliotis, 1967; Taylor, 1971). There are numerous laboratory, greenhouse, and field methods used to screen for resistance or sources of resistance to Meloidogyne spp. Dropkin, Davis and Webb (1967) screened seedlings infested with root-knot larvae on agar slants with the assumption that seedling response corresponded to older plant response. Fassuliotis and Corley (1967) used plastic growth pouches to screen seedlings for resistance and Carter, Nietro and Veech (1977) used rag dolls, normally used for seed germination tests, for the same purpose. These aforementioned methods of screening for resistance do not involve any measurements of nematode reproduction and can be conducted in the laboratory.

Most screening tests are conducted in the greenhouse because most plants can be uprooted, indexed for resistance and then replanted (Barrons, 1939; Bailey, 1940; Fassuliotis, 1979). Field plots are desirable because large populations can be grown and those plants classified as resistant can

then be selected for desirable agronomic or horticultural traits. This would not be recommended for initial screening because field plots are rarely uniformly infested (Fassuliotis, 1979). If greenhouse facilities are inadequate for initial screening and field plots are used, the method of Ross and Brim (1957) may preclude selecting escapes because a highly susceptible plant is planted in close proximity to a test plant and both are evaluated at the same time. The majority of the methods for assaying nematode reproduction are rather laborious and seem beyond the capabilities of many breeding programs. According to Holbrook (1981), the method used by Fenner (1962) to determine nematode mortality can be used to highlight egg masses on the roots of nematode-infested plants. This may be an indirect means of assaying nematode reproduction and might be less laborious and/or complicated than many other methods used for this purpose.

Root-knot nematodes often interact with other plant-pathogenic organisms causing crop losses more severe than would be expected from the additive effects of each organism. Some of these interactions include Meloidogyne-Fusarium (Powell, 1963), Meloidogyne-Verticillum (McClellan, Wilhelm, and George, 1955), Meloidogyne-Phytophthora (Nusbaum and Chaplain, 1952) and Meloidogyne-Rhizoctonia (Batten and Powell, 1971). It seems the nematode provides an entry point for the disease organism and/or predisposes the plant to attack.

Meloidogyne-herbicide interactions are less well documented but Griffin and Anderson (1978) did report that the combination of trifluralin (α,α,α,-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) and M. hapla reduced plant height and weights of tomato (Lycopersicon esculentum L.) and alfalfa (Medicago sativa L.) more than the additive effects of the nematode and the herbicide. Griffin and Anderson (1979) found that EPTC (S-ethyl dipropylthiocarbamate) reduced the resistance of 'Nev Syn XX' alfalfa to M. hapla. They also found that chlorpropham (isopropyl m-chlorocarbinilate) and DCPA (dimethyl tetrachloroterephthalate) severely reduced the root growth of alfalfa thereby reducing infection by M. hapla because of fewer infection sites. Johnson, Dowler, and Hauser (1975) reported that soil-applied herbicides (unspecified types) did not significantly affect nematode population densities.

In Florida, land is frequently cleared and vegetables planted year after year until the buildup of soil pests, including nematodes, and diseases makes vegetable production uneconomical. Then, grass pastures are often planted on this land with the idea that grass is a less suitable host to the pests and diseases and will reduce the soil populations of pests and diseases while making the land economically productive. This practice often precludes the use of some forage legumes in these pastures. Kretschmer, Sonoda, and Snyder (1980) report that 'Florida' carpon desmodium

[Desmodium heterocarpon (L.) DC.], a tropical forage legume released in Florida, is highly susceptible to root-knot nematodes and should not be planted in areas infested with these nematodes. They did report that Florida Common American jointvetch (Aeschynomene americana L.) was resistant to Meloidogyne spp. Rhoades (1980) reported that A. americana exhibited a high degree of resistance to M. incognita and might have use as a cover crop for the purpose of reducing soil populations of M. incognita.

## MATERIALS AND METHODS

The study was conducted in two parts. In Part 1, 18 genotypes from five species of the genus Aeschynomene and 11 genotypes from two species of the genus Desmodium were screened for resistance to the southern root-knot nematode (Tables 1, 2, and 3). These genoytpes were selected because of their potential as forage legumes in the state of Florida (Quesenberry, personal communication*) and the availability of sufficient seed to complete this part of the study. Aeschynomene americana, Desmodium barbatum (L.) Benth. and Oerst., and D. heterocarpon were the genera and species of primary interest. Aeschynomene brasiliana (Poir.) DC., Aeschynomene indica L., Aeschynomene rudis Benth., and Aeschynomene villosa Poir. in Lam. were included to increase the scope of the experiment. Since each of these latter species was represented by only one or two genotypes, no generalizations about a particular species were attempted. The central hypothesis in Part 1 of this study was that root gall scores could be used to identify genotypes that were susceptible to the southern

*K. H. Quesenberry, Associate Professor, Department of Agronomy, University of Florida, Gainesville, Florida, 1979.

Table 1. Source and identification of genotypes of *Aeschynomene americana*.

| Entry | Identification† | Origin |
|---|---|---|
| 1 | P.I. 421680 | Florida |
| 2 | Florida Common | Florida (Commercial) |
| 3 | IRFL 1982 | Brazil |
| 4 | IRFL 2054 | Leticia Colombia |
| 5 | P.I. 420304 | Australia |
| 6 | P.I. 420313 | Australia |
| 7 | P.I. 420314 | Australia |
| 8 | CIAT 2868 | Valle del Cauca Colombia |
| 9 | CIAT 9666 | Mato Grosso Brazil |
| 10 | CIAT 9881 | Choco Colombia |
| 11 | CIAT 9882 | Choco Colombia |

† P.I. = USDA plant introduction number; IRFL = Indian River Field Lab number assigned by Dr. A. E. Kretschmer, Jr.; CIAT = Centro Internacional de Agricultura number, Cali, Colombia.

Table 2. Source and identification of genotypes of Aeschynomene spp.

| Entry | Species | Identification† | Origin |
|---|---|---|---|
| 12 | brasiliana | CIAT 7011 | Herrera Panama |
| 13 | " | IRFL 2017 | Brazil |
| 14 | indica | P.I. 420283 | Australia |
| 15 | " | P.I. 420288 | Australia |
| 16 | rudis | CIAT 9875 | Antioquia Colombia |
| 17 | villosa | IRFL 2925 | Yumbo Colombia |
| 18 | " | IRFL 2929 | Lologuerrero Colombia |

† CIAT = Centro Internacional de Agricultura Tropical number, Cali, Colombia; IRFL = Indian River Field Lab number assigned by Dr. A. E. Kretschmer, Jr.; P.I. = USDA plant introduction number.

Table 3. Source and identification of genotypes of *Desmodium* spp.

| Entry | Species | Identification† | Origin |
|---|---|---|---|
| 19 | barbatum | CIAT 3010 | Cochabamba Bolivia |
| 20 | " | CIAT 3125 | Vichada Colombia |
| 21 | " | CIAT 3239 | Belize |
| 22 | " | CIAT 3563 | Monagas Venezuela |
| 23 | heterocarpon | CIAT 3116 | (ex Florida) |
| 24‡ | " | P.I. 317049 | India |
| 25 | " | 'Florida' Carpon | India |
| 26‡ | " | P.I. 317049 | India |
| 27 | " | CIAT 3669 | India |
| 28 | " | CIAT 3671 | Fiji Islands |
| 29§ | " | CIAT 3670 | Fiji Islands |

† CIAT = Centro Internacional de Agricultura Tropical number, Cali, Colombia; P.I. = USDA plant introduction number.

‡ Received as P.I. 317049 from the Southern Regional Plant Introduction Station and as IRFL #854 from Dr. A. E. Kretschmer, Jr.

§ Received as *D. heterocarpon* but identified by some as *D. heterocarpon* var. ovalifolium.

root-knot nematode. Essential to this hypothesis was the correlation between gall scores and the effect of the nematode on the plant (plant growth) and between gall scores and the effect of the plant on the nematode (nematode reproduction).

In part 2 of this study, two genotypes of A. americana were studied to determine the effects of three herbicides on the legume and the southern root-knot nematode. 'Treflan' (α,α,α,-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine), 'Sonalan' (N-ethyl-N(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine), and Paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) were the herbicides selected because of their effects on the weeds that were expected to be the major source of competition.

## Part 1

### Greenhouse 1980

On 15 January 1980, seeds from each entry were mechanically scarified and germinated in Petri dishes. The seedlings were planted in 20.5 cm 'Conetainers' filled with a 3:1 mixture of sterilized Pomona sand (sandy, siliceous, hyperthermic Ultic Haplaquod) and vermiculite. The mixture had been amended with sufficient ground limestone to raise the pH to 6.0 (determined with a 'Coleman metrion IV' pH meter). The seedlings were inoculated at planting with 'Nitragin' 'EL' culture Rhizobium (cowpea type).

The seedlings were placed in a growth room with a 13-hour day length and daytime and nighttime temperatures of 32 and 26°C, respectively, in an attempt to simulate late spring and early summer light and temperature conditions in mid-Florida. The seedlings were watered when necessary and amended biweekly with a phosphorous-potassium solution. Light intensity in the growth room could not be increased beyond 100 $\mu Em^{-2}$ $sec^{-1}$. After eight weeks, the seedlings were moved to a greenhouse because of very slow plant growth. Daytime and nighttime temperatures in the greenhouse ranged from 43 to 24°C, respectively.

On 26 March 1980, the seedlings were infested with M. incognita eggs separated from the roots of 'Rutgers' tomato plants by the method of Hussey and Barker (1973). Three levels of infestation were used: no infestation; 1 egg/g soil; and 10 eggs/g soil.

Six and 10 weeks after infestation, three plants selected at random from each entry-treatment combination were visually scored for degree of root galling, degree of vigor, and degree of nodulation. Galling was scored on a 0-5 scale where 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls. Vigor was scored on a 0-5 scale; 0 = a dead plant and 5 = a very vigorous plant. Nodulation was also scored on a 0-5 scale; 0 = no nodules and 5 = a well nodulated plant. In addition, root and top weights were determined for each plant.

Field 1980

In the summer of 1980, the study was continued at the Agronomy Farm and the Beef Research Unit (BRU). The Agronomy Farm is located near the campus of the University of Florida, Gainesville, Florida, and is typified by Kendrick fine sand (loamy, siliceous, hyperthermic Arenic Paleudult). The BRU is located approximately 10 miles north of Gainesville, Florida, and is typified by Pomona sand. The soil pH at both locations was 5.6 or above (determined by the Florida Cooperative Extension Service, Gainesville, Florida).

On 10 May 1980, seeds from all entries were mechanically scarified and germinated in Petri dishes. The seedlings were inoculated with 'Nitragin' 'EL' culture Rhizobium (cowpea type) and planted in 20.5 cm 'Conetainers' or in 'Speedling' trays filled with a 1:1 mixture of sterilized Pomona sand and 'Jiffy Mix' (peat + vermiculite). On 4 June 1980, one-half of the seedlings of each entry were infested with one M. incognita egg/g soil; the eggs obtained as described previously.

Both locations were fertilized with 448 kg/ha of 0-10-20 fertilizer that had been amended with 'FTE 503' (contains the equivalent of 9.6% $B_2O_3$, 3.8% CuO, 25.7% $Fe_2O_3$, 9.7% MnO, 0.3% $MoO_3$, and 8.7% ZnO by weight) at the rate of 20 kg/metric ton of fertilizer. After fertilization, the soil fumigants 'D-D' (AI 1,3-dichloropropene and 1,2-dichloropropane) at the rate of 128 l/ha and 'Telone II' (AI, 1,3-

dichloropropene) at the rate of 173 l/ha were applied at the Agronomy Farm and the BRU, respectively, in an attempt to reduce the soil population of the southern root-knot nematode. The fumigants were applied with a chisel applicator at a depth of approximately 20 cm with an inter-chisel spacing of 45 cm. A minimum of two weeks between fumigant application and planting elapsed to alleviate any phytotoxic effects of the fumigants.

On 18 and 25 June, the seedlings were transplanted at the Agronomy Farm and the BRU, respectively. Because of seed quantity, it was necessary to conduct this experiment on spaced plants. The paired-plot technique was used with three replications at each location with one plot planted with non-infested plants and its sister plot planted with infested plants of the same genotype. A plot consisted of a row of nine plants with an intra-row spacing of 0.5 m and an inter-row spacing of 1.0 m. Throughout this experiment, supplemental irrigation was provided when necessary and weed control was accomplished by hand.

Three dry matter harvests were made at 6-week intervals beginning eight weeks after transplanting. A harvest consisted of hand-cutting three randomly selected plants from each plot, excluding end-of-row plants. The remaining unharvested plants in each plot were cut back to the same height as those plants harvested for dry matter.

Seventeen weeks after transplanting, one randomly selected plant was dug with a shovel from each plot. The

root system was visually scored for degree of root galling on the same 0-5 scale used previously. Approximately 10 grams of root material were cut into 5 mm pieces and incubated for 24 hours using a modified Baermann technique (Dunn, personal communication*) for the purpose of assaying nematode reproduction. Three sub-samples were drawn to count M. incognita larvae, the counts averaged for each plot and adjusted to reflect nematode numbers per 10 grams of root material.

Greenhouse 1981

In January 1981, the 1980 greenhouse experiment was conducted again because of missing data, to check repeatability of the results, and to obtain additional data. On 5 January, 15 seeds from all entries were mechanically scarified and germinated in Petri dishes. The germinating seedlings were planted in 10.3 cm diameter plastic pots. Pots were used instead of 'Conetainers' because it had been hypothesized that the slow plant growth seen in the 1980 greenhouse experiment may have been due, in part, to the limited volume of the 'Conetainers.'' The pots were filled with sterilized Pomona sand that had been amended with ground limestone to bring the pH to 6.0 (determined with a 'Coleman metrion IV' pH meter) and with a 448 kg/ha

*R. A. Dunn, Extension Nematologist, Department of Entomology and Nematology, University of Florida, Gainesville, Florida, 1980.

equivalent of 0-10-20 fertilizer containing 20 kg of 'FTE 503' per metric ton of fertilizer. The decision to use soil instead of a soil-vermiculite mixture was made because of the difficulty encountered previously in separating root material from the vermiculite. The seedlings were not inoculated with Rhizobium because some of the entries nodulated poorly or not at all in the preceding experiments. The seedlings were placed in a greenhouse where daytime and nighttime temperatures ranged from 32 to 22°C, respectively. All plants were watered when necessary and fertilized biweekly with a 12-10-20 fertilizer containing trace elements.

On 24 January, one-third of the plants from each entry were infested with 10 M. incognita eggs/g soil; one-third were infested with 10 M. arenaria eggs/g soil; and the remaining third served as a check. The nematode eggs were obtained as previously described.

Ten weeks after infestation, all plants were scored for degree of root galling and degree of root growth. Root galling was visually scored on the 0-5 scale used previously. Degree of root growth was assayed by two methods. The first was a visual evaluation on a 0-5 scale; 0 = normal root growth and 5 = little or no secondary root growth. The second method was to immerse the root system of each plant in 500 ml of water and record the amount of water the root system displaced. Two D. heterocarpon genotypes reported to be resistant to Meloidogyne spp., IRFL #1699 and #1946

(Kretschmer et al., 1980), were added to this experiment as entries #30 and #31. They were infested with M. arenaria and M. incognita and scored for degree of root galling but not for root growth.

## Part 2

In May of 1981, the study was continued at the Agronomy Farm on the same site used in Part 1 of the study. A commercial seed source of Florida Common American jointvetch, thought to be resistant to M. incognita (Kretschmer et al., 1980; Rhoades, 1980), and entry #9, found to be susceptible to the southern root-knot nematode in Part 1 of the study, were used in an attempt to assess the effects of the herbicides on A. americana and M. incognita.

The site was fertilized at the rate of 448 kg/ha with an 0-10-20 fertilizer that had been amended with 20 kg of 'FTE 503' per metric ton of fertilizer. Subsequent to fertilization, 16 4 x 8 meter plots were fumigated with methyl bromide at the rate of 2.2 kg/9.8 $m^2$. The purpose of the fumigation was to remove as much competition as possible so that the effects of the herbicides on the legume could be assessed. A split-split-split-plot design of eight replications was used. A whole plot consisted of two 4 x 8 meter areas (one fumigated and one non-fumigated) to which one genotype of Aeschynomene was planted, a subplot consisted

of one 4 x 8 meter area (fumigated and non-fumigated), and a sub-sub-plot consisted of one 2 x 4 meter area to which a herbicide treatment was applied: check, 'Treflan', 'Sonalan', or Paraquat. This design was chosen inasmuch as herbicide effects were the area of primary interest.

Immediately prior to planting, one sub-sub-plot in each subplot was sprayed with 'Treflan' at the rate of 0.56 kg/ha and incorporated with a rototiller. Following this, the entire site was cultipacked and hand-broadcast with seed that had been mechanically scarified and coated with a mixture of 'Pel-gel' sticker and 'Nitragin' 'El' culture Rhizobium (cowpea type). Sufficient seed, based on a 25% emergence rate, was broadcast in an effort to assure one plant every 25.8 $cm^2$. Immediately following planting, the site was cultipacked and one sub-sub-plot in each subplot was sprayed with 'Sonalan' at the rate of 1.0 kg/ha. The entire site was sprinkler-irrigated the same day and irrigation was subsequently provided as often as possible in an effort to aid germination and emergence. After seedling emergence, irrigation was provided when necessary. On 28 May, one sub-sub-plot in each subplot was sprayed with Paraquat at the rate of 0.25 kg/ha.

During the period 29 June to 2 July, two plants from each sub-sub-plot in the fumigated subplots were selected at random, dug, and assayed for nitrogenase activity ($C_2H_2$ reduction). Acetylene reduction assays were not conducted on non-fumigated sub-plots because of severe weed growth.

Tops and roots of those plants dug were separated and the root system scored for degree of galling and nodulation using the scales previously described. The root system of each plant was placed in individual 0.96 ℓ glass jars the tops of which had been fitted with serum stoppers. A volume of air equal to the volume of acetylene to be injected was withdrawn from the jars and the reaction initiated by acetylene injection to 10% (v/v). At 30 and 60 minutes after acetylene injection, 0.5 ml was withdrawn from each jar and assayed with a 'Varian' model 940 gas chromatograph for acetylene and ethylene. The tops and roots from each plant assayed were dried and weighed. Acetylene reduction values were adjusted to nM/hr/g of plant biomass.

On 8 July, a 1 x 3 meter area of each sub-sub-plot was harvested for dry matter yield with a 'Carter' plot harvester. Prior to harvest, each sub-sub-plot was visually scored for percent Aeschynomene and the dry matter yield was adjusted to reflect the amount of Aeschynomene harvested based on this visual estimate. After harvest and on 13 August, two plants selected at random from each sub-sub-plot in non-fumigated subplots were dug and the root system visually scored for degree of root galling using the scale described previously.

Data from both parts of the study were analyzed at the Northeast Regional Data Center of the State University System of Florida, Gainesville, FL 32611, using the

Statistical Analysis System (SAS) on an 'Amdahl 470 V/6-II' computer with OS/MVS Release 3.8 and JES 2/NJE Release 3.0. Because the data were unbalanced in the sense that there were unequal numbers of entries in different species, the data were analyzed by species.

## RESULTS AND DISCUSSION

### Part 1

#### Greenhouse 1980

As indicated previously, plant growth was less than satisfactory. Roots of some entries were necrotic at both sampling dates which may have been due to the effects of the southern root-knot nematode but was probably compounded by the conditions in the growth room. Galling symptoms were more pronounced and thus easier to score at the higher infestation rate and at the 10-week sampling date.

Seven of the 11 genotypes of A. americana tested appeared to be susceptible to the southern root-knot nematode (Table 4). No reason can be given to explain why entry #9 showed galling symptoms at the 6-week sampling date but not at the 10-week sampling date. Vigor was the only variable significantly correlated to gall scores but the correlation coefficient of -0.17 seemed too low to be of any value (Table 5). It is not surprising that top weight, root weight, vigor, and degree of nodulation are significantly correlated. In effect, the first three variables are indirect measurements of each other and because

Table 4. Gall scores in response to *Meloidogyne incognita* for 11 genotypes of *Aeschynomene americana* at two sampling dates and two rates of infestation (Greenhouse 1980).

| Entry | Sampling Date | | | |
|---|---|---|---|---|
| | 6-week | | 10-week | |
| | 1 egg/g soil | 10 eggs/g soil | 1 egg/g soil | 10 eggs/g soil |
| | gall scores† | | | |
| 1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.0 | 0.0 | 1.3 | 1.3 |
| 4 | 0.0 | 0.0 | 0.0 | 2.0 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.0 | 0.0 | 0.0 | 2.0 |
| 7 | 0.0 | 2.0 | 3.0 | 4.0 |
| 8 | 1.0 | 0.0 | 0.0 | 0.0 |
| 9 | 3.0 | 3.0 | 0.0 | 0.0 |
| 10 | 2.0 | 0.0 | 0.0 | 4.0 |
| 11 | 3.0 | 2.0 | 0.0 | 3.0 |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

Table 5. Correlation of gall scores with top weight, root weight, plant vigor, and degree of nodulation in response to Meloidogyne incognita for 11 genotypes of Aeschynomene americana (Greenhouse 1980).

| | Top Weight | Root Weight | Plant Vigor | Nodulation Score |
|---|---|---|---|---|
| Gall Scores | -0.01 | 0.08 | -0.17* | -0.01 |
| Top Weight | | 0.79** | 0.40** | 0.35** |
| Root Weight | | | 0.31** | 0.34** |
| Plant Vigor | | | | 0.53** |

*, ** Significance at the 5 and 1% probability level, respectively.

no nitrogen fertilizer was provided the plants, degree of nodulation would be expected to have a direct bearing on plant growth.

Two of the genotypes tested in the remaining species of Aeschynomene showed galling symptoms in response to M. incognita (Table 6).

One of the four genotypes of D. barbatum tested appeared to be susceptible to M. incognita (Table 7). The positive significant correlation between gall scores and top weight may not be meaningful (Table 8). The southern root-knot nematode is expected to adversely affect the growth of susceptible plants, so this correlation should be negative for significance. The positive significant correlation between gall scores and root weight may be meaningful because the root system of a heavily galled plant might weigh more than the healthy root system of a plant of the same genotype.

All genotypes of D. heterocarpon tested seemed to be susceptible to the southern root-knot nematode (Table 7). As was the case with entry #9, entry #25 showed galling symptoms at the 6-week sampling date but not at the 10-week sampling date. The lack of a significant correlation between gall scores and the other variables and the significant correlations among the variables top weight, root weight, vigor, and degree of nodulation (Table 9) are similar to the correlations in A. americana (Table 5) and

Table 6. Gall scores in response to Meloidogyne incognita for four species of Aeschynomene at two sampling dates and two rates of infestation (Greenhouse 1980).

| Entry | Species | Sampling Date | | | |
|---|---|---|---|---|---|
| | | 6-week | | 10-week | |
| | | 1 egg/g soil | 10 eggs/g soil | 1 egg/g soil | 10 eggs/g soil |
| | | gall scores† | | | |
| 12 | brasiliana | 0.0 | 0.0 | ND‡ | ND |
| 13 | " | 0.0 | 0.0 | ND | ND |
| 14 | indica | 0.0 | 0.0 | 4.0 | 4.0 |
| 15 | " | 0.0 | 0.0 | ND | ND |
| 16 | rudis | 0.0 | 0.0 | 0.0 | 2.0 |
| 17 | villosa | 0.0 | 0.0 | 0.0 | 0.0 |
| 18 | " | 0.0 | 0.0 | 0.0 | 0.0 |

† 0 = no galls, 1 = 1-2 galls, 2 - 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

‡ ND = all plants dead at the 10-week sampling date.

Table 7. Gall scores in response to Meloidogyne incognita for two species of Desmodium at two sampling dates and two rates of infestation (Greenhouse 1980).

| Entry | Species | Sampling Date | | | |
|---|---|---|---|---|---|
| | | 6-week | | 10-week | |
| | | 1 egg/g soil | 10 eggs/g soil | 1 egg/g soil | 10 eggs/g soil |
| | | gall scores† | | | |
| 19 | barbatum | 0.0 | 0.0 | 0.0 | 0.0 |
| 20 | " | 0.0 | 0.0 | 3.5 | 3.5 |
| 21 | " | 0.0 | 0.0 | 0.0 | 0.0 |
| 22 | " | 0.0 | 0.0 | 0.0 | 0.0 |
| 23 | heterocarpon | 0.0 | 0.0 | 4.0 | 4.0 |
| 24 | " | 0.0 | 1.0 | 3.0 | 4.0 |
| 25 | " | 2.0 | 2.0 | 0.0 | 0.0 |
| 26 | " | 0.0 | 0.0 | 2.0 | 3.5 |
| 27 | " | 0.0 | 0.0 | 3.5 | 4.0 |
| 28 | " | 0.0 | 0.0 | 2.5 | 0.0 |
| 29 | " | 0.0 | 0.0 | 4.0 | 3.0 |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, 5 = over 100 galls.

Table 8. Correlation of gall scores with top weight, root weight, plant vigor, and degree of nodulation in response to Meloidogyne incognita for seven genotypes of Desmodium barbatum (Greenhouse 1980).

| | Top Weight | Root Weight | Plant Vigor | Nodulation Score |
|---|---|---|---|---|
| Gall Scores | 0.25* | 0.43* | 0.07 | 0.16 |
| Top Weight | | 0.90** | 0.63** | 0.63** |
| Root Weight | | | 0.62** | 0.64** |
| Plant Vigor | | | | 0.88** |

*, ** Significance at the 5 and 1% probability level, respectively.

Table 9. Correlation of gall scores with top weight, root weight, plant vigor, and degree of nodulation in response to Meloidogyne incognita for four genotypes of Desmodium heterocarpon (Greenhouse 1980).

| | Top Weight | Root Weight | Plant Vigor | Nodulation Score |
|---|---|---|---|---|
| Gall Scores | -0.01 | 0.03 | -0.04 | 0.09 |
| Top Weight | | 0.93** | 0.75** | 0.66** |
| Root Weight | | | 0.74** | 0.69** |
| Plant Vigor | | | | 0.83** |

**Significance at the 1% probability level.

would seem to indicate that factors other than the southern root-knot nematode affected top weight, root weight, vigor, and degree of nodulation.

Field 1980

Degree of root galling was the standard by which the effectiveness of treatments was to be judged and yield differences between treatments within entries was the measurement of the effect of M. incognita on the plant. Thus, if the non-infested treatment is galled due to indigenous soil populations of M. incognita to an extent equal to the infested treatment, the effect of the southern root-knot nematode on a genotype could not be determined. Nematodes were counted to determine if those entries that galled also supported nematode reproduction, not to determine if there were differences in the level of nematode reproduction among those entries that galled. It would seem that the environment would have to be narrowly defined and rigidly controlled in order to detect true inter-line differences in levels of nematode reproduction because of the number of factors that can affect nematode reproduction.

The data from the Agronomy Farm indicate that treatments were ineffective because those lines that galled did so whether in infested or non-infested plots (Tables 10, 11, and 12). The data from the BRU indicate that, with the exception of entry #6, the treatments were effective because

Table 10. Gall scores and nematode numbers for 11 genotypes of Aeschynomene americana grown in non-infested plots (NIP) and plots infested with Meloidogyne incognita (IIP) at two locations (Agronomy Farm and Beef Research Unit 1980).

| Entry | Agronomy Farm | | | | Beef Research Unit | | | |
|---|---|---|---|---|---|---|---|---|
| | NIP | | IIP | | NIP | | IIP | |
| | Gall | Nematode | Gall | Nematode | Gall | Nematode | Gall | Nematode |
| | scores† | no. | scores† | no. | scores† | no. | scores† | no. |
| 1 | 0.0 | 0 | 0.0 | 10 | 0.0 | 27 | 0.0 | 0 |
| 2 | 0.0 | 0 | 0.0 | 26 | 0.0 | 0 | 0.0 | 0 |
| 3 | 0.0 | 33 | 0.0 | 12 | 0.0 | 0 | 0.0 | 0 |
| 4 | 4.7 | 241 | 5.0 | 236 | 0.0 | 0 | 5.0 | 181 |
| 5 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 28 |
| 6 | 5.0 | 1034 | 5.0 | 643 | 3.0 | 682 | 5.0 | 1563 |
| 7 | 5.0 | 1437 | 4.0 | 932 | 0.0 | 0 | 5.0 | 642 |
| 8 | 5.0 | 352 | 4.3 | 248 | 0.0 | 0 | 4.3 | 208 |
| 9 | 5.0 | 414 | 5.0 | 414 | 0.0 | 0 | 4.5 | 902 |
| 10 | 5.0 | 776 | 5.0 | 1637 | 0.0 | 30 | 5.0 | 905 |
| 11 | 5.0 | 469 | 5.0 | 476 | 0.0 | 0 | 5.0 | 322 |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

Table 11. Gall scores and nematode numbers for four species of Aeschynomene grown in non-infested plots (NIP) and plots infested with Meloidogyne incognita (IIP) at two locations (Agronomy Farm and Beef Research Unit 1980).

| Entry | Species | Agronomy Farm | | | | Beef Research Unit | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | NIP | | IIP | | NIP | | IIP | |
| | | Gall | Nematode | Gall | Nematode | Gall | Nematode | Gall | Nematode |
| | | scores† | no. | scores† | no. | scores† | no. | scores† | no. |
| 12 | brasiliana | 0.0 | 0 | 0.0 | 47 | 0.0 | 0 | 0.0 | 0 |
| 13 | " | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| 14 | indica | 2.7 | 1304 | 4.7 | 1086 | 0.0 | 0 | 5.0 | 353 |
| 15 | " | 3.0 | 1068 | 3.0 | 1280 | 0.0 | 0 | 2.0 | 651 |
| 16 | rudis | 2.7 | 240 | 3.7 | 2619 | 0.0 | 0 | 0.0 | 160 |
| 17 | villosa | 0.0 | 12 | 0.0 | 23 | 0.0 | 13 | 0.0 | 0 |
| 18 | " | 4.5 | 154 | 2.5 | 80 | 0.0 | 0 | 2.3 | 154 |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, 5 = over 100 galls.

Table 12. Gall scores and nematode numbers for two species of Desmodium grown in non-infested plots (NIP) and plots infested with Meloidogyne incognita (IIP) at two locations (Agronomy Farm and Beef Research Unit 1980).

| Entry | Species | Agronomy Farm | | | | Beef Research Unit | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | NIP | | IIP | | NIP | | IIP | |
| | | Gall | Nematode | Gall | Nematode | Gall | Nematode | Gall | Nematode |
| | | scores† | no. | scores† | no. | scores† | no. | scores† | no. |
| 19 | barbatum | 0.0 | 33 | 0.0 | 16 | 0.0 | 0 | 0.0 | 0 |
| 20 | " | 4.5 | 2201 | 3.7 | 1849 | 0.0 | 0 | 4.3 | 424 |
| 21 | " | 0.0 | 70 | 0.0 | 0 | 0.0 | 0 | 0.0 | 16 |
| 22 | " | 0.0 | 0 | 0.0 | 29 | 0.0 | 0 | 0.0 | 9 |
| 23 | heterocarpon | 4.7 | 1178 | 4.7 | 1781 | 0.0 | 0 | 5.0 | 3120 |
| 24 | " | 4.5 | 1833 | 5.0 | 1146 | 0.0 | 251 | 5.0 | 4534 |
| 25 | " | 4.0 | 775 | 4.7 | 1247 | 0.0 | 0 | 5.0 | 776 |
| 26 | " | 5.0 | 2345 | 5.0 | 1007 | 0.0 | 61 | 5.0 | 3100 |
| 27 | " | 4.0 | 1573 | 5.0 | 1208 | 0.0 | 26 | 5.0 | 1332 |
| 28 | " | 4.7 | 2224 | 5.0 | 730 | 0.0 | 38 | 5.0 | 2362 |
| 29 | " | 4.5 | 1226 | 4.7 | 1321 | 0.0 | 68 | 5.0 | 1035 |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, 5 = over 100 galls.

those lines that galled did so only in infested plots. These differences may have been due to differences in the levels of soil populations of M. incognita and/or differences in the effectiveness of the soil fumigants used at the two locations. Entry #16 appeared to show galling symptoms at the Agronomy Farm but not at the BRU. This may have been due to a misclassification because the roots of this entry were rather necrotic when sampled at both locations.

Those lines that galled also supported nematode reproduction and some ungalled lines appeared to support nematode reproduction at both locations. Every effort was made to wash all soil from the root systems of those plants assayed for nematode reproduction but it is possible that some soil adhered to the root system and the nematodes seen from ungalled root systems may have been from the soil although Fassuliotis, Deakin, and Hoffman (1970) did report that normal nematode reproduction occurred on some lines of Phaseolus spp. that showed no galling symptoms in response to root-knot nematodes.

Because of these location differences, the BRU results were concluded to be the more valid estimate of the effects of M. incognita on yield. There were significant treatment differences for yield in the 11 genotypes of A. americana tested at the BRU (Table 13). Yields in non-infested plots generally increased with date of harvest and yield differences

Table 13. Dry matter yields for three harvest dates for 11 genotypes of Aeschynomene americana grown in non-infested plots and plots infested with Meloidogyne incognita (Beef Research Unit 1980).

| Entry | Treatment† | Date of Harvest | | |
|---|---|---|---|---|
| | | 17 July | 28 August | 3 October |
| | | g/3 plants | | |
| 1 | 1 | 158 | 270 | 376 |
| | 2 | 158 | 281 | 338 |
| 2 | 1 | 137 | 275 | 370 |
| | 2 | 130 | 300 | 396 |
| 3 | 1 | 176 | 219 | 402 |
| | 2 | 145 | 253 | 446 |
| 4‡ | 1 | 155 | 261 | 335 |
| | 2 | 103 | 188 | 150 |
| 5 | 1 | 126 | 255 | 335 |
| | 2 | 112 | 263 | 295 |
| 6‡ | 1 | 77 | 213 | 239 |
| | 2 | 70 | 105 | 60 |
| 7‡ | 1 | 120 | 241 | 361 |
| | 2 | 73 | 163 | 46 |
| 8‡ | 1 | 79 | 259 | 196 |
| | 2 | 27 | 221 | 142 |
| 9‡ | 1 | 128 | 294 | 394 |
| | 2 | 106 | 206 | 215 |
| 10‡ | 1 | 134 | 227 | 243 |
| | 2 | 143 | 127 | 141 |
| 11‡ | 1 | 177 | 295 | 327 |
| | 2 | 130 | 187 | 22 |
| L.S.D. (0.05) | | 41 | 67 | 73 |

† 1 = non-infested plots; 2 = infested with M. incognita.

‡ Those entries showing gall symptoms in infested plots.

between infested and non-infested plots tended to increase with date of harvest for those entries showing gall symptoms.

Gall scores were significantly correlated to all other variables for the genotypes of A. americana tested at the BRU (Table 14). Because nematode numbers were considered an indication of nematode reproduction on a plant and yield differences between infested and non-infested plots an indication of the effect of the southern root-knot nematode on the plant, it seems that field gall scores are quite useful for predicting the susceptibility of A. americana genotypes to M. incognita. It is of interest that the correlation between gall scores and nematode numbers improved when the log of nematode numbers was used in the correlation. This was probably due to the fact that gall scores were fairly consistent across replications whereas nematode numbers were highly variable.

There were significant treatment differences for yield in the genotypes of D. barbatum tested at the BRU although not in the entry that showed gall symptoms in infested plots (Table 15). The significant yield differences between treatments for entry #21 are of interest because the root system of this entry from an infested plot was not galled but did show a marked reduction in secondary root growth when visually compared with the root system of a plant from a non-infested paired-plot. This may be an example of a resistant but intolerant genotype. That is, this

Table 14. Correlation of field gall scores with dry matter yields from three harvests and with nematode numbers for 11 genotypes of Aeschynomene americana grown in non-infested plots and plots infested with Meloidogyne incognita (Beef Research Unit 1980).

| | Harvest 1 Yield | Harvest 2 Yield | Harvest 3 Yield | Total Yield | Nematode Numbers | Log Nematode Numbers |
|---|---|---|---|---|---|---|
| Gall Scores | -0.43** | -0.63** | -0.78** | -0.81** | 0.65** | 0.90** |
| Harvest 1 Yield | | 0.34** | 0.38** | 0.58** | -0.24** | -0.36** |
| Harvest 2 Yield | | | 0.59** | 0.79** | -0.47** | -0.55** |
| Harvest 3 Yield | | | | 0.94** | -0.54** | -0.72** |
| Total Yield | | | | | -0.56** | -0.74** |
| Nematode Numbers | | | | | | 0.73** |

** Significance at the 1% probability level.

Table 15. Dry matter yields for three harvest dates for four genotypes of Desmodium barbatum grown in non-infested plots and plots infested with Meloidogyne incognita (Beef Research Unit 1980).

| Entry | Treatment† | Date of Harvest | | |
|---|---|---|---|---|
| | | 17 July | 28 August | 3 October |
| | | g/3 plants | | |
| 19 | 1 | 103 | 63 | 80 |
| | 2 | 59 | 69 | 84 |
| 20‡ | 1 | 27 | 35 | 30 |
| | 2 | 29 | 9 | 0 |
| 21 | 1 | 145 | 176 | 160 |
| | 2 | 69 | 124 | 88 |
| 22 | 1 | 56 | 131 | 78 |
| | 2 | 74 | 145 | 80 |
| L.S.D. (0.05) | | 35 | 64 | 65 |

† 1 = non-infested plots; 2 = plots infested with M. incognita.

‡ Indicates those entries showing gall symptoms in infested plots.

genotype does not gall or support nematode reproduction but suffers a significant yield reduction in the presence of the southern root-knot nematode.

Gall scores were significantly correlated to all other variables in the genotypes of D. barbatum tested at the BRU (Table 16). The correlation between gall scores and yield(s) is rather low, probably because entry #21 suffered a significant yield reduction without galling. But gall scores and nematode numbers were highly correlated and because nematode reproduction is generally accepted as a measure of susceptibility, it would seem that field gall scores are an effective indication of the susceptibility of D. barbatum genotypes to M. incognita.

Four of the seven genotypes of D. heterocarpon tested at the BRU had significant yield differences between treatments in the last two harvests (Table 17). The L.S.D., in general, exceeded the yields of the remaining three genotypes at all harvests.

Gall scores were significantly correlated to all other variables except the first harvest dry matter yields in the genotypes of D. heterocarpon tested at the BRU (Table 18). As was the case with A. americana, and probably due to the same reason, the correlation between gall scores and log of nematode numbers showed a marked improvement over the correlation between gall scores and nematode numbers. It would seem that field gall scores can be used as a measure of the susceptibility of genotypes of D. heterocarpon to M. incognita.

Table 16. Correlation of field gall scores with dry matter yields from three harvests and with nematode numbers for four gentoypes of Desmodium barbatum grown in non-infested plots and plots infested with Meloidogyne incognita (Beef Research Unit 1980).

| | Harvest 1 Yield | Harvest 2 Yield | Harvest 3 Yield | Total Yield | Nematode Numbers |
|---|---|---|---|---|---|
| Gall Scores | -0.38** | -0.51** | -0.52** | -0.52** | 0.90** |
| Harvest 1 Yield | | 0.66** | 0.86** | 0.89** | -0.34** |
| Harvest 2 Yield | | | 0.80** | 0.92** | -0.45** |
| Harvest 3 Yield | | | | 0.96** | -0.46** |
| Total Yield | | | | | -0.46** |

**Significance at the 1% probability level.

Table 17. Dry matter yields for three harvest dates for seven genotypes of Desmodium heterocarpon grown in non-infested plots and plots infested with Meloidogyne incognita (Beef Research Unit 1980).

| Entry | Treatment† | Date of Harvest | | |
|---|---|---|---|---|
| | | 17 July | 28 August | 3 October |
| | | g/3 plants | | |
| 23‡ | 1 | 27 | 41 | 0 |
| | 2 | 27 | 45 | 0 |
| 24‡ | 1 | 3 | 14 | 12 |
| | 2 | 12 | 54 | 13 |
| 25‡ | 1 | 15 | 81 | 66 |
| | 2 | 19 | 33 | 0 |
| 26‡ | 1 | 34 | 121 | 70 |
| | 2 | 41 | 37 | 5 |
| 27‡ | 1 | 64 | 168 | 83 |
| | 2 | 64 | 80 | 0 |
| 28‡ | 1 | 55 | 172 | 104 |
| | 2 | 61 | 29 | 0 |
| 29‡ | 1 | 9 | 30 | 33 |
| | 2 | 18 | 32 | 22 |
| L.S.D. (0.05) | | 32 | 41 | 24 |

† 1 = non-infested plots; 2 = plots infested with M. incognita.

‡ Those entries showing gall symptoms in infested plots.

Table 18. Correlation of field gall scores with dry matter yields from three harvests and with nematode numbers for seven genotypes of Desmodium heterocarpon grown in non-infested plots and plots infested with Meloidogyne incognita (Beef Research Unit 1980).

| | Harvest 1 Yield | Harvest 2 Yield | Harvest 3 Yield | Total Yield | Nematode Numbers | Log Nematode Numbers |
|---|---|---|---|---|---|---|
| Gall Scores | 0.01 | -0.38** | -0.62** | -0.45** | 0.50** | 0.85** |
| Harvest 1 Yield | | 0.24** | 0.14 | 0.49** | -0.02 | -0.06 |
| Harvest 2 Yield | | | 0.72** | 0.93** | -0.21** | -0.35** |
| Harvest 3 Yield | | | | 0.84** | -0.38** | -0.56** |
| Total Yield | | | | | -0.27** | -0.43** |
| Nematode Numbers | | | | | | 0.64** |

**Significance at the 1% probability level.

Greenhouse 1981

Because field gall scores were generally higher than greenhouse gall scores, Taylor's (1971) description of a very resistant plant was used to divide greenhouse gall scores into two categories: a score of less than 2 indicated a resistant plant and a score of 2 or more indicated a susceptible plant. By this standard, 1981 greenhouse gall scores identified the resistance or susceptibility to M. incognita (as determined at the BRU) for 10 of the 11 genotypes of A. americana with entry #9 being misclassified as resistant (Table 19). The 1980 greenhouse gall scores also correctly identified 10 of the 11 genotypes with entry #8 being misclassified as resistant. There appeared to be variability for resistance to M. arenaria within A. americana (Table 20). Gall scores in response to M. arenaria appeared to be of a lesser magnitude than gall scores in response to M. incognita. Certain entries which galled in response to M. arenaria did not in response to M. incognita and vice versa. This suggests that two different genetic mechanisms exist within A. americana for resistance to M. arenaria and M. incognita.

The significant correlation between gall scores and root volume for A. americana (Table 21) do not seem meaningful when the data are examined (Table 22). In some entries, the non-infested root system had a larger volume than the infested root system; in other entries the opposite was

Table 19. Gall scores in response to Meloidogyne incognita for 11 genotypes of Aeschynomene americana [Beef Research Unit (BRU) 1980, Greenhouse 1980 (GH80), and Greenhouse 1981 (GH81)].

| Entry | BRU | GH80 | GH81 |
|---|---|---|---|
| | gall scores† | | |
| 1 | 0.0(R)‡ | 0.0(R) | 0.0(R) |
| 2 | 0.0(R) | 0.0(R) | 0.0(R) |
| 3 | 0.0(R) | 1.3(R) | 0.0(R) |
| 4 | 5.0(S) | 2.0(S) | 5.0(S) |
| 5 | 0.0(R) | 0.0(R) | 0.0(R) |
| 6 | 5.0(S) | 2.0(S) | 5.0(S) |
| 7 | 4.0(S) | 4.0(S) | 5.0(S) |
| 8 | 4.3(S) | 0.0(R) | 3.8(S) |
| 9 | 5.0(S) | 3.0(S) | 0.7(R) |
| 10 | 5.0(S) | 4.0(S) | 5.0(S) |
| 11 | 5.0(S) | 3.0(S) | 5.0(S) |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

‡ R = resistant and S = susceptible to M. incognita.

Table 20. Gall scores in response to two species of *Meloidogyne* for 11 genotypes of *Aeschynomene americana* (Greenhouse 1981).

| Entry | Nematode | |
|---|---|---|
| | *M. arenaria* | *M. incognita* |
| | gall scores† | |
| 1 | 0.7 | 0.0 |
| 2 | 0.3 | 0.0 |
| 3 | 1.3 | 0.0 |
| 4 | 0.0 | 5.0 |
| 5 | 0.3 | 0.0 |
| 6 | 0.7 | 5.0 |
| 7 | 2.8 | 5.0 |
| 8 | 0.0 | 3.8 |
| 9 | 0.0 | 0.7 |
| 10 | 1.5 | 5.0 |
| 11 | 0.0 | 5.0 |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

Table 21. Correlation of gall scores with root volume and with visual root scores for 11 genotypes of Aeschynomene americana (Greenhouse 1981).

| | Root Volume | Visual Root Scores |
|---|---|---|
| Gall Scores | -0.29** | 0.84** |
| Root Volume | | -0.36** |

** Significance at the 1% probability level.

Table 22. Root volume as affected by two species of Meloidogyne for 11 genotypes of Aeschynomene americana (Greenhouse 1981).

| Entry | Treatment | | |
|---|---|---|---|
| | Untreated | M. arenaria | M. incognita |
| | ml | | |
| 1† | 8.8 | 5.0 | 10.0 |
| 2‡ | 7.5 | 7.5 | 8.8 |
| 3† | 8.8 | 8.8 | 8.8 |
| 4§ | 10.0 | 8.8 | 6.3 |
| 5† | 6.3 | 8.8 | 10.0 |
| 6‡ | 6.3 | 6.3 | 5.0 |
| 7‡ | 5.0 | 6.3 | 5.0 |
| 8§ | 7.5 | 8.8 | 8.8 |
| 9§ | 7.5 | 8.8 | 7.5 |
| 10‡ | 7.5 | 6.3 | 7.5 |
| 11§ | 6.3 | 7.5 | 5.0 |

† Those lines showing gall symptoms in response to M. arenaria.

‡ Those lines showing gall symptoms in response to M. arenaria and M. incognita.

§ Those lines showing gall symptoms in response to M. incognita.

true. The significant correlation between gall scores and visual root scores may be biased in that the evaluator might unconsciously assign a more severe visual root score to a heavily galled plant than to a healthy plant. Thus, in A. americana, an assessment of root growth may be useful only in those entries not showing gall symptoms.

Dunn (personal communication*) believes that heavy root galling indicates susceptibility to M. incognita. By this description, the 1980 BRU results failed to identify the susceptibility of entries #13, #16, and #17 and the 1981 greenhouse results failed to identify the susceptibility of entry #15 to M. incognita for the seven genotypes of Aeschynomene spp. used in the study (Table 23). Resistance can be modified by plant genotype and environmental factors (Rohde, 1965). Dropkin (1969) found that 'Nematex' tomatoes grown at a soil temperature of 28°C were highly resistant to M. incognita acrita but at a soil temperature of 33°C seedlings were fully susceptible. Conversely, he observed that the resistance of the African horned cucumber (Cucumis metuliferus E. May) to M. incognita acrita increased as soil temperatures rose from 28 to 32°C. These observations may explain, in part, the differences between the 1980 BRU and 1981 greenhouse results because the conditions in the field were not the same as those in the greenhouse. Plant

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*R. A. Dunn, Extension Nematologist, Department of Entomology and Nematology, University of Florida, Gainesville, Florida, 1981.

Table 23. Gall scores in response to Meloidogyne incognita for four species of Aeschynomene [Beef Research Unit (BRU) 1980, Greenhouse 1980 (GH80), and Greenhouse 1981 (GH81)].

| Entry | Species | BRU | GH80 | GH81 |
|---|---|---|---|---|
| | | gall scores† | | |
| 12 | brasiliana | 0.0(R)‡ | ND§ | 0.8(R) |
| 13 | " | 0.0(R) | ND | 3.0(S) |
| 14 | indica | 5.0(S) | 4.0(S) | 2.0(S) |
| 15 | " | 2.0(S) | ND | 0.5(R) |
| 16[a] | rudis | 3.7(S) | 0.0(R) | 4.3(S) |
| 17 | villosa | 0.0(R) | 0.0(R) | 2.3(S) |
| 18 | " | 2.5(S) | 0.0(R) | 2.7(S) |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

‡ R = resistant and S = susceptible to M. incognita.

§ ND = no data due to death of plants.

[a] Found to be resistant at the BRU and susceptible at the Agronomy Farm.

growth of these Aeschynomene spp. was so poor in the 1980 greenhouse experiment that no generalizations of this segment of the 1980 greenhouse experiment can be made. There did appear to be variability for resistance to M. arenaria within the seven genotypes of Aeschynomene spp. (Table 24).

Both the 1980 and 1981 greenhouse gall scores correctly identified the resistance or susceptibility to M. incognita for four genotypes of D. barbatum (Table 25). There appeared to be variability for resistance to M. arenaria within the genotypes of D. barbatum tested (Table 26). Those genotypes that galled or did not gall did so to both M. arenaria and M. incognita. Also, the magnitude of the gall scores in response to the two nematodes seemed similar.

The variables gall scores, root volume, and visual root scores were significantly correlated within the genotypes of D. barbatum (Table 27). In contrast to A. americana, the non-infested entries generally had a larger root volume that did those same entries that were infested with M. arenaria or M. incognita (Table 28), indicating that an assessment of root growth may be useful in D. barbatum although these results were based on only four genotypes.

The 1980 and 1981 greenhouse gall scores correctly identified the susceptibility to M. incognita for seven genotypes of D. heterocarpon (Table 25). Entries #30 and #31 seemed to be resistant to both M. incognita and M. arenaria (Table 26). There appeared to be variability for resistance to M. arenaria in the nine genotypes of

Table 24. Gall scores in response to two species of *Meloidogyne* for four species of *Aeschynomene* (Greenhouse 1981).

| Entry | Species | Nematode | |
|---|---|---|---|
| | | *M. arenaria* | *M. incognita* |
| | | gall scores† | |
| 12 | brasiliana | 2.0 | 0.8 |
| 13 | " | 2.5 | 3.0 |
| 14 | indica | 3.0 | 2.0 |
| 15 | " | 1.3 | 0.5 |
| 16 | rudis | 5.0 | 4.3 |
| 17 | villosa | 0.3 | 2.3 |
| 18 | " | 0.0 | 2.7 |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

Table 25. Gall scores in response to Meloidogyne incognita for two species of Desmodium [Beef Research Unit (BRU) 1980, Greenhouse 1980 (GH80), and Greenhouse 1981 (GH81)].

| Entry | Species | BRU | GH80 | GH81 |
|---|---|---|---|---|
| | | gall scores† | | |
| 19 | barbatum | 0.0(R)‡ | 0.0(R) | 1.0(R) |
| 20 | " | 4.3(S) | 3.5(S) | 3.5(S) |
| 21 | " | 0.0(R) | 0.0(R) | 0.0(R) |
| 22 | " | 0.0(R) | 0.0(R) | 1.0(R) |
| 23 | heterocarpon | 5.0(S) | 4.0(S) | 2.8(S) |
| 24 | " | 5.0(S) | 2.0(S) | 4.0(S) |
| 25 | " | 5.0(S) | 2.0(S) | 3.0(S) |
| 26 | " | 5.0(S) | 3.5(S) | 3.8(S) |
| 27 | " | 5.0(S) | 4.5(S) | 4.5(S) |
| 28 | " | 5.0(S) | 2.5(S) | 3.8(S) |
| 29 | " | 5.0(S) | 3.0(S) | 4.0(S) |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

‡ R = resistant and S = susceptible to M. incognita.

Table 26. Gall scores in response to two species of Meloidogyne for two species of Desmodium (Greenhouse 1981).

| Entry | Species | Nematode | |
|---|---|---|---|
| | | M. arenaria | M. incognita |
| | | gall scores† | |
| 19 | barbatum | 3.0 | 1.0 |
| 20 | " | 3.0 | 3.5 |
| 21 | " | 0.0 | 0.0 |
| 22 | " | 1.5 | 1.0 |
| 23 | heterocarpon | 3.3 | 2.8 |
| 24 | " | 3.0 | 4.0 |
| 25 | " | 3.5 | 3.0 |
| 26 | " | 2.3 | 3.8 |
| 27 | " | 5.0 | 4.5 |
| 28 | " | 5.0 | 3.8 |
| 29 | " | 4.3 | 4.0 |
| 30 | " | 0.0 | 0.0 |
| 31 | " | 0.0 | 0.0 |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

Table 27. Correlation of gall scores with root volume and with visual root scores for four genotypes of Desmodium barbatum (Greenhouse 1981).

| | Root Volume | Visual Root Scores |
|---|---|---|
| Gall Scores | -0.41** | 0.59** |
| Root Volume | | -0.61** |

**Significance at the 1% probability level.

Table 28. Root volume as affected by two species of Meloidogyne for two species of Desmodium (Greenhouse 1981).

| Entry | Species | Treatment | | |
|---|---|---|---|---|
| | | Untreated | M. arenaria | M. incognita |
| | | ml | | |
| 19† | barbatum | 5.0 | 3.8 | 2.0 |
| 20† | " | 4.0 | 1.5 | 2.3 |
| 21 | " | 4.0 | 3.8 | 4.5 |
| 22† | " | 5.0 | 4.3 | 4.0 |
| 23† | heterocarpon | 5.0 | 3.5 | 4.5 |
| 24† | " | 10.0 | 4.3 | 4.0 |
| 25† | " | 5.0 | 4.5 | 4.5 |
| 26† | " | 6.3 | 5.0 | 8.8 |
| 27† | " | 10.0 | 4.8 | 5.3 |
| 28† | " | 5.0 | 4.3 | 4.0 |
| 29† | " | 5.0 | 4.3 | 4.3 |

† Those lines showing galling symptoms in response to both M. arenaria and M. incognita.

D. heterocarpon tested. Those entries that galled did so in response to both M. arenaria and M. incognita and gall scores in response to both nematodes were of the same general magnitude. There is no evidence to conclude that two different genetic mechanisms exist within D. heterocarpon or D. barbatum for resistance to M. arenaria and M. incognita.

The variable gall scores, visual root scores, and root volume were significantly correlated (Table 29), and the root volume of non-infested plants was generally greater than the root volume of infested plants for the seven genotypes of D. heterocarpon tested (Table 28). It would seem, therefore, that some method of assessing root growth may also be useful in D. heterocarpon.

## Part 2

The performance of the genotypes in fumigated subplots was intended to be used to assess herbicide effects and the performance in non-fumigated subplots used to assess the effects of the herbicide on the southern root-knot nematode and on the genotypes. Weed competition in the non-fumigated subplots was so severe that no assessment of dry matter yields, nitrogenase activity, or percent dry matter was attempted. Gall scores in fumigated subplots were used to determine the effectiveness of the fumigant.

Table 29. Correlation of gall scores with root volume and with visual root scores for seven genotypes of Desmodium heterocarpon (Greenhouse 1981).

| | Root Volume | Visual Root Scores |
|---|---|---|
| Gall Scores | -0.31** | 0.76** |
| Root Volume | | -0.36** |

* Significance at the 1% probability level.

Fumigation appeared to be effective because no root galling was observed in either genotype in the fumigated subplots (Table 30). There were significant herbicide effects on dry matter yields in fumigated subplots for both genotypes (Table 31). No herbicide treatment was, however, significantly different from the check. Herbicides did not seem to affect nitrogenase activity, percent dry matter, or degree of nodulation in either genotype (Tables 30, and 31).

In the non-fumigated subplots, there were no significant herbicide effects for degree of root galling or percent stand (Table 32). Root galling scores were highly variable across replications which would seem to indicate that relying on field infestations of the southern root-knot nematode for studying herbicide by nematode interaction is unsatisfactory. Also, the genotype of A. americana thought to be resistant to root-knot nematodes (Kretschmer et al., 1980; Rhoades, 1980) showed galling symptoms which would seem to require that each seed source of Florida Common American jointvetch be screened for resistance to Meloidogyne spp. before using it in a breeding program or before planting it in root-knot nematode infested fields.

Percent stand, percent dry matter, and dry matter yields were highest in 'Treflan' treated sub-sub-plots. Whether this was due to the effect(s) of 'Treflan', or because 'Treflan' treated sub-sub-plots were tilled just

Table 30. Herbicide effects on nodulation and root galling for two genotypes of Aeschynomene americana in fumigated subplots (Agronomy Farm 1981).

| Herbicide | Genotype | | | |
|---|---|---|---|---|
| | Florida Common | | CIAT #9666 | |
| | Nodulation† | Gall‡ | Nodulation† | Gall‡ |
| | scores | | | |
| None | 5.0 | 0.0 | 5.0 | 0.0 |
| 'Treflan' | 4.9 | 0.0 | 5.0 | 0.0 |
| 'Sonalan' | 4.8 | 0.0 | 4.9 | 0.0 |
| Paraquat | 5.0 | 0.0 | 4.8 | 0.0 |
| L.S.D. (0.05) | 0.6 | | 0.8 | |

† 0 = no nodules and 5 = a well nodulated plant.

‡ 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

Table 31. Herbicide effects on dry matter yields, percent dry matter (DM), and nitrogenase activity (AR) for two genotypes of Aeschynomene americana grown in fumigated subplots (Agronomy Farm 1981).

| Herbicide | Genotype | | | | | |
|---|---|---|---|---|---|---|
| | Florida Common | | | CIAT #9666 | | |
| | Yields | DM | AR | Yields | DM | AR |
| | kg/ha | % | nM/hr/g plant | kg/ha | % | nM/hr/g plant |
| None | 2618 | 21.8 | 688 | 2663 | 24.2 | 602 |
| 'Treflan' | 3087 | 26.6 | 761 | 3193 | 26.9 | 734 |
| 'Sonalan' | 2906 | 24.0 | 776 | 2421 | 25.6 | 674 |
| Paraquat | 2179 | 21.9 | 917 | 2179 | 24.1 | 903 |
| L.S.D. (0.05) | 580 | 6.2 | 804 | 854 | 6.5 | 792 |

Table 32. Herbicide effects on root galling at two sampling dates and on percent stand for two genotypes of Aeschynomene americana grown in non-fumigated subplots (Agronomy Farm 1981).

| Herbicide | Genotype | | | | | |
|---|---|---|---|---|---|---|
| | Florida Common | | | CIAT #9666 | | |
| | Stand | 8 July | 13 August | Stand | 8 July | 13 August |
| | % | —— gall scores† —— | | % | —— gall scores† —— | |
| None | 21.3 | 0.7 | 1.8 | 8.8 | 1.1 | 1.8 |
| 'Treflan' | 50.6 | 0.3 | 0.9 | 28.8 | 1.1 | 2.6 |
| 'Sonalan' | 45.0 | 0.4 | 1.0 | 13.3 | 0.9 | 2.9 |
| Paraquat | 28.8 | 0.4 | 1.7 | 16.4 | 0.8 | 2.4 |
| L.S.D. (0.05) | 29.4 | 2.0 | 0.9 | 20.2 | 2.5 | 1.3 |

† 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = over 100 galls.

prior to planting, or a combination of both cannot be concluded. Conversely, Paraquat treated sub-sub-plots had a higher percent stand and lower dry matter yields than the check treatment. This would seem to indicate that Paraquat reduces weed competition but has a detrimental effect on Aeschynomene growth.

## CONCLUSION

Genotypes resistant to M. incognita were identified in A. americana, A. brasiliana, A. villosa, and D. barbatum. One genotype of D. barbatum was identified as resistant but intolerant to the southern root-knot nematode. Visual root gall scores from plants grown in the field in plots infested with M. incognita and in check plots were highly correlated with plot yields and nematode reproduction. Visual root gall scores from plants grown in the greenhouse and infested with M. incognita were generally effective in identifying susceptible genotypes of A. americana, D. barbatum, and D. heterocarpon and seem quite suitable as a preliminary technique for screening large numbers of genotypes of these species. Visual vigor scores, degree of nodulation, and root and shoot weights of nematode-infested plants grown in the greenhouse were not useful for identifying nematode-susceptible genotypes. Root volume and visual root growth scores may be useful for assessing the effects of the nematode on the plant. Genotypes in the aforementioned species were identified that appeared to be resistant or susceptible to the peanut root-knot nematode.

There were significant differences in the effects of the herbicides 'Treflan', 'Sonalan', and Paraquat on dry

matter yields of two genotypes of A. americana. There were no significant herbicide effects on degree of nodulation, degree of root galling, nitrogenase activity, percent dry matter, or percent stand. 'Treflan' treated sub-sub-plots had the highest dry matter yields, percent dry matter, and percent stand while Paraquat treated sub-sub-plots had a higher percent stand and lower dry matter yields than check sub-sub-plots. No information was gained concerning the effects of the herbicides on M. incognita and the field did not seem a suitable environment for assessing herbicide by nematode interactions because of the variability noted in the degree of root galling symptoms across replications. The study did point out that herbicide selection could influence a study of nematode effects on dry matter yields. Florida Common American jointvetch has been reported as resistant to Meloidogyne spp. but the source of Florida Common used in Part 2 of this study showed galling symptoms which would seem to indicate that all sources of Florida Common may not be resistant to Meloidogyne spp.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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