THE PREVALENCE, HOST RANGE AND CONTROL OF *MELOIDOGYNE* SPECIES IN LEBANON

By

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MELOIDOGYNE SPECIES

TANVEER

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AN ABSTRACT OF THESIS OF

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Title: The Prevalence, host range and control of Meloidogyne species in Lebanon.

The occurrence, identity, prevalence and host range of the Meloidogyne species in Lebanon was studied through extensive field surveys, during the years 1966-67. Green house and growth chamber experiments were conducted to study the host range and control of the root-knot nematodes. Three species, M. arenaria, M. incognita and M. javanica were recorded.

One hundred and forty different host plants including 37 previously unreported hosts for M. incognita and 13 for M. javanica were collected from 17 localities of Lebanon.

Host range studies in the green house revealed that 35 out of 41 plant species tested were suitable hosts of M. incognita and M. javanica.

M. javanica was unable to parasitize two varieties of corn out of five tested and all the three varieties of pepper. Similarly, M. incognita failed to parasitize two varieties of bean, two of pea out of six varieties of each crop and two varieties of corn out of five.

Nemagon, Nemaphos and D-D soil treatments were most effective in reducing the incidence of the disease.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

Lebanon is predominantly an agricultural country. It is famous for its fruit and vegetable production which comprise 24.8% of its total exports (4). One of the handicaps in the way of further development of this industry is the serious losses caused by diseases every year.

The root-knot disease caused by Meloidogyne spp. has been commonly observed causing severe damage on many cultivated and wild plants especially on species of Chenopodiaceae, Cucurbitaceae, Gramineae, Solanaceae and also in the banana plantations. A survey conducted by Khalidy revealed that more than 94% of the up-rooted banana suckers were infested with the root-knot disease at the time of planting in various localities of Lebanon (36).

Infested plants are conspicuous in the field because of their unthrifty growth and tendency to wilt in warmer days. On the roots, galls of varying sizes are prominent (Fig. 1). When the infestation is very high, young seedlings may be killed. Thus, not only reducing the yield but some times failure of the crop results. This constitutes a major problem for the agriculture of

Lebanon.

Although the nematode problem seems to be serious, no systematic efforts have been made to study its spread and control. The present investigations were therefore under taken with the following purposes in view:

1. To study the prevalence and identity of the root-knot nematode species attacking different host plants in different areas of Lebanon.
2. To determine the host range of Meloidogyne species prevalent in Lebanon.
3. To investigate possible control measures for the root-knot disease.

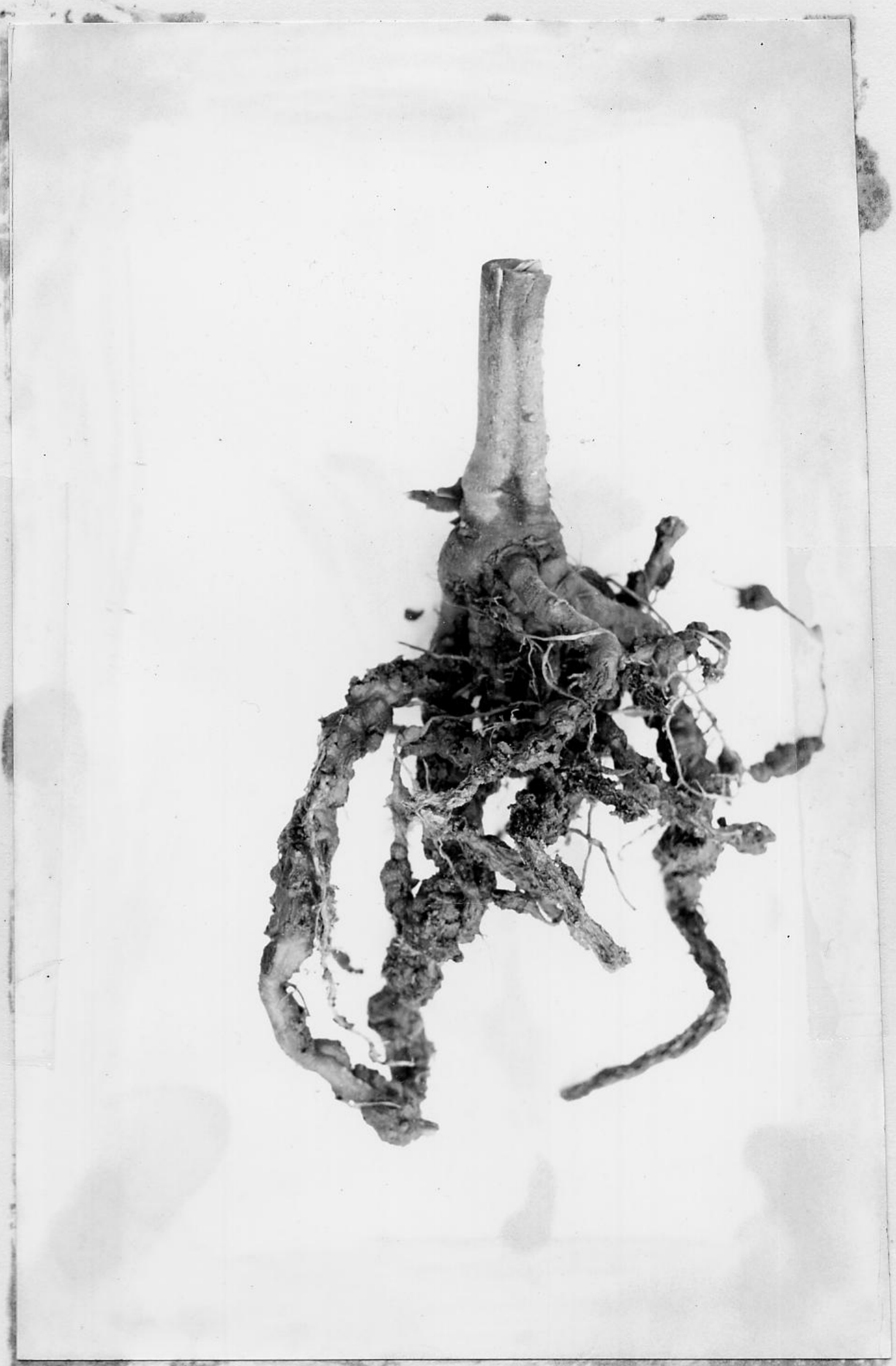


Figure 1. Tomato roots heavily affected by root-knot disease.

II. REVIEW OF LITERATURE

Geographical Distribution

The root-knot disease on plants caused by nematode species of the genus Meloidogyne is world-wide in distribution. This disease, according to Sasser (58), was first reported by Berkeley in 1855 on cucumber roots taken from a green house in England. Soon after, it was found to occur in other European countries like France, Germany, Italy, and Russia (33, pp. 892-893).

In the United States, the disease was first observed on violet plants in 1876 (58). Later on it has been reported from various other localities. Heavily infested areas include Arizona, California, Georgia, Indiana, Maryland, New York, North and South Carolina, Oklahoma, and Texas (2, 16, 37, 42, 58, 62, 65, 68).

In Asia very serious infestations were found to occur in the countries of Ceylon, India, Japan, Phillipines, and Thailand (8, 14, 35, 49). It is of common occurrence in other countries like Brazil, East Africa, Kenya, Queensland and Rhodesia (12, 27, 41, 43, 76).

Recently the pathogen has been found to occur in the Middle Eastern countries of Cyprus, Egypt, Iran,

Iraq, Israel and Lebanon (15, 18, 36, 47, 48).

Identification of the Root-Knot Nematode Species

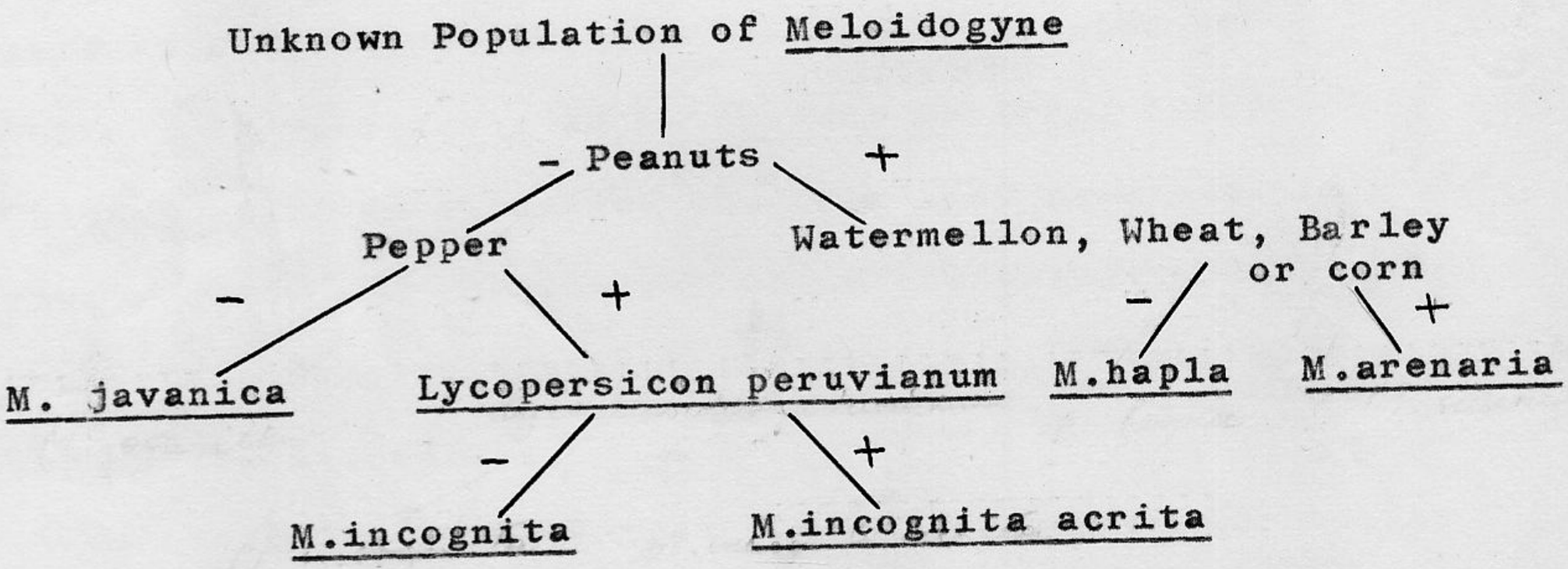
a) Morphology of the Perineal Patterns: The root-knot nematodes were grouped together under the name Heterodera marioni, up to the middle of this century, because of their marked sexual dimorphism, vermiform males, well developed oesophagus, absence of bursa, flask shaped females with two ovaries and the terminal anus.

Chitwood in 1949, according to Thorne (72, pp. 312-335), revised this group and separated them from the genus Heterodera. He assigned them to the genus Meloidogyne, which was erected by Goldei in 1887, on the basis of the form of the lip region in males, females and larvae and the anterior position of the excretory pore in the females. The females of the Meloidogyne species also differed from those of Heterodera in:

1) The laying of their eggs in an egg-sac instead of retention of eggs within the body, 2) the thin cuticle and 3) in not forming cysts (63, pp. 59-85). At the same time Chitwood separated the genus Meloidogyne into five different species and one variety on the basis of differences in the morphology of the perineal patterns of adult females (63, pp. 59-85). Since then several papers have been published showing micro-photographs of perineal patterns of various other species and some of

the variations encountered within the same species (10, 58, 66, 73, 74). Recently Southey (63, pp. 82) has put a key for the identification of 16 known species of Meloidogyne on the basis of the morphology of the perineal patterns.

b) Host Differentials: In 1954 Sasser (58) proposed a scheme for the identification of the Root-knot nematode (Meloidogyne) species by the host reaction as follows:



Soon after that it was realized by various workers (10, 11, 16, 19, 26, 44, 59, 73, 74) that different populations of the same species may vary in their ability to attack a specific host species. Such variations have been reported for M. incognita (11, 19, 20, 30, 31, 44, 54, 59, 74), M. hapla (11, 19, 20, 59, 75, 78), M. arenaria (11, 19, 20, 30, 59, 75) and M. javanica (19, 20, 26, 30, 54, 69, 71, 75, 78, 79). Due to this fact, none of the workers has then used host differentials

alone for the identification of Meloidogyne species.

Host Range

The root-knot nematodes have a very wide host range. Over one thousand species of plants have been reported as susceptible hosts to one or more species of Meloidogyne. These hosts include practically all of our field, truck, garden, orchard, ornamental and green house plants.

Until 1949 the host records of the root-knot nematodes were grouped together under the species Heterodera radicicola or Heterodera marioni. When Chitwood in 1949 separated the root-knot nematodes into five species and one variety under the genus Meloidogyne, host range reports for each of the species began appearing in the literature.

Alfalfa, bean, cotton, cucumber, egg plant, tomato and watermelon are the most commonly reported hosts of Meloidogyne spp. Goodey et al (23) published comprehensive host range records, of Meloidogyne species, that have been reported up to the end of 1963. The following are up-to-date lists of the hosts reported in the literature, for M. arenaria, M. incognita, M. incognita acrita, M. javanica and Meloidogyne spp. after 1963.

M. arenaria: Chrysanthemum morifolium (13); Ilex crenata 'convexa', I. crenata 'helleri', I. crenata

'latifolia' (32, 60).

M. incognita: Achyranthes aspera (50); Bidens biternata, Cannabis sativa (49); Celosia plumosa (50); Cosmos bipinnatus (49); Craniotome versicolor (50); Cyathocline byrata (49); Dahlia variabilis (50); Galinsoga parviflora (49); Ilex crenata 'convexa', I. crenata 'helleri', I. crenata 'latifolia' (32, 60); Impatiens gigantea, Ipomoea purporea, Mazus japonicus (50); Justicia pubigera, Nicandra physaloides (49); Sieges backia (50).

M. incognita acrita: Agrostis cawna, A. palustris, Festuca rubra (17); Ilex crenata 'helleri' (32) Poa compressa, P. trivialis (17).

M. javanica: Aerua scandens (49); Ageratum conyzoides, Argemone maxicana (50); Eupatorium odoratum (49); Gynandropis pentaphylla (50); Ilex crenata 'convexa', I. crenata 'helleri', I. crenata 'latifolia' (32, 60); Justicia simplex, Lucas aspera, Morus indica, Sida rhombifolia (50); S. vernonicafolis (49); Stellaria media (50); Trianthema monogina, T. postulaceratum (49); Zanthoxylum clava-herculis (28).

Meloidogyne spp: Calotropis procea, Lepidium virginicum Maranta arundinaceae, Musa martinii (64).

Control Measures

a) Root-Knot resistance in plants: Soon after the recognition of host specificity to Meloidogyne spp, it was found that a population of a certain species of Meloidogyne varies in its attack on different varieties of a particular species of a host. On the other hand, one variety may be resistant or immune to a population of a species of Meloidogyne but the same variety may be susceptible to other populations of the same species (7, 11, 24, 46, 54, 56, 58).

Barron (7) reported one variety of bean, Albama no I, to be resistant to the root-knot nematodes. Later Allard (5) found 12 strains of beans highly resistant to M. incognita and M. incognita acrita. Among a large number of Cucurbitaceous plants tested Cucumis anguria (58) and C. sativus (78) were found to be resistant to M. arenaria, M. incognita, M. incognita acrita and M. javanica. Thomason and McKinney (70) did not find any variety of cantaloupe, cucumber, pumpkin, spuash, watermelon or wintermelon to be resistant to M. incognita or M. javanica. The reaction of many varieties of watermelon to Meloidogyne species have been tested by Sasser (58), Thomason and McKinney (70), and Winstead and Riggs (79), none of the varieties was found to be resistant against M. arenaria, M. incognita, M. incognita acrita or M. javanica. All varieties however were re-

sistant to M. hapla. The varieties and selections (Ahahu, Kalohi, 6586 (6351), 3-2 F8 and STEP 402) in tomato have been reported to be resistant to M. incognita (34). In addition to these host crops, resistant varieties have been reported in alfalfa (53, 54), Bermuda grass (57), blue grass (17), cow pea (46, 69), fig (9, pp. 72-73), gladiolus (75), lespedeza (29), peach, rose (9, pp. 72-73), sweet potato (19, 20), and tobacco (25, 26).

b) Chemical Control: During the last two decades various chemicals have been tried for the control of nematodes. Very few of these have shown to be effective and at the same time economical to use. These included 1,2-dibromo-3-chloropropane (Nemagon), O,2,4-dichlorophenyl O,O-dicthyl phosphorothioate (v-c13 Nemacide); 1, 3-dichloropropene (Telone), 1, 3-dichloropropene and 1,2-dichloropropane (D-D), O,O-dicthyl O,2-pyrazinyl phosphorothioate (Nemaphos), 3, 5-dimethyl tetrahydro-1, 3,5,2H- thiadiazinethione (Mylone), Ethylene dibromide (EDB), Ethylene dibromide 1, 3-dichloropropene (Dorlone), Methyl bromide chloropicrin (Dowfume MC-2), Sodium methyldithiocarbamate (Vapam), and tetrachlorothiophene (Penphene) (22). Nemagon, Nemaphos, EDB and D-D have been reported by many workers to be effective for the control of the root-knot nematodes (6, 21, 37, 38, 51, 52). Nusbaum (51) found EDB, D-D and Nemagon to give

satisfactory control of the root-knot nematodes on tobacco in North Carolina. D-D gave better results than EDB and Nemagon on sandy soils. Similar results on the efficacy of these nematocides have been reported (21, 37, 38, 77, 80). Efficacy of Nemagon alone for the control of the root-knot nematodes has been reported by Aycock and Sasser (6), Peachy and Hooper (52) and Ahmadi (1) on different crops.

III. MATERIALS AND METHODS

Detection and Prevalence of Meloidogyne Species

Studies on the identity and the prevalence of Meloidogyne species in Lebanon involved extensive field surveys of different localities. Specimens were collected from field crops, nursery seedlings, vegetables, fruits and flowering plants from all over Lebanon during the two years of 1966 and 1967. Apparently unthrifty plants were pulled out and checked for the presence of root-knots. Specimens of plants showing symptoms of the disease were placed in plastic bags and kept under refrigeration until checked microscopically, in the laboratory, to determine the species of the pathogen.

Species determination was based on the characteristics of the female perineal patterns (63, pp. 82-85; 66, 72, pp. 312-335). In addition host differentials were also used in some cases (58).

a) Perineal Patterns: These were examined as follows: Egg-laying females were obtained from infected roots by maceration in a morter and pestle with a small quantity of water. The macerate so prepared contained nematode females, eggs, migratory larvae and plant tissue material. With the help of a dissecting stereo-

scopic microscope, the females were picked-up by a fine dropper and placed on a microscopic slide. At a point slightly posterior to the female's widest part, a puncture was made to allow the escape of body contents. The female body was then lifted with a needle to a drop of water on another slide. The posterior end of the body was then cut-off resulting in a more or less cup-like piece of body wall. The edge of this cup-like piece of wall was cut close to the cuticular area showing the perineal pattern. Granular material was removed by cleaning with a camel-hair brush. Finally the cleaned specimen was transferred to another slide containing one drop of lactophenol, for mounting. A cover-slip was gently placed over the specimen and excess lactophenol was blotted out. For each of the infected plants up-to-10 perineal patterns were examined under a phase contrast microscope with magnifications of 600 x to 2000 x. The patterns of the collected specimens were compared with the descriptions and photographs made by Southey (63, pp. 59-85), Sasser (58), and Taylor et al (66).

b) Host Differentials: Soil samples from Maachouk-Sour and Daura areas, heavily infested with M. incognita and M. javanica respectively, were collected along with infected roots of plants. The infected roots were chopped into small pieces and mixed with the soil. Sterilized sand was mixed with the infested soil sample in the ratio of 1:1. The resulting soil mixture was

placed in flats measuring 8 x 32 x 52 cm. To increase the nematode population in this soil, susceptible tomatoes of the variety 'Rutgers' were grown in the flats. After one month, when prominent galls on the tomato roots developed, the plants were removed and their roots chopped and mixed back with soil. Peanuts (local), pepper (California Wonder), tomato (Rutgers) and watermelon (Dixie Queens) were used as differential hosts. Every treatment was composed of one row of 25 plants per flat. Four flats were included as four replications. The flats were inoculated in a room under artificial light. The day temperatures ranged from 25° to 30° C and at night the range was 21° to 24° C. The flats were watered once every third day with a hand sprinkler. The reaction of the differentials was noted after 20 days of the date of sowing.

Host Range Studies on *Meloidogyne* Species

Infested fields were surveyed to determine the host range of the detected *Meloidogyne* species. Green house experiments were also carried to determine the host range of *M. incognita* and *M. javanica*.

a) *Naturally Infected Hosts*: During field surveys for the prevalence of *Meloidogyne* species, specimens of naturally infected plants were collected from cultivated, volunteer and weed hosts occurring in the area. The nematode species for each of the specimens

was determined as described earlier. Severity of the disease was recorded on the basis of visual estimation, using the following symbols:

+	to denote Low incidence
++	to denote Medium incidence
+++	to denote High incidence
++++	to denote Very high incidence

b) Green-house Studies on Host Range: Forty one plant species including field and vegetable crops were tested for their susceptibility to M. incognita and M. javanica. The experiments were conducted on the plant species grown in heavily infested soil in flats. The flats were kept in the green-house under the conditions described earlier for host differentials experiments. Data were collected 20 days after the date of sowing on; 1) the disease index and 2) the percentage of plants affected. The disease index was based on the degree of gall incidence and calculated as the number of galls per centimeter of root length. The following symbols were used to indicate the magnitudes of the disease index.

Disease Index	Average Number of Galls/cm of Root Length	Severity Indications
0	0	No infection
1	1	Very low infection
2	1-3	Low infection
3	3-6	Medium infection
4	6-9	High infection
5	9	Very High infection

The presence and identity of the nematode species in the infected roots of the experimental plants were also verified microscopically.

Varietal Resistance to Meloidogyne Species

Varieties of barley, beans, cucumber, muskmelon, peas, pepper, sweet corn, tomato, watermelon and wheat were sown in flats with soil heavily infested with M. incognita and M. javanica. The seeds were sown at a distance of two centimeters in rows six centimeters apart. Three replications were used. The experiment was conducted under room temperature conditions described earlier.

Chemical Control of the Root-Knot Disease

Flats with heavily infested soil were treated with 5 different nematocides at the rates shown in Table 1.

Table 1. The application rates of five nematocides

Treatment No.	Nematocides	Application Rate Per Flat	Application Rate Per Acre
1	Nemagon-75	0.2 ml	1 gallon
2	EDB	0.4 ml	2 gallons
3	D-D	4.6 ml	23 gallons
4	Maposol*	1.6 ml	8 gallons
5	Nemaphos	1.5 gram	2 lbs actual zinophos

The dose per flat of the liquid nematocides was diluted with 250 ml of water and applied in furrows, while Nemaphos granues were diluted with 500 grams of sand and also applied in open furrows. Each flat had two 50 cm furrows cut along its length 4 cm deep and 20 cm apart and 10 cm from sides. The furrows were covered with soil immediately after the application of the chemicals. Fifteen days later, 50 seeds of each of cabbage (Burns Wick), cucumber (Amco Green), egg plant (Florida high bush), lettuce (Romain Vert) and tomato (Marglobe) were planted in rows in each of the treated flats. The distance between the rows was six centimeters and seeds were sown one cm apart in the row. Two flats were used per treatment and two untreated flats to serve as the control. The flats were kept in a growth chamber under artificial light at 27° C and 70-80% relative humidity. Data on disease incidence was collected 18 days after seed germination.

* Maposol = 32.7% anhydrous sodium N-methyl dithiocarbomate.

IV. RESULTS AND DISCUSSION

Identity of Meloidogyne Species in Lebanon

Three species of the root-knot nematode of the genus Meloidogyne were found to occur in Lebanon. M. incognita and M. javanica are more prevalent than M. arenaria.

The female nemas, of the species Meloidogyne arenaria (Neal) Chitwood, had a low rounded arch forming an oval shaped perineal pattern, (Fig. 2). Lateral fields were marked by irregularities in the striae. Near the lateral lines there were numerous short disordered striae. The vulva was seen wide and the phasmids widely spaced often farther apart than vulval length. The perineal patterns were more or less distinct and the cuticle was thin.

Members of the species identified as Meloidogyne incognita (kofoid and White) Chitwood (Fig. 3, 4)had perineal patterns with a high arch composed of closely spaced, wavy to zig-zag striae. There was a strong tendency toward forking of both dorsal and ventral striae, along the lateral lines. The patterns in this species were very variable, in some cases these were very close to M. incognita acrita.

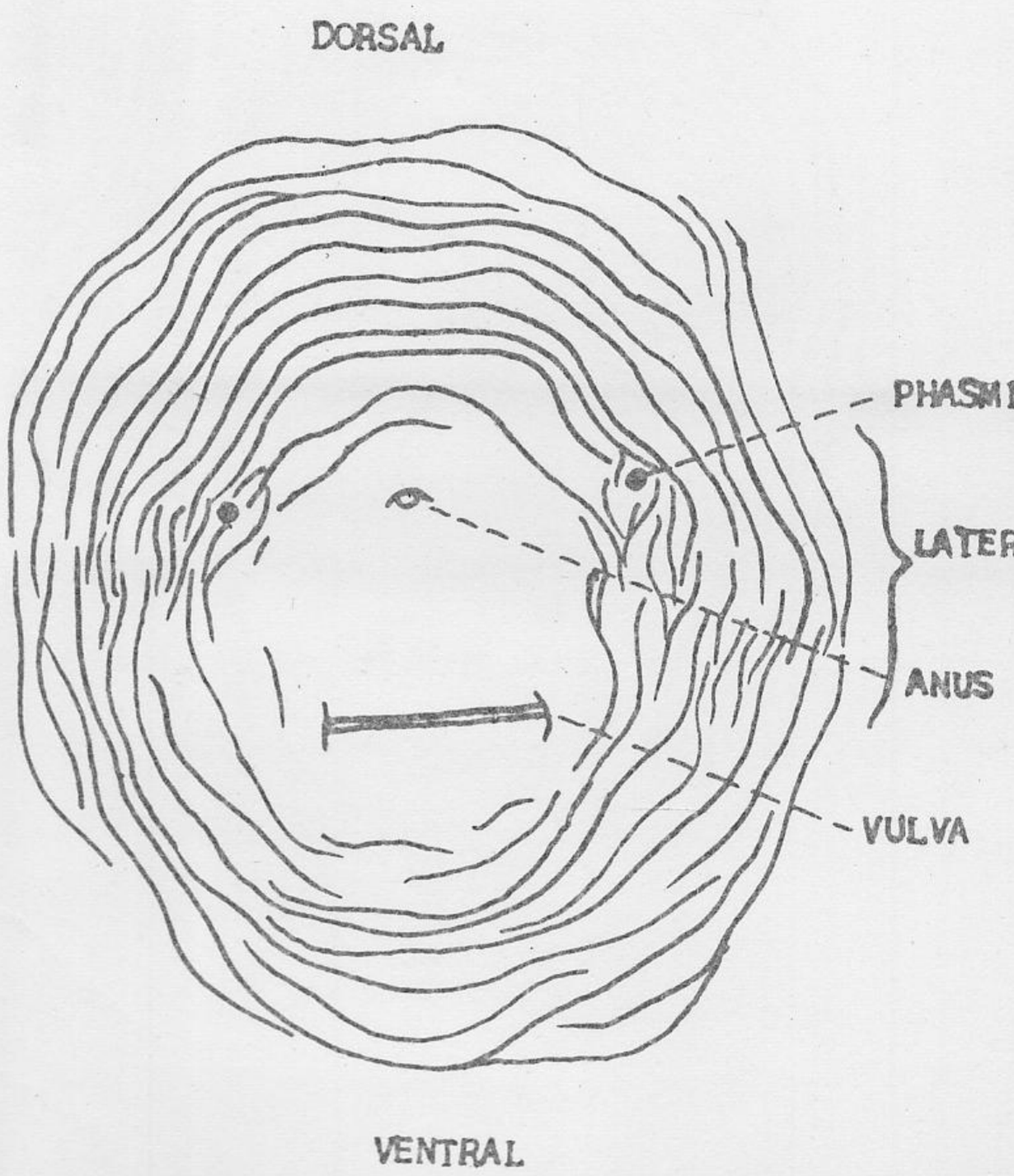


Figure 2. Diagram of perineal pattern of Meloidogyne arenaria showing the different parts.

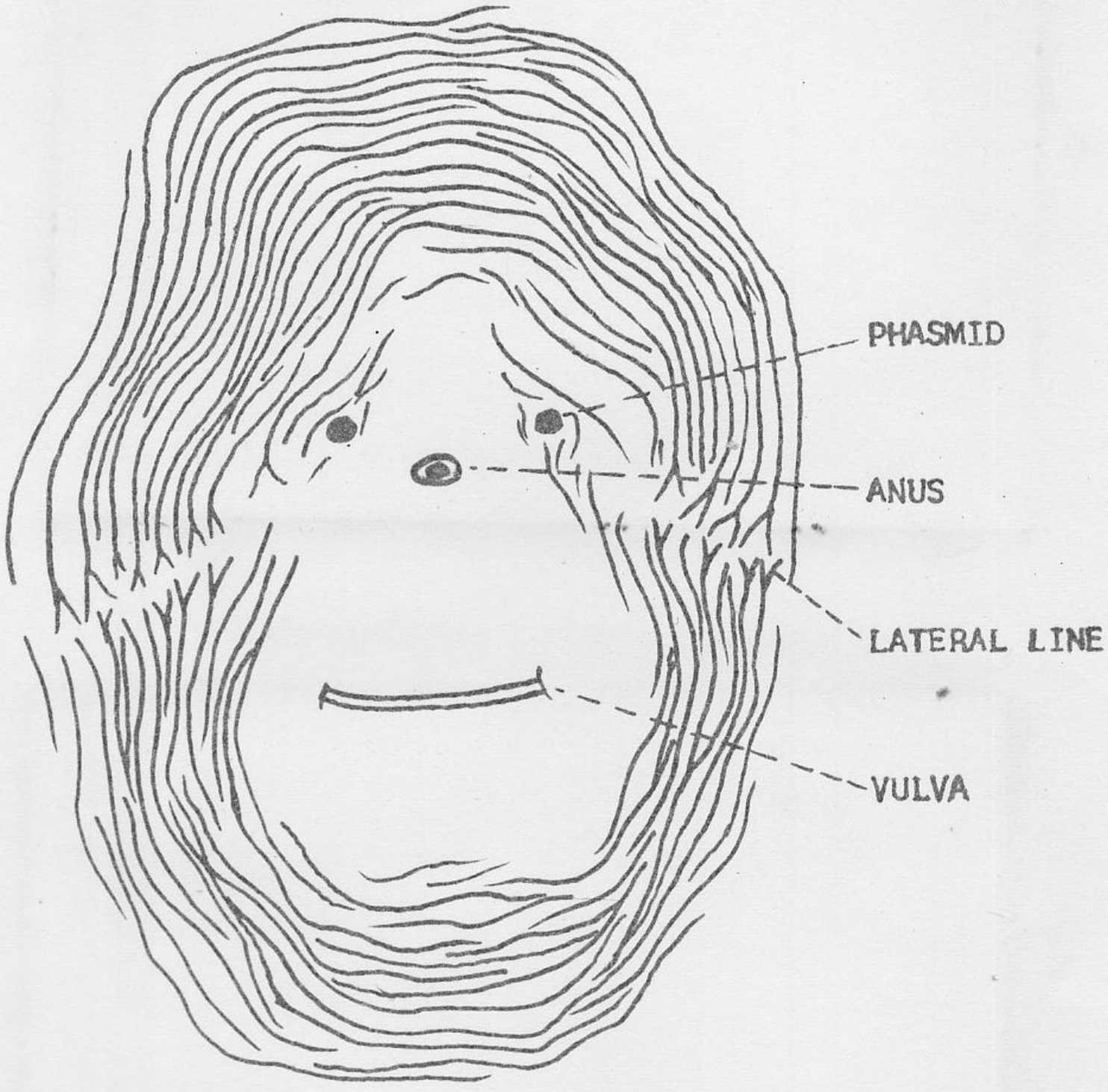


Figure 3. Diagram of perineal pattern of Meloidogyne incognita showing different parts.

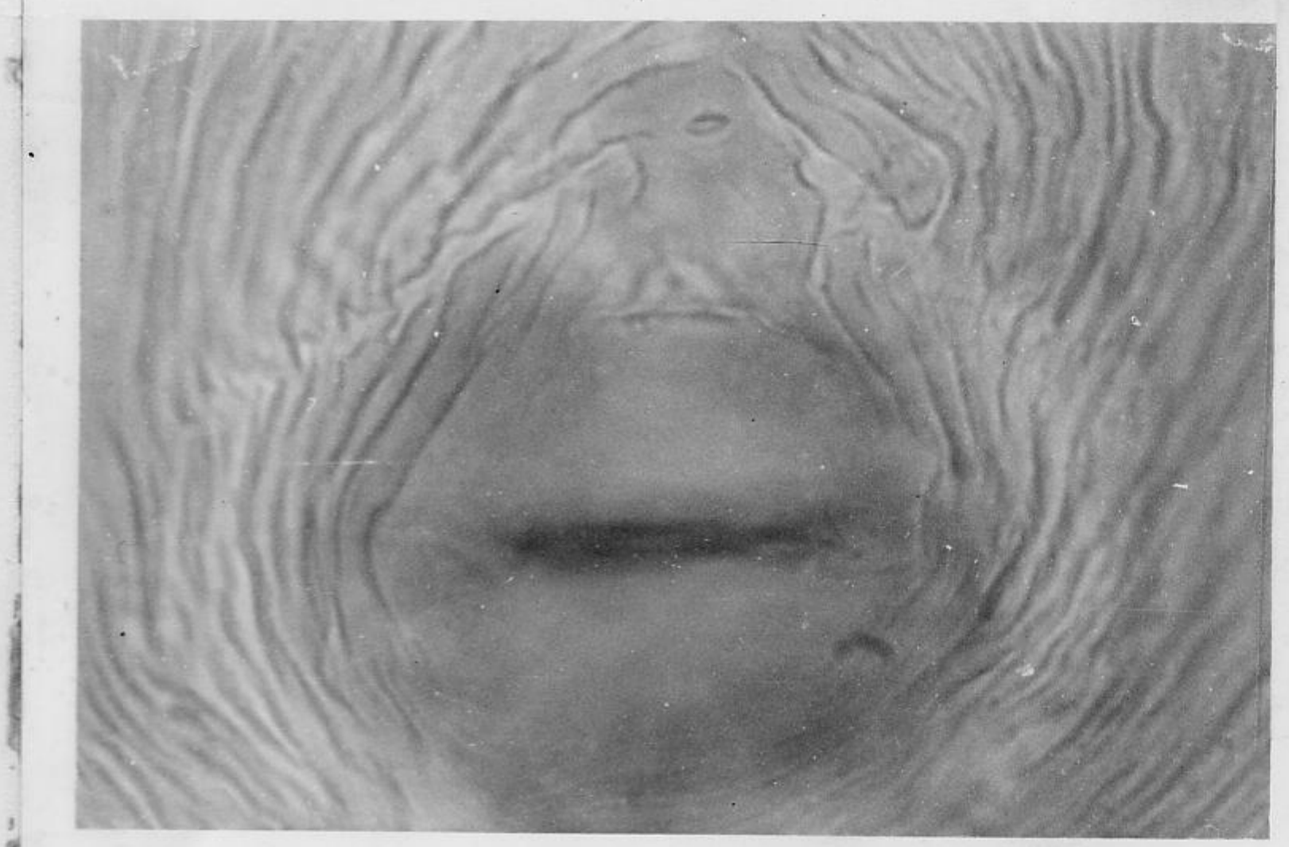


Figure 4. Microphotographs showing perineal patterns of Meloidogyne incognita.

Populations of this species, when checked on host differentials, were unable to parasitize pea-nut but pepper was susceptible (Table 2).

The perineal patterns of M. javanica (Trub) chitwood (Fig. 5, 6) had typically a low arch which did vary in some variantsw. The cuticle was thin and the pattern was very distinct. Lateral lines in most cases were parallel to vulva and showed distinct incisure cuttings through the striae of the perineal pattern especially in the region near the tail. These lines extended far away showing irregularities in the striae. A distinct small irregular circle was present at the tail tip. Phasmids at the higher magnifications were distinct. When a population of this species was tested on host differentials used by Sasser (58), pea-nut and pepper were found to be immune while tomato and watermelon susceptible (Table 2).

Table 2. The reaction of the host differentials to Meloidogyne species.

Meloidogyne Species	Peanut (Local)	Watermelon (Dixie Queens)	Pepper (California Wonder)	Tomato (Rutgers)
M. incognita	-*	+	+	+
M. javanica	-	+	-	+

* Plus signs indicate susceptibility; and minus signs indicate resistance or immunity.

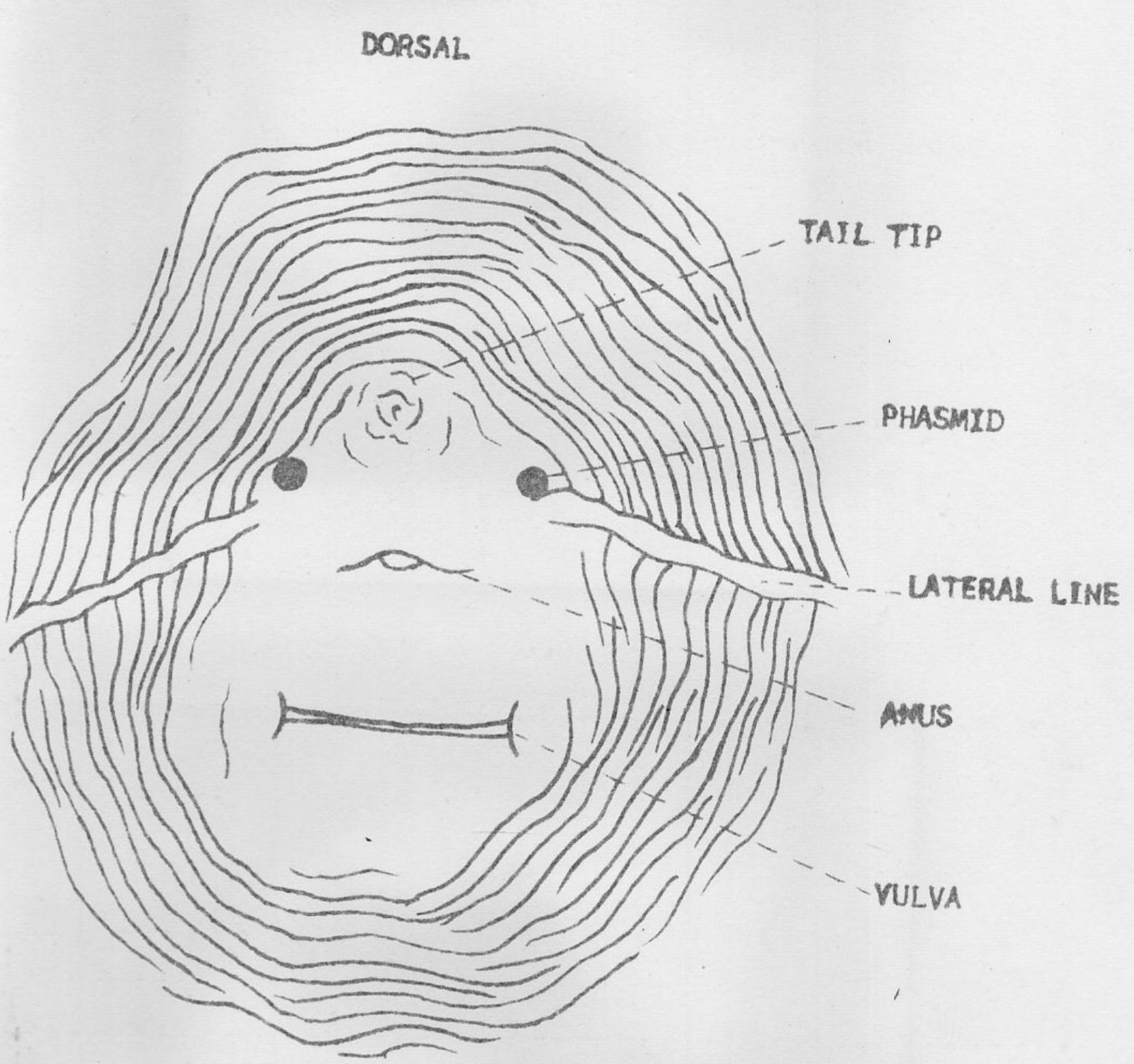


Figure 5. Diagram of perineal pattern of Meloidogyne javanica showing different parts.

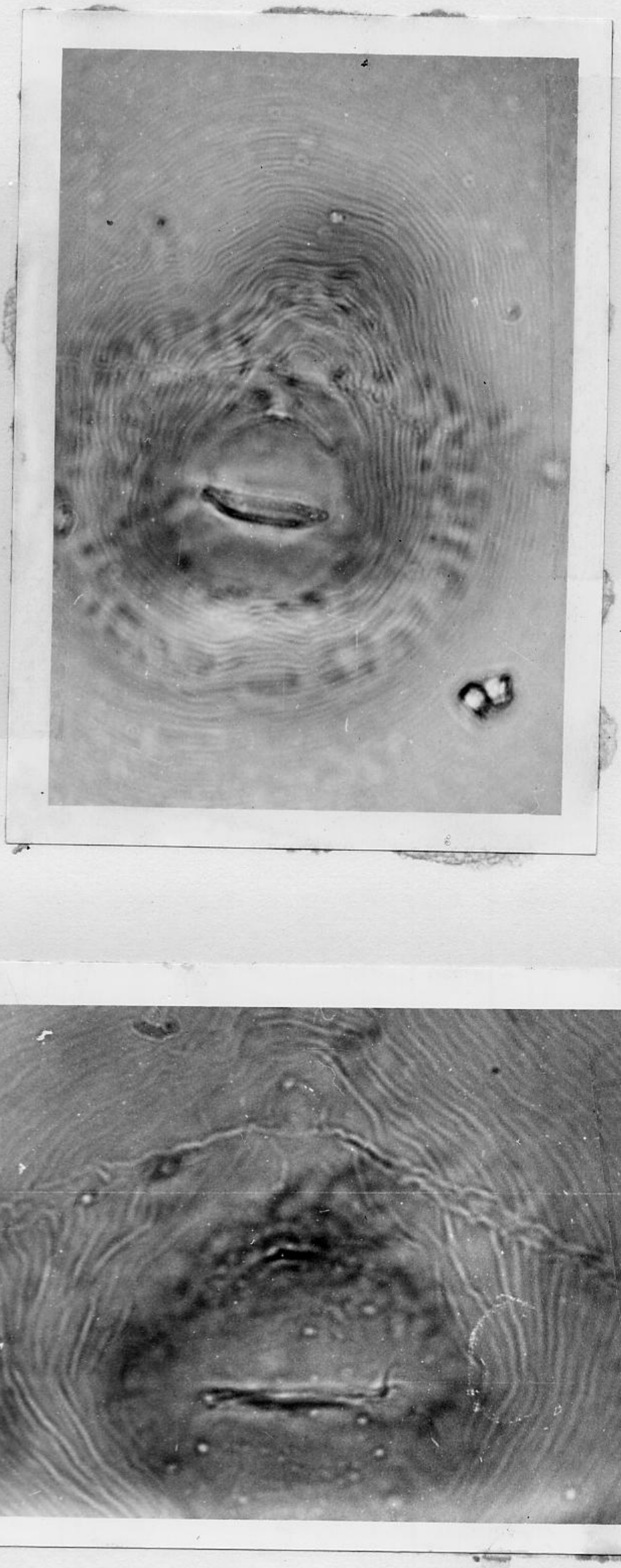


Figure 6. Microphotographs showing perineal patterns of Meloidogyne javanica.

The description of the perineal pattern of each of the species closely agreed with those of Thorne (72, pp. 312-335), Southey (63, pp. 59-85), Triantaphyllou and Sasser (13) and Taylor et al (66).

Because of the occurrence of physiological races in the Meloidogyne species (7, 11, 24, 46, 54, 56), which vary in their ability to attack a particular variety and not the other, host index method for the identification of Meloidogyne species is not being used widely. Hence for the present study, morphology of the perineal pattern was used as the principal character for species determination. Variations in the perineal patterns were observed by Sasser (59) Triantaphyllou and Sasser (74) and even in the present study, but if enough patterns from a given population are examined with the idea of finding similarities rather than differences, it is always possible to find a prepondrance of patterns obviously of the general type described for that species.

Prevalence of Meloidogyne Species in Lebanon

The three species of Meloidogyne: M. arenaria M. incognita and M. javanica, found to occur in Lebanon, varied in their prevalence and geographical distribution. Approximate locations are given in Table 3 and shown in Figure 7.

Table 3. Geographical distribution and intensity of infestation of Meloidogyne species in Lebanon.

Meloidogyne Species	Location	Intensity of Infestation
M. arenaria	Coastal	
	Nahr-el-Kalb	+ +
M. incognita	Bekaa	
	Shtoora	+ +
	Zahle	+ +
	Coastal	
	Beirut	+ + + +
	Jiyeh	+
	Maachook	+ + + +
	Mreijeh	+ + +
	Ras-el-ain	+ + +
	Rumaileh	+ +
	Sarafand	+ + +
	Tyre	+ + + +
M. javanica	Coastal	
	Beirut	+ + + +
	Byblos	+ + + +
	Dawra	+ + + +
	Nahr-Ibrahim	+ + + +
	Nahr-el-Kalb	+ + + +
	Saida	+ +
	Zahrani	+ +
	Mountainous	
	Batroun	+ + +

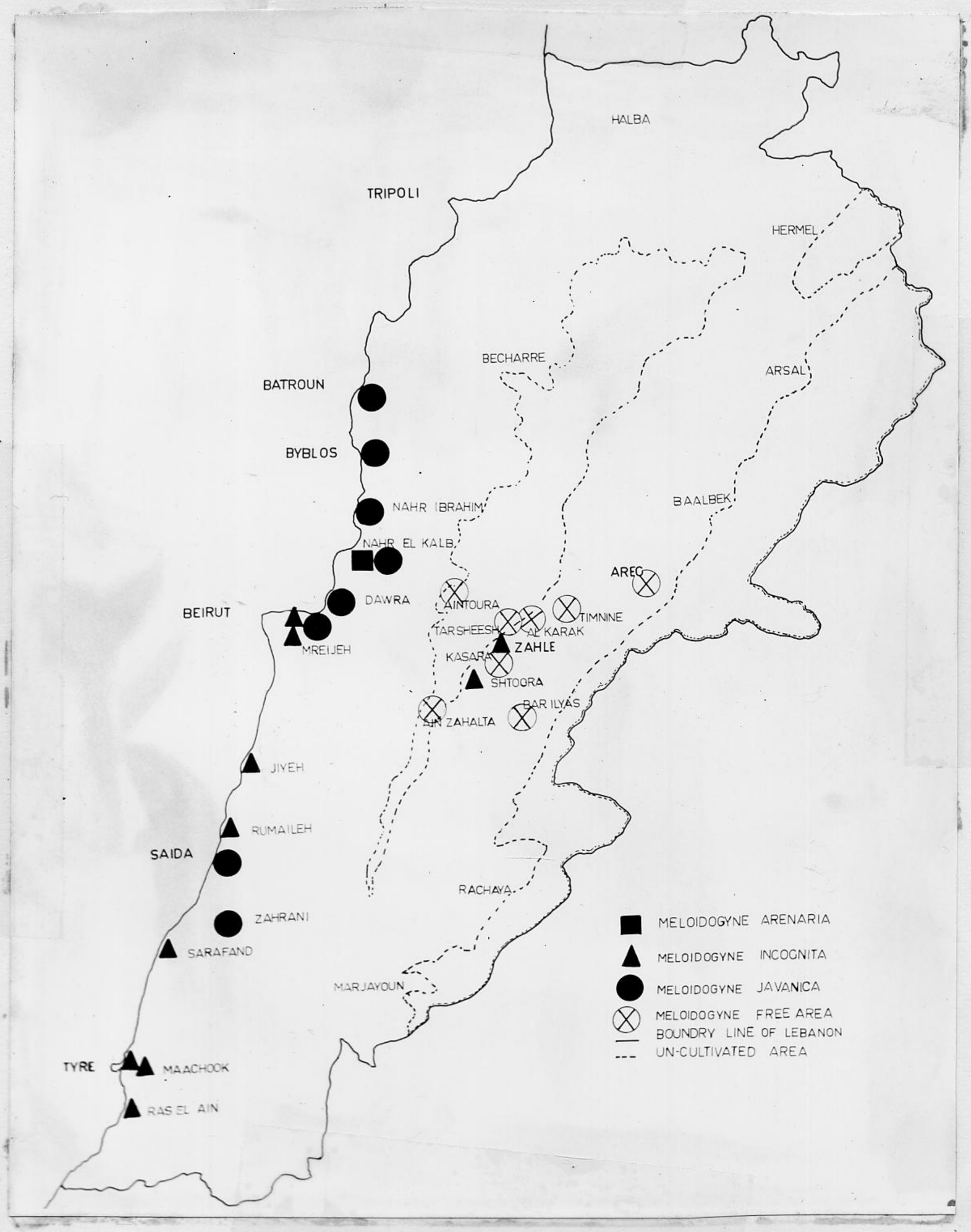


Figure 7. Geographical distribution of Meloidogyne species in Lebanon.

The following localities were also surveyed and found to be free of the disease:

Bekaa: Alkarak, AREC*, Beit Naim, Bar-Ilyas, and Timneen.

Mountains: Aintowra, Ainzhalta, Mejdel Tarsheesh, and Tarsheesh.

From Table 3 it is seen that the intensity of the disease varied in the different localities. It was more severe in the coastal area than in the Bekaa or the Mountains, where occasional infestations of mid intensity were noted. The high infestation of the Root-knot nematodes in the littoral zone is probably due to the prevalence of favorable temperatures (25° to 30° C) in most parts of the year (Table 4), which according to Christie (9, pp. 64) are optimum for the spread of M. incognita and M. javanica.

It is evident from Table 4 that the favorable temperature for the spread and population increase of Meloidogyne species is not common for the larger part of the year in the Bekaa and the Mountains. The nematode species, even if present in these areas, will not be very active, hence, their populations in the soil will be kept at a very low level. To start with such a low density of nematodes under favorable temperature conditions which exist in the summers, the population density rarely goes up to a level to cause serious

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* Agricultural Research and Education Center.

Table 4. Average monthly temperatures in three major localities of Lebanon (3).

Months	Beirut (AUB)* [i]	Bekaa (Haouch Snaid) [ii]	Mountains (Bikfaya) [iii]
January	13.6	4.2	7.1
February	14.0	4.8	7.7
March	15.9	8.2	10.3
April	19.0	12.2	14.3
May	22.7	16.5	17.9
June	25.9	21.2	20.9
July	28.1	23.2	22.1
August	28.7	23.6	22.4
September	27.1	20.5	20.2
October	24.0	16.4	17.7
November	19.4	10.6	13.2
December	15.3	7.3	9.5

* i Average of 30 years, in centigrade.

ii Average of 8 years, in centigrade.

iii Average of 14 years, in centigrade.

losses. The multiplication of these species is once again checked by the low temperatures of winter months (December and January) (61, pp. 357 and 388). In contrast to the Bekaa and Mountainous areas, the population density of the Meloidogyne species in the coastal area remains high in winter and spring and is further increased during summer. The prevalence of a large number

of susceptible weeds, volunteer plants and the continuous year round cropping of the susceptible crops are other important factors which keep the coastal area heavily infested with Meloidogyne populations.

M. incognita and M. javanica are of common occurrence and greater prevalence than M. arenaria (Table 3). M. arenaria was found to occur only in Nahr-el-Kalb area. M. javanica occurs mainly in the North of Beirut, whereas, M. incognita in the South and the Bekaa (Shtoora and Zahle). M. javanica was also observed in Saida and Zaharani (South). This could be a contamination from the North through diseased seedling. M. incognita was never found to occur in the Northern areas.

The high intensity and prevalence of both of these species, M. incognita and M. javanica, in the coastal areas indicate their possible presence since a long time.

Host Range

a) Host Plants of Meloidogyne Species in the Field: Ninety five cultivated as well as non-cultivated host plants from 17 different localities of Lebanon were found to be naturally infected with Meloidogyne species. The names of these hosts, their families and the localities, from where they were collected, are listed in tables 5 to 9.

Table 5. Naturally infected hosts of M. arenaria collected in Lebanon and previously reported from other countries.

Host			Locality
Family	Scientific Name	Common Name	
Cucurbitaceae	Cucumis sativus	Cucumber	Nahr-el-Kalb.
Solanaceae	Lycopersicon esculentum	Tomato	Nahr-el-Kalb.

Table 6. Naturally infected hosts of Meloidogyne incognita collected in Lebanon and previously reported from other countries.

Host			Locality
Family	Scientific Name	Common Name	
Amaranthaceae	Amaranthus retro flexus	Amaranth	Beirut, Shtoora.
	Celosia argentea	Cockscomb	Beirut.
Apocynaceae	Nerium oleander	Oleander	Beirut.
Cannaceae	Canna sp.	Canna	Beirut.
Chenopodiaceae	Beta vulgaris Var.Cicla	Swiss Chard	Maachouk, Mreijeh, Sour.
	Chenopodium album	Goosefoot	Beirut, Maachouk, Sarafand, Shtoora, Tyre.

Table 6 (Continued)

Host			Locality
Family	Scientific Name	Common Name	
Compositae	Cichorium intybus	Chicory	Maachouk, Tyre.
	Chrysanthemum maximum.	Max Dairy	Beirut.
	Dahlia sp.	Dahlia	Beirut.
	Sonchus oleraceus	Sow Thistle	Beirut.
	Zinnia elegans	Youth-and-old-age	Beirut.
Convolvulaceae	Ipomoea purpurea	Morning glory	Beirut.
Cucurbitaceae	Cucumis sativus	Cucumber	Shtoora, Tyre.
Euphorbiaceae	Euphorbia peplus	Spurge	Beirut.
Gramineae	Digitaria sanguinalis	Panie grass	Beirut.
	Sorghum halepense	Sorghum	Beirut.
	Zea mays	Corn	Beirut.
Labiatae	Coleus sp.	-	Beirut.
Malvaceae	Hibiscus esculentus	Okra	Beirut, Maachouk.
	H. rosa-sinensis	-	Beirut.
Musaceae	Musa cavendishii	Banana	Beirut.
Oleaceae	Olea europaea	Olives	Tyre
Papilionaceae	Phaseolus vulgaris	Beans	Maachouk, Tyre
Passifloraceae	Passiflora edulis	Purple Granadilla	Beirut.

Table 6 (Continued)

Host			Locality
Family	Scientific Name	Common Name	
Portulacaceae	Portulaca oleracea	Purslane	Beirut, Shtoora.
Punicaceae	Punica granatum var.nana	Pomegranate	Beirut.
Rosaceae	Prunus amygdalus	Almond	Tyre.
	Rosa sp.	Rose	Beirut.
Solanaceae	Datura stramonium	Jimson-weed	Beirut, Shtoora.
	Lycopersicon esculentum	Tomato	Beirut, Maachouk, Tyre.
	Nicotiana tabacum	Tobacco	Beirut.
	Petunia hybrida	Petunia	Beirut.
	Solanum melongena	Egg-plant	Beirut, Maachouk, Ras-el-ain, Sarafand, Tyre, Zahle.
Tiliaceae	Corchorus olitorius	Jew's-mallow	Beirut, Rumaileh, Sarafand.
Umbelliferae	Petroselinum hortense	Parsley	Sarafand.
Vitaceae	Vitis vinifera	Grape	Beirut.

Table 7. Naturally infected hosts of Meloidogyne javanica collected in Lebanon and previously reported from other countries.

Host			Locality
Family	Scientific Name	Common Name	
Amaranthaceae	Amaranthus viridis	Ameranth	Beirut.
Apocynaceae	Nerium oleander	Oleander	Beirut.
Chenopodiaceae	Beta vulgaris	Sugar beet	Beirut.
	B.vulgaris var. Cicla	Swiss Chard	Dawra.
	Chenopodium album	Goosefoot	Dawra.
Compositae	Calendula officinalis	Pot Marigold	Beirut.
	Zinnia elegans	Yout-and-old-age	Beirut.
Convolvulaceae	Convolvulus arvensis	Bind-weed	Beirut.
Cucurbitaceae	Citrullus vulgaris	Water melon	Beirut, Dawra, Saida.
	Cucumis sativus	Cucumber	Beirut, Dawra.
Cyperaceae	Cyperus rotundus	Nut Grass	Beirut.
Gramineae	Dactylis glomerata	Cock's-foot Grass	Beirut, Dawra.
	Digitaria sanguinalis	Panic Grass	Beirut.
	Setaria verticillata	Foxtail Grass	Dawra.
	S. viridis	Foxtail Grass	Beirut.
Labiatae	Coleus sp.	-	Beirut.
Malvaceae	Hibiscus esculentus	Okra	Beirut.
	Malva sp.	Cammon mellow	Dawra.

Table 7 (Continued)

Host			Locality
Family	Scientific Name	Common Name	
Palmae	Phoenix dactylifera	Date Palm	Beirut.
Papilionaceae	Phaseolus vulgaris	Beans	Beirut, Byblos.
Portulacaceae	Portulaca oleracea	Purslane	Dawra, Zahrani.
Punicaceae	Punica granatum	Pomegranate	Beirut.
Solanaceae	Lycopersicon esculentum	Tomato	Beirut, Byblos, Dawra, Nahr-el-Kalb, Nahr-Ibrahim.
	Solanum nigrum	Sunberry	Dawra,
Tiliaceae	Chorchorus olitorius	Jew's mallow	Beirut.
Umbelliferae	Ammi majus	Bishop's-weed	Beirut, Dawra.
	Foeniculum vulgare	Fennel	Dawra.

In addition to the above mentioned hosts, 50 plant species, previously unreported as hosts of Meloidogyne species, were found to be naturally infected in the field. Lists of these new hosts are given in tables 8 to 9.

Table 8. Naturally infected new hosts of Meloidogyne incognita.

Host			Locality
Family	Scientific Name	Common Name	
Amaranthaceae	Alternanthera amoena	-	Beirut.
	Amaranthus viridis	Amaranth	Beirut.
Bignoniaceae	Bignonia riscasoliana	Bignonia	Beirut.
Cactaceae	Hylocereus undatus	Night-blooming Cereus	Beirut.
Campanulaceae	Campanula medium	Canterbury Bells	Beirut.
Celastraceae	Euonymus japonicus	Spindle-tree	Beirut.
Compositae	Ageratum houstonianum	-	Beirut.
	Felicia hybrida	Dairy	Beirut.
	Gazania rigens	-	Beirut.
	G. splendens	-	Beirut.
	Gerbera jamesonii	Transvaal Daisy	Beirut.
Compositae	Erigeron crispus	Fleabane	Tyr.
Convolvulaceae	Dichondra elegans	-	Beirut.
Crassulaceae	Bryophyllum pinnatum	Floppers	Beirut.
Euphorbiaceae	Chrozophora vebascifolia	-	Beirut.
	Croton tinctoria	-	Beirut.
Geraniaceae	Geranium peltatum	Ivy Geranium	Beirut.
Gramineae	Cynadon dactylon	Bermuda Grass	Beirut.

Table 8 (Continued)

Host			Locality
Family	Scientific Name	Common Name	
	Dactyloctenium aegyptiacum	Crowfoot Grass	Beirut.
	Echinochloa colonum	Panic Grass	Beirut.
	Eragrostis ciliaanensis	Love Grass	Maachouk.
	Setaria verticillata	Foxtail Grass	Jeye.
	S. viridis	Foxtail Grass	Beirut.
Labiatae	Rosmarinus officinalis	Rosemary	Beirut.
	Salvia splendens	Scarlet sage	Beirut.
Liliaceae	Asparagus sprengeri	Asparagus	Beirut.
Malvaceae	Althaea rosea	Hollyhock	Beirut.
Mesembryaceae	Mesembryanthemum roseum	-	Beirut.
Moraceae	Ficus elastica	Rubber plant	Beirut.
Orobanchaceae	Orobanche aegyptiaca	Broom-rape	Maachouk.
Solanaceae	Datura arborea	-	Beirut.
	D. stramonium	Jimson-weed	Beirut.
	Solanum alatum	-	Shtoora.
	S.wendlandii	-	Beirut.
Verbenaceae	Clerodendrum fragrans	Glory-bower	Beirut.
	Duranta plumieri	Sky-flower	Beirut.
	Lippia nodiflora	Mat Grass	Beirut.

Table 9. Naturally infected new hosts of *Meloidogyne javanica*.

Host			Locality
Family	Scientific Name	Common Name	
Apocynaceae	*Vinca minor*	Periwinkle	Beirut.
Boraginaceae	*Heliotropium villosum*	Heliotrope	Beirut.
Compositae	*Erigeron crispus*	Fleabane	Beirut, Dawra.
	Sonchus oleraceus	Sow thistle	Beirut, Dawra.
Cycadaceae	*Cycas revoluta*	Sago-palm	Beirut.
Euphorbiaceae	*Croton tinctoria*	-	Beirut.
	Euphorbia lantana	Spurge	Beirut.
Mesembryaceae	*Mesembryanthemum roseum*	-	Beirut.
Oxalidaceae	*Oxalis cernua*	Wood Sorrel	Beirut.
Palmaceae	*Washingtonia filifera*	Washington palm	Beirut.
Primulaceae	*Anagallis arvensis*	Poor Man's Weatherglass	Beirut.
Simarubaceae	*Ailanthus glandulosa*	Tree of heaven	Beirut.
Verbinaceae	*Lippia nodiflora*	Mat Grass	Beirut.

Meloidogyne species have a very wide host range, parasitizing members of 42 different families, as shown in tables 5 to 9. *Meloidogyne arenaria* was found on

cucumber and tomato in Nahr-el-Kalb area. M. javanica was found on 43 different plant species (Table 7 and 9), including 13 new hosts (Table 8). The most common hosts were members of the Cucurbitaceae, Gramineae and Solanaceae growing in the littoral zone, North of Beirut. Seventy three hosts (Table 6 and 8) including 37 new ones (Table 8) were found to be naturally infected by M. incognita, growing in the Bekaa and Coastal area, South of Beirut. These hosts were mainly members of Chenopodiaceae, Compositae and Gramineae families.

b) Host Range Studies in the Green House: Results of the green house investigations on the host range of M. incognita and M. javanica are shown in Table 10.

Table 10. Host range of Meloidogyne species, disease index and percentage incidence of infected plants in the green house experiment.

Host Species	Common Name	Variety	M.incognita		M.javanica	
			Infected Plant (%)	Disease Index	Infected Plant (%)	Disease Index
Arachis hypogea	Pea nut	Local	0	0	0	0
Avena sativa	Oat	Local	100	2	100	2
Beta vulgaris	Sugar beet	Detroit Red	100	3	100	3
B. vulgaris var. Cicla	Swiss Chard	Local	100	2	100	2
Brassica oleracea var. Botrytis	Cauli-flower	All Season	100	3	100	4
B. oleracea var. Capitata	Cabbage	Burn's-wick	100	4	100	2
B. oleracea var. Gemmifera	Brussel Sprout	Local	0	0	0	0
Capsicum annuum	Pepper	California Wonder	100	4	0	0
Carthamnus tinctorius	Safflower	Local	0	0	100	3
Cicer arietinum	Chick-pea	Local	100	4*	100	4*
Citrullus vulgaris	Water-melon	Dixie Queen	100	5	100	5
Coriandrum sativum	Coriand-er	Local	90	1*	90	2
Cucumis melo	Musk-melon	Honey Dew	100	5	100	5

* Do not appear to have been reported earlier (23).

Table 10 (Continued)

Host Species	Common Name	Variety	M. incognita		M. javanica	
			Infected Plant (%)	Disease Index	Infected Plant (%)	Disease Index
C. sativus	Cucumber	Amco Green	100	5	80	5
Cucurbita pepo	Squash	Local	100	5	0	0
Datura stramonium	Gimson Weed	-	90	4*	100	4
Daucus carota	Carrot	Local	80	3	100	2
Eruca sativa	Garden rocket	Local	0	0	0	0
Glycine max	Soybean	Lindarin	100	3	100	3
Gomphrena globosa	Globe-amaranth	-	100	3*	100	3
Helianthus annus	Sunflower	v88-83	100	5	100	5
Hibiscus esculentus	Okra	Local	60	2	100	3
Hordeum vulgare	Barley	Local	95	3	80	2
Lactuca sativa	Lettuce	Romain Vert	100	3	100	3
Lepidium sativum	Garden Cress	Local	0	0	0	0
Lupinus angustifolius	Lupine	Local	80	3	100	2
Lycopersicon esculentum	Tomato	Marglobe	100	5	100	5
Medicago sativa	Alfalfa	Hairy Peruvian	100	4	100	4
Nicotiana tabacum	Tobacco	Samsun	100	5	100	5
N. glutinosa	Tobacco	-	100	5	100	5

* Do not appear to have been reported earlier (23).

Table 10 (Continued)

Host Species	Common Name	Variety	M. incognita		M.javanica	
			Infected Plant (%)	Disease Index	Infected Plant (%)	Disease Index
Petroselinum hortense	Parsley	Local	100	3	100	3
Phaseolus vulgaris	Bean	Tender Pod	80	2	100	5
Pisum sativum	Pea	Local	80	3	90	5
Raphanus sativa	Radish	Local	0	0	0	0
Ricinus communis	Castor bean	Local	100	2	100	2
Solanum melongena	Egg Plant	Florida High bush	100	5	100	5
Sorghum vulgare	Sorghum	Local	75	1	60	1
Spinacea oleracea	Spinach	Local	60	2	73	1
Thymus sp.	Thyme	Local	0	0	0	0
Triticum vulgare	Wheat	FAO 8685	100	4	100	2
Zea mays	Corn	Asgrow-99k	100	2	100	2

Green house experiments on host range have shown that M. incognita and M. javanica are able to infect a large number of plant species from different families (Table 10).

Arachis hypogea, Brassica oleracea var Gemmifera Eruca sativa, Lepidium sativum, Raphanus sativa and Thymus sp. were found to be resistant to

both species. Raphanus sativa has been reported to be susceptible to both species, M. incognita and M. javanica (58). Like wise Carthamnus tinctorius has been reported to be susceptible to M. incognita (55) and Cucumis pepo to M. javanica (70). The difference in the infectivity may be attributed to the difference in the host variety used as well as to possible differences in pathogenic races of Meloidogyne species (7, 11, 56).

Plant species belonging to the Gramineae family showed very low disease index (ratings of 1 and 2).

Eight plant species were found to be highly susceptible (disease index of 5) to both species of Meloidogyne. These included Citrullus vulgaris, Cucumis melo, C. sativus, Helianthus annus, Lycopersicon esculentum Nicotiana tabacum, N. glutinosa and Solanum melongena. Other highly susceptible host species for M. javanica were Phaseolus vulgare and Pisum sativum, and Cucurbita pepo for M. incognita. These results were in complete correlation with those obtained from surveys of naturally infected hosts. These results were also in close agreement with various previous reports in the literature by other workers (58, 70, 78).

Varietal Resistance to Meloidogyne Species

Forty four varieties of ten cultivated plant species were tested for their reaction to M. incognita and

M. javanica. Results on the degree of susceptibility of these varieties to M. incognita and M. javanica are shown in Table 11.

Table 11. Varietal reaction of various locally cultivated crops to Meloidogyne species.

Host Species	Common Name	Variety	M. incognita		M. javanica	
			Infected Plant (%)	Disease Index	Infected Plant (%)	Disease Index
Capsicum annuum	Pepper	Sharp	90	4	0	0
		California Wonder	100	4	0	0
		Local	100	4	0	0
Citrullus vulgaris	Watermelon	Dixie Queen	100	5	100	5
		Florida Giant	100	5	100	5
		Charleston Gray	100	4	100	5
		New Hampshire Midget	100	5	100	5
		Kleckley Sweek Improved	100	4	100	5
		Peacock	100	4	100	5
		Local	100	5	100	5
Cucumis melo	Musk melon	Hearts of Gold	100	3	100	4
		Honey Dew	100	5	100	5

Table 11 (Continued)

Host Species	Common Name	Variety	M. incognita		M. javanica	
			Infected Plant (%)	Disease Index	Infected Plant (%)	Disease Index
		Hails Best	100	5	100	5
		Crenshaw	100	5	100	5
		Local	100	4	100	4
Cucumis sativus	Cucumber	Amco Green	100	5	80	5
		OHIO MR 17	100	5	100	5
		Wisconsin SMr-18	98	5	100	5
Hordeum vulgare	Barley	Athinais	90	2	75	2
		Baladi	95	3	80	2
		Telamara No. 25	98	3	100	3
Lycopersicon esculentum	Tomato	Marglobe	100	5	100	5
		Homestead 24	100	5	100	5
		Rutgers	100	5	100	5
Pisum sativum	Pea	Burpeeana Early	80	0	90	2
		Blue Bantam	90	1	100	4
		Carter's Dairy	100	1	100	3
		Wando	0	0	100	1
		Onward	100	3	100	3
		Local	80	3	90	5

Table 11 (Continued)

Host Species	Common Name	Variety	M.incognita		M.javanica	
			Infected Plant (%)	Disease Index	Infected Plant (%)	Disease Index
Phaseolus vulgaris	Bean	Brittle Wax	0	0	100	2
		Bountiful	0	0	100	2
		Contender	100	4	100	2
		Tender Pod	100	2	100	5
		Pencil Pod Black Wax	100	2	100	4
		Local	100	4	90	5
Triticum vulgare	Wheat	FAO 8685	100	4	100	2
		Hurani	100	2	100	2
		Najah	100	2	80	1
Zea mays	Corn	Carmel Cross	0	0	0	0
		Golden Beauty Hybrid	80	2	80	4
		Golden Cross Bantam	100	2	100	4
		Local	100	3	100	4
		Span-cross	0	0	0	0

Two varieties of corn (Carmel Cross and Span Cross) were found to be resistant to both species of Meloidogyne (Table 11).

M. javanica was unable to parasitize any of the varieties of pepper. Resistance in pepper against M. javanica has been reported by many workers (30, 31, 58). Varieties of the other plant species varied in their reaction (disease index 1-5) to M. javanica. Varieties of barley (Althinois and Baladi), bean (Brittle Wax, Bountiful and Contender), Pea (Burpee's Early and Wando) and all varieties of wheat showed various degrees of resistance as indicated by disease index of 1 and 2.

M. incognita failed to parasitize bean (Brittle and Bountiful) and pea (Burpee's Early and Wando). Some resistance varieties with a disease index rating of 1-2 included, barley (Athinais), bean (Tender Pod and Pencil Pod Black Wax), Pea (Blue Bantam and Carter's Dairy), corn (Golden Beauty Hybrid and Golden Cross Bantam) and wheat (Huroni and Najah).

All varieties of watermelon, cucumber, muskmelon and tomato were found to be highly susceptible to both species of Meloidogyne. Similar results on the susceptibility of cucurbits and tomato have been reported by previous workers (56, 58, 70, 71, 78, 79).

Chemical Control of The Root-Knot Disease

The data on the efficacy of the different nematocides used are given in Table 12.

Nemagon along with Nemaphos and D-D were most effective in reducing the incidence of the disease as measured by the percentage of infected plants. Maximum incidence of the disease (97%) was observed in the untreated check. Maposol treatments was not significantly different from the untreated check. Disease incidence in Maposol treated flats was 89.6%. The average disease index (Table 12) was also very low in soils treated with Nemagon, Nemaphos and D-D as compared with that of the untreated check. These results are in conformity with previous findings by other workers (6, 21, 37, 38, 51, 52). The intensity of root-knot disease also varied with different crops. The disease incidence of cabbage (40.5%) was significantly different from tomato (50.6%).

Table 12. Average disease index and percentage of root-knot on cabbage, cucumber, egg plant, lettuce and tomato as affected by different nematocides.

Crops	Treatments											
	Check		EDB		D-D		Nemagon		Nemaphos		Maposol	
	D.I	Disease %age	D.I	Disease %age	D.I	Disease %age	D.I	Disease %age	D.I	Disease %age	D.I	Disease %age
Cabbage	3.5	93.9	1	70.5	0.0	0.0	0.0	0.0	0.0	0.0	2.5	78.8
Cucumber	4.0	100.0	2.5	78.2	0.5	15.1	0.0	0.0	0.5	12.6	3.5	97.6
Egg plant	3.5	98.0	1	89.0	0.5	10.0	0.0	0.0	0.0	0.0	2.5	90.0
Lettuce	3.5	94.0	1	74.0	0.0	0.0	0.5	5.0	0.5	5.0	3.0	86.8
Tomato	3.5	99.0	1.5	84.1	0.0	0.0	0.0	0.0	0.0	0.0	2.5	95.0

Chemicals	Nemagon	Nemaphos	D-D	EDB	Maposol	Check
Means	1	2.5	5.0	79.1	89.6	97.0

Crops	Cabbage	Lettuce	Tomato	Egg plant	Cucumber
Means	40.5	44.1	46.3	47.8	50.6

Treatment means underlined do not differ significantly at 5% level.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The occurrence, identity, prevalence and host range of the Meloidogyne species in Lebanon were studied through extensive field surveys during the years of 1966-67. Green house and growth chamber experiments were conducted to study the host range and control of root-knot nematodes. The determination of the species was based on the characteristics of the female perineal pattern and on the reaction of indicator plants. The species M. arenaria, M. incognita and M. javanica were recorded. M. incognita and M. javanica were more prevalent than M. arenaria. Soils in the litteral zone showed a higher infestation than those of the Bekaa and mountains.

One hundred and forty five different host plants, collected from 17 localities of Lebanon were found to be naturally infected with one or more of the Meloidogyne species. Thirty seven new hosts for M. incognita and 13 for M. javanica were discovered. The most common hosts were species of the Cucurbitaceae, Gramineae and Solanaceae.

The host range studies in the green house revealed that 35 out of 41 plant species tested were the

suitable hosts for M. incognita and M. javanica.

Investigations on the varietal resistance of locally grown crops to M. incognita and M. javanica showed that two varieties of corn out of five were resistant to both species of Meloidogyne. M. javanica was unable to parasitize all the three varieties of pepper, so was M. incognita on two varieties of bean and two varieties of pea out of six of each crop. All varieties of cucumber, muskmelon, tomato, and watermelon, under study were highly susceptible to both species of Meloidogyne.

Nemagon, Nemaphos and D-D were most effective in reducing the incidence of the disease. Maposol treatment was not significantly different from the untreated check.

The results of these investigations indicated that the root-knot nematode is a very serious and prevalent disease in Lebanon, infecting a large number of cultivated as well as non cultivated plants. Such a situation calls for an immediate adoption of control measures in the infested areas. Based on the results obtained in the present study and from information available in the literature, it is recommended that the root-knot nematode population can be reduced by the following practices:

1) 2-3 years crop rotation of resistant or immune crops with the susceptible ones to interrupt the rapid build-up of the root-knot nematodes.
2) The use of resistant varieties.
3) Dry fallow with 2 to 3 deep plowings in hot summer months.
4) Removal of weeds and volunteer plants.
5) Fumigation of soil in nurseries and heavily infested fields, with Nemagon, Namaphos or D-D.

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APPENDIX

APPENDIX A

Analysis of variance of percentage of root-knot on different crops as affected by different nematocides.

Source	D.F	M.S.S.	F	L.S.D at 5% Level
Replication	1	80.74	1.13	N.S
Chemical	5	22233.91	310.61 *	9.71
Error (a)	5	71.58		
Crops	4	175.40	4.60 *	5.14
Crops x Chemicals	20	47.17	1.24	N.S
Error (b)	24	38.16		

* Statistical analysis was run at 5% only.