Worldwide Dissemination and Importance of the Root-knot Nematodes, Meloidogyne spp.[1]

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Abstract: Root-knot nematodes are widely distributed throughout the world. Their distribution and economic importance are purported to be related to biological and environmental factors favorable to *Meloidogyne* spp. A scheme for comparing *Meloidogyne* spp. with two other genera of diverse biological characteristics is presented to support this hypothesis. It is further suggested that a probability index can be developed to predict the likelihood of a given nematode species being transported, established, and becoming economically important in regions of the world where it does not already occur. *Key Words:* root-knot nematodes, *Meloidogyne* spp., distribution.

Root-knot nematodes of the genus *Meloidogyne* are more widely distributed throughout the world than any other major group of plant-parasitic nematodes. Furthermore, when their importance is considered on a worldwide basis, they rank high on the list of animate pathogens affecting the production of economic plants. If one assumes that these two observations are true, certain biological characteristics and environmental influences favorable to *Meloidogyne* spp. must account for their wide distribution and economic importance.

Information concerning distribution of described species of *Meloidogyne* is presented, but no attempt is made to indicate countries in which each species occurs. More importantly, biological characteristics of nematodes which influence successful dissemination and establishment in a new environment are discussed.

In any discussion about root-knot nematodes, one can separate the species into two categories: *(i)* the most common and well-known species, *Meloidogyne incognita, M. javanica, M. arenaria,* and *M. hapla,* included in Chitwood's 1949 revision of the genus (1); and *(ii)* the less widespread species, most of which were described later.

Since 1949, additional species have been described from the United States and from other parts of the world so that approximately 35 are now recognized (6). Of these, 11, including those species listed previously plus *M. ovalis* (22), *M. carolinensis* (7), *M. thamesi* (2), *M. naasi* (9), *M. ottersoni* (27, 28), *M. graminis* (25, 28), and *M. graminicola* (12), are known to occur in the United States. *Meloidogyne incognita, M. javanica, M. arenaria, M. hapla,* and *M. graminis* are widespread in the United States, although distribution varies with species. The other species known to occur in the United States are more host specific, a factor which may account for their limited distribution. For example, *M. carolinensis* has been reported only from blueberry in eastern North Carolina; *M. ottersoni* from Canary grass, Wind Lake area, Wisconsin; *M. ovalis* from maple in Wisconsin; *M. graminicola* on grasses in Louisiana; and *M. naasi* on various gramineae from California, Illinois, Oregon, Kansas, and Maryland.

Twenty-four additional species, which are lesser known and of more restricted distribution, were described or first reported from other continents or regions of the world. The most common and well-known species in the United States, indicated in parenthesis, also occur in most other continents or regions.

Central and South America: Meloidogyne exigua (11, 18), *M. coffeicola* (19), *M. lordelloi* (21), *M. inornata* (17), *M. bauruensis* (16), (*M. incognita, M. javanica, M. arenaria,* and *M. hapla*).

Africa: M. africana (29), *M. acronea* (3), *M. kikuyensis* (4), *M. ethiopica* (30), *M. decalineata* (30), *M. megadora* (30), *M. oteifae* (5), (*M. incognita, M. javanica, M. arenaria,* and *M. hapla*).

India: M. indica (30), *M. lucknowica* (24), *M. brevicauda* (15), (*M. incognita, M. arenaria, M. javanica, M. graminicola,* and *M. hapla*). *M. brevicauda* occurs in Sri Lanka (Ceylon) where it was first reported.

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England: M. artiellia (8), *M. naasi* (9), *M. ardenensis* (23), and *(M. hapla).*

Remainder of Europe and the Mediterranean region: M. deconincki (5), *M. litoralis* (5), *M. naasi,* (*M. incognita, M. javanica, M. arenaria,* and *M. hapla*).

Russia: M. kirjanovae (26), *M. megriensis* (6), and *M. tadshikistanica* (14), *(M. incognita).*

Japan: M. mali (13), (*M. hapla, M. javanica, M. incognita,* and *M. arenaria*).

Southeast Asia, Australia, Fiji Islands: No new species described. (*M. incognita, M. javanica,* and *M. arenaria*).

Canada: M. microtyla (20), (*M. hapla* and *M. incognita*).

Of the lesser known species described outside the United States since 1950, only *M. naasi* has been reported as occurring in the United States. Thus, despite very active investigation in many parts of the world, only five or six cosmopolitan species have been found. Yet, all of these seem to have the same biological characteristics, except possibly limitation of host range. A closer look is necessary.

A comparison of *Meloidogyne* spp. with two other genera of diverse biological characteristics may illustrate and support the hypothesis that distribution and economic importance of a given nematode can be explained on the basis of biological advantages or disadvantages and environmental influences. If this can be done, there is reason to believe that a formula or index can be developed which would help predict whether or not a particular nematode pest is likely to spread and become important in areas where it does not already occur. For convenience, consideration will be given to each of three phases as follows: *(i)* dissemination of live developmental stages of a nematode species from one part of the world to another, *(ii)* successful establishment in a new location, and *(iii)* conditions or factors favoring the likelihood that the introduced species would develop to the point of becoming an economically important pest. It is important to realize also that the first phase can occur without the second, and that the first two phases can occur without the third. A problem emerges in a new area only when all three phases are completed.

The factors shown in Table 1 obviously influence the chances of successful dissemination and establishment of a nematode species and the likelihood that it will become economicaly important. From the known facts, we should be able to predict the probability that a particular species of nematode can compete in all three phases by placing numerical values on factors influencing distribution and establishment. For example, if we rate each biological or environmental factor on a scale of 0-10, with 0 being most *unfavorable* and 10 being most *favorable,* an index of success could be estimated. In Table 1, *M. incognita* is compared with two other nematode species which represent very diverse characteristics within the parameters considered.

In the hypothetical scheme presented in Table 1, some factors should probably be given more weight in a formula than others. This adjustment could be done rather easily. Also, any one of several factors could impede or stop the process. Therefore, in the development of a formula for predicting the likelihood of all three phases being completed, a built-in value or constant has to be inserted. Values given are subjective and vary among individuals making the ratings. In spite of these limitations, a formula or index can be devised which would enable scientists to predict with a reasonable degree of accuracy the relative probability of spread and establishment among many nematode groups and species. It seems reasonable that the genus *Meloidogyne* is widely disseminated and economically important because of the high ratings reflected for several of the key factors in the *"establishment"* and the *"economically important phases." Anguina tritici* has a higher value for the "in transit" phase but lesser values than *M. incognita* for the "establishment" and "economic importance" phases. *Belonolaimus longicaudatus* would rank third among these three genera in the likelihood of being transported and becoming established in a new environment. This fact can be attributed to its ectoparasitic life habit, low reproductive rate, specific soil requirements, and perhaps other factors.

There are many nematode species which are not widespread but which have the potential of becoming economically important should they be transported to

TABLE 1. Some factors which influence successful dissemination, establishment, and economic importance of a parasitic nematode.

Biological and/or Environmental Influences	Probability Index[a] *Meloidogyne incognita*	*Belonolaimus longicaudatus*	*Anguina tritici*
In transit phase			
1) Endo-/or Ectoparasite	6	3	10
2) Developmental stage(s) involved in transit	6	3	10
3) Amount of inoculum and frequency of transport	10	1	10
4) Type and condition of carrier—soil, fleshy root, seed, or leaves	6	3	10
5) Sensitivity to desiccation	3	2	10
Establishment phase			
1) Number and relative suitability of available hosts	10	3	1
2) Amount of inoculum and frequency of transport	10	1	10
3) Temperature requirements	7	4	6
4) Moisture requirements	7	6	5
5) Soil requirements	7	1	9
6) Mode of reproduction	10	2	5
7) Survival mechanisms	3	3	1
8) Capacity to change and adapt to new situations and cultivars	5	1	1
Economic importance phase			
1) Host range and economic importance of crops attacked	10	2	1
2) Number of life cycles and reproductive capacity at prevailing environmental conditions	10	3	3
3) Pathogenicity	6	8	10
4) Ability to interact with other soil-borne pathogens in disease complexes	10	5	2
5) Cropping systems and land management practices	—	—	—

[a]Probability index—Scale of 0-10; 0=highly unfavorable; 10=highly favorable.

certain parts of the world. For example, the red ring disease of coconut caused by *Rhadinaphelenchus cocophilus* is restricted to the Caribbean region and certain adjacent countries. What are this nematode's chances of being introduced into Africa and Southeast Asia where its effects on the economy could be catastrophic? Also, the lespedeza cyst nematode, *Heterodera lespedezae,* is reported only from North Carolina and Illinois. The tobacco cyst nematode is limited in its distribution. Many other examples could be given. If the hypothesis set forth in this paper could be tested to determine the relative importance of each factor, we should gain information which would be helpful in preventing further spread of those species now occurring in localized areas of the world.

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