SUSCEPTIBILITY OF OAKS TO ROOT-KNOT NEMATODES

by Frank S. Santamour, Jr.

Abstract. With few exceptions, white oaks (subg. *Quercus*) and red oaks (subg. *Erythrobalanus*), as well as species belonging to the subg. *Cyclobalanopsis* and subg. *Protobalanus* were resistant or tolerant to artificial inoculation with the common root-knot nematodes (*Meloidogyne arenaria*- two races, *M. hapla, M. Incognita, M. javanica*). However, all four species of subg. *Cerris* tested were susceptible to at least one of these nematodes. The oak root-knot nematode *(M. querciana)*, reported only from Virginia, was successful in parasitizing all 10 red oaks tested and one or more of the species in the other four subgenera. The galls produced by this nematode appeared to be concentrated on shallow roots, which might facillitate their observation in the field.

Two species of root-knot nematodes (*Meloidogyne* spp.) have been reported as parasitizing the roots of oaks (*Quercus* spp). In 1979, Golden (3) described *M. querciana* Golden, the oak root-knot nematode, first found in 1965 on nursery-grown *Q. palustris* in Virginia. He determined that both this oak and *Q. rubra* were susceptible to inoculation, but this nematode has not been reported on any oak since 1965. In 1986, *M. christiei* Golden & Kaplan was described from roots of *Q. laevis* Walt. in Florida (4). Both of these nematode species may have restricted host ranges (3, 4) limited to members of the oak or beech family (Fagaceae).

Unidentified nematodes have been reported on *Q. agrifolia* (1) and *Q.* suber (1, 2). Attempts to inoculate *Q. virginiana* with *M. ovalis* (5) and *Q. palustris* with *M. incognita* (3) indicated that these oaks were resistant.

The present study was undertaken to determine the susceptibility or resistance of a wide range of oak species to *M. querciana* and the common root-knot nematodes: *M. arenaria* (two races), *M. hapla, M. incognita,* and *M. javanica.*

Materials and Methods

With only two exceptions, all nematode inoculations were made on oak seedlings grown from acorns collected by the author or cooperators in the autumn of 1989. Those exceptions were seedlings of *Q. acuta* from a 1985 collection in Korea and *Q. virginiana* from a 1986 collection in North Carolina. The acorns were stored temporarily, shortly after receipt of collection, in sealed glass jars in a refrigerator. Again, with a couple of exceptions, the acorns of all species except those in subg. *Erythrobalanus* were sown in flats in the greenhouse on 9 November 1989, at which time germination had already begun in some species. The exceptions to this procedure were *Q. agrifolia* (an early-germinating red oak) and *Q. fusiformis* from Texas (sown 19 December 1989). Acorns of the rest of the red oaks (and seed of American beech) were stratified in flats for 90 days, beginning on 18 December 1989, before being placed in a warm greenhouse.

With all of the variables of numbers of acorns, times of germination, and differences in growth rate, it is not practical to give the exact dates of nematode inoculation and the pre-examination time periods for each of the oak-nematode combination. Generally from two to five seedlings of each oak species were inoculated with the common nematodes, using the same techniques as with willow (8), and they were examined after 70 to 90 days.

We obtained our original inoculum of *M. querciana* as galls on the roots of willow oak from Hedwig H. Triantaphyllou, North Carolina State University, under permit from the USDA Animal and Plant Health Inspection Service. Since none of the standard rapid-growing herbaceous nematode hosts (e.g. tomato) were susceptible to *M. querciana*, we had to build up our populations slowly by successive increases (up to 50) in the numbers of susceptible oak seedlings (*Q. palustris* and *Q. rubra*) inoculated. The first inoculations on oaks of unknown susceptibility, mostly the early-germinating white oaks, were made on 20 April 1990. Single seedlings of each species were unpotted on 22 August 1990 and examined for nematode galls—with somewhat disappointing results. A few galls (up to 10) were found on only *Q. mongolica, Q. robur*, and *Q. agrifolia*. However, there were also viable egg masses on all three species, and the galls were concentrated on a few roots that had developed near the surface of the growing media. First-year oak seedlings growing in containers tend to develop a taproot and then a circle of roots around the bottom of the container. We suspected that the depth of potentially susceptible roots and poor aeration of the medium in the bottom of the container could have had negative effects on the ability of this nematode to parasitize oak roots. Therefore, the remaining plants from the 20 April 1990 inoculations, as well as all other seedlings, whether inoculated or not, were repotted with all of their roots in the upper one-third of the container on 19 September 1990. Media from previously-inoculated containers was used to fill the pots and an average of five fresh galls were used to re-inoculate each plant. These plants were unpotted for examination on 13 June 1991, nearly nine months after repotting. Results for all species except *Q. acuta* and *Q. virginiana* were based on the June 1991 data.

According to the conditions under which the permit to experiment with *M. querciana* was issued, all plant material and growing media were autoclaved and containers and equipment decontaminated. No cultures of *M. querciana* were maintained beyond the permit expiration date of 30 September 1991.

Results and Discussion

The results of our inoculations are given in Table 1. The oak species are listed under the five subgenera recognized in an earlier paper (6). The only difference between the entries in this Table and those included in our earlier work on willows (8) is that the occurrence of viable egg masses is not quantified, but only noted as present or absent. The roots of oaks are not as fleshy as those of willows and the females, especially of *M. querciana*, may be embedded in the root tissue.

All of the red oak (subg. *Erythrobalanus*) species as well as those classified in subg. *Cyclobalanopsis* and subg. *Protobalanus* were resistant or tolerant to inoculation with the common root-knot nematodes. All of the species in subg. *Cerris* were susceptible to one or more of the common nematodes, but only two white oaks, *Q. dentata* and *Q. mongolica*, of subg. *Quercus* were susceptible to one of the common nematodes. The oak root-knot nematode (*M. querciana*) was successful in parasitizing and reproducing on 18 of the 30 oak taxa tested, including all of the red oaks and one or more of the taxa in the other four subgenera.

The galls produced by *M. querciana* appeared to develop most frequently on well-aerated roots near the soil surface. The only known locality for *M. querciana* was a nursery in Virginia (USA), but our results suggest that perhaps all the American red oaks, and at least two American white oaks (*Q. lobata* and *Q. virginiana*), are susceptible to this nematode. It seems highly unlikely, given the potential host range, that *M. querciana* would occupy a restricted geographic area. Examination of the shallow portions of the root systems of dying or recently deceased oaks might well reveal a wider distribution of this nematode and even implicate the nematode as a factor in the poorly-understood sudden-oak-death-syndrome (SODS), that cannot be attributed to oak wilt. There may well be a synergistic relationship between the oak nematode and various root-rot fungi, but there has been no research on this topic.

One other point of interest is that although Golden (3) reported that the American chestnut (*Castanea dentata*), which belongs to the same family (Fagaceae) as the oaks, was susceptible to inoculation with *M. querciana*, we found the American beech (*Fagus grandifolia*) to be resistant.

However, the data given in the Table are based on only a few seedlings that generally were the progeny of a single tree of each species. Therefore, it is likely that some seedlings or geographic origins of oak species reported here as nematode-resistant (or -tolerant) or nematode-susceptible may exhibit different responses. Despite these shortcomings of host sampling, our knowledge of root-knot nematodes on oaks has been greatly expanded and the new information can be used to plan future studies.

Table 1. Response of oak (*Quercus*) taxa to inoculation with root-knot nematodes (*Meloidogyne* spp.)[1]

Subgenus / Species	M. arenaria Race 1	M. arenaria Race 2	M. hapla	M. incognita	M. javanica	M. querciana
Quercus						
Q. alba L.	R(0-0)	R(0-0)	R(0-0)	R(0-0)	R(0-0)	R(0-0)
Q. bicolor Willd.	—	—	—	—	—	R(0-0)
Q. dentata Thunb.	T(2-0)	T(10-)	—	S(3-+)	T(2-0)	R(0-0)
Q. glandulifera Blume	R(0-0)	R(0-0)	—	R(0-0)	R(0-0)	R(0-0)
Q. lobata Nee	R(0-0)	R(0-0)	—	R(0-0)	R(0-0)	S(5-+)
Q. macrocarpa Michx	T(2-0)	T(2-0)	T(2-0)	T(3-0)	T(2-0)	T(2-0)
Q. mongolica Fisch.	T(2-0)	s(4-+)	—	T(2-0)	R(0-0)	S(4-+)
Q. petraea (Matt.) Liebl.	R(0-0)	R(0-0)	—	R(0-0)	R(0-0)	R(0-0)
Q. prinus L.	T(1-0)	R(0-0)	R(0-0)	T(2-0)	R(0-0)	R(0-0)
Q. pubescens Willd.	R(0-0)	R(0-0)	—	R(0-0)	R(0-0)	S(4-+)
Q. robur L.	R(0-0)	T(2-0)	—	R(0-0)	R(0-0)	S(5-+0
Q. stellata Wangh.	R(0-0)	R(0-0)	—	R(0-0)	T(2-0)	R(0-0)
Q. virginiana Mill.	R(0-0)	R(0-0)	—	R(0-0)	R(0-0)	S(3-+)
(Q. fusiformis Small)	R(0-0)	T(1-0)	R(0-0)	R(0-0)	R(0-0)	T(2-0)
Erythrobalanus (Spach) Oersted						
Q. agrifolia Nee	T(2-0)	T(2-0)	—	T(2-0)	T(2-0)	S(5-+)
Q. coccinea Muenchh.	T(1-0)	T(2-0)	R(0-0)	R(0-0)	T(2-0)	S(3-+)
Q. falcata Michx.	T(1-0)	R(0-0)	—	T(2-0)	R(0-0)	S(4-+)
Q. hemisphaerica Bartr. ex Willd.	T(1-0)	R(0-0)	—	R(0-0)	R(0-0)	S(3-+)
Q. imbricaria Michx.	R(0-0)	T(2-0)	—	R(0-0)	—	—
Q. laurifolia Michx.	T(2-0)	T(1-0)	—	T(2-0)	—	—
Q. marilandica Muenchh.	R(0-0)	R(0-0)	—	R(0-0)	R(0-0)	S(4-+)
Q. plaustris Muenchh.	R(0-0)	R(0-0)	R(0-0)	T(1-0)	R(0-0)	S(4-+)
Q. phellos L.	R(0-0)	R(0-0)	T(1-0)	R(0-0)	R(0-0)	S(4-=)
Q. rubra L.	T(1-0)	T(2-0)	T(1-0)	T(2-0)	R(0-0)	S(5-+)
Q. velutina Lam.	T(1-0)	R(0-0)	—	T(1-0)	R(0-0)	S(4-+)
Cerris Oersted						
Q. acutissima Blume	R(0-0)	S(2-+)	—	R(0-0)	R(0-0)	T(3-0)
Q. cerris L.	S(2-+)	T(2-))	R(0-0)	R(0-0)	R(0-0)	S(3-+)
Q. suber L.	S(3-+)	—	—	—	—	S(3-+)
Q. variabilis Carr.	T(2-0)	S(3-+)	—	S(3-+)	T(2-0)	R(0-0)
Cyclobalanopsis (Oersted) Schneid.						
Q. acuta Blume	T(2-0)	—	R(0-0)	T(2-0)	—	S(4-+)
Q. myrsinaefolia Blume	T(2-0)	—	T(1-0)	T(2-0)	—	R(0-0)
Protobalanus Muller						
Q. chrysolepis Liebm.	R(0-0)	R(0-0)	R(0-0)	R(0-0)	R(0-0)	S(3-+)

1/ Key to Table. S = susceptible, galls and egg masses noted; T = tolerant, some galls but no egg masses; R = resistant, no galls and no egg masses. First figure in parentheses refers to gall rating: 0 = no galls; 1 = from one to two galls; 2 = three to 10 galls; 3 = 11 to 30 galls; 4 = 31 to 100 galls; 5 = more than 100 galls per root system. (+) denotes that two or more egg masses with potentially viable eggs were found. (0) denotes that no egg masses were found.

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Resumé. À quelques exceptions près, les chênes blancs (sous-genre *Quercus*) et les chênes rouges (sous-genre *Erythrobalanus*), tout comme les espèces appartenant aux sous-genres *Cyclobalanopsis* and et *Protobalanus,* étaient résistants ou tolérants à l'inoculation artificielle avec les nématodes communs des racines (*Meloidogyne arenaria* [deux races], *M. hapla, M. incognita, M. javanica*). Cependant, les quatre espèces testées du sous-genre *Cerris* étaient sensibles à au moins un de ces nématodes. Le nématode des racines du chêne (*M. querciana*), observé seulement en Virginie, était efficace en parasitant les dix chênes rogues testés et un ou plus de chacune des espèces des quatre autres sous-genres. Les galles produites par ce nématode étaient concentrées sur les racines à faibles profondeurs, ce qui peut faciliter leur observation sur le terrain.

Zusammenfassung. Weißeichen (Untergattung *Quercus*) und Roteichen (Untergattung *Erythrobalanus*) sowie einige Arten der Untergattung *Cyclobalanopsis* und *Protobalanus* sind mit einigen Ausnahmen resistent order tolerant gegenüber künstlicher Beimpfung mit der gewöhnlichen Wurzel-Gallen-Nematode (*Meloidogyne arenaria* (zwei Rassen), *M. hapla, M. incognita, M. javanica*). Die vier getesteten Arten der Untergattung *Cerris* waren jedoch alle empfindlich gegen mindestens einer dieser Nematoden. Die Eichenwurzel-Gallen-Nematode (*M. querciana*), die bisher nur in Virginia genfunden wurde, war erfolgreich in der Parasitierung aller zehn getesteten Roteichen und einer bzw. mehrerer der Arten in den anderen vier Untergattungen. Die von diesen Nematoden produzierten Gallen konzentrieren sich an Wurzeln direkt unter der Oberfläche, was das Auffinden und Beobachten im Feld wesentlich erleichtern könnte.