SUSCEPTIBILITY OF REDBUDS (CERCIS) TO ROOT-KNOT NEMATODES

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Abstract. The native eastern American redbud (*Cercis canadensis*) was susceptible to parasitization by the northern root-knot nematode (*Meloidogyne hapla*), which produced galls and viable egg masses on this host. Two Chinese redbud species, *C. chinensis* and *C. yunnanensis*, were similar to *C. canadensis* in being susceptible to *M. hapla* and also apparently resistant to the reproduction of the other nematodes. Three other species (*C. occidentalis* from western United States, *C. racemosa* from China, and *C. siliquastrum* from Europe) were also susceptible to *M. hapla* as well as to *M. arenaria* (two races), *M. incognita*, and *M. javanica*. This is the first report of root-knot nematodes on *Cercis* The potential for synergism between the nematodes and Verticillium wilt fungi is discussed.

For approximately 18 years (1958-1976), the Shrub Breeding Project at the U.S. National Arboretum was involved with *Cercis* (redbuds), evaluating germplasm and attempting some interspecific hybridizations. This work was abandoned because of canker and wilt problems among the progenies and selections. Recently, spurred by the introduction and flowering of the Chinese *C. racemosa* Oliv., a tree-type species that produces its flowers in long racemes, work with this genus has begun again. Resistance to cankers caused by *Botryosphaeria dothidea* and to Verticillium wilt (caused by *V. albo-atrum* and *V. dahliae*) will be major goals of this research program.

Screening for resistance or tolerance to Verticillium wilt by artificial inoculation with the pathogen may not truly reflect the behavior of plants in field situations where other organisms are present. We have recently reported (9) that certain clones of Norway maple that showed high tolerance to Verticillium wilt inoculations could be killed back by the synergistic effects of *V. dahliae* and several species of root-knot nematodes (*Meloidogyne* spp.).

In our compilation of the world literature concerning root-knot nematodes on landscape trees (10), no reports were found on *Cercis* spp. Therefore, we undertook to determine the response of various *Cercis* taxa to inoculation with several common root-knot nematodes as part of the overall selection and breeding program.

Materials and Methods

Open-pollinated seed was collected in 1992 from plants of *C. chinensis*, *C. chingii* Chun, *C. racemosa*, and *C. yunnanensis* at the U.S. National Arboretum. It was later determined that the specimens grown as *C. chingii* could be more properly considered as *C. chinensis* but the seedlots and seedlings were kept separate for the nematode tests. Seed of *C. occidentalis* (Torr.) ex Gray and *C. siliquastrum* were obtained from a commercial source. The nomenclatural status of *C. occidentalis* is in doubt, and although the correct designation of this material might be as a subspecies of *C. californica* (Torr.) ex Benth. or *C. orbiculata* Greene, lack of information on provenance suggests that we retain "*C. occidentalis*" at present.

Seedlots of *C. canadensis* included material from a commercial source as well as wild-collected seed from five different provenances. All of these collections could be considered as *C. canadensis* subsp. *canadensis*.

All of the seedlings except those from the various native provenances of *C. canadensis* were growing in individual containers in a soil-free medium consisting of four parts Metromix and one part perlite, with micronutrients added. The provenance seedlings were growing in flats in a sand-sphagnum medium and were potted two weeks prior to nematode inoculation.

At the time of inoculation on 9 August 1993, all of the seedlings except those of *C. siliquastrum* and the provenances of *C. canadensis* were between eight inches and twelve inches in height and were growing vigorously. The seedlings of *C.*

siliquastrum were only about six inches tall, but were very healthy. On the other hand, the provenance seedlings of *C. canadensis* were weak-appearing plants ranging from four to six inches in height.

Nematode cultures of *Meloidogyne arenaria* (Neal) Chitwood-two races, *M. hapla* Chitwood, *M. incognita* (Kofoid and White) Chitwood, and *M. javanica* (Treub) Chitwood were maintained on plants of 'Rutgers' tomato. The nematode inoculum consisted of finely chopped root galls mixed with the tomato growing medium in a 2:1 ratio. Each *Cercis* seedling was inoculated by placing two 25 cc aliquots of the chopped gall inoculum into each container. Three seedlings of each of the 12 *Cercis* seedlots were inoculated with each of five nematodes, giving a total of 180 plants.

The inoculated seedlings were unpotted 70 to 80 days after inoculation. The root systems were removed, rinsed relatively free of growing medium, and stored in plastic bags in a refrigerator at 4°C until critical examination. All galls on all root systems were counted. The percentage of galls containing viable egg masses was determined by examining all galls on root systems with fewer than 100 galls and at least 100 galls on root systems harboring larger numbers of galls.

Results and Discussion

Results of the nematode analyses are given in Table 1. All of the nematodes were capable of producing substantial numbers of galls on the roots of all vigorous seedlings of all the *Cercis* taxa tested. In previous generic surveys of willows (11), oaks (7), and maples (8), we found that at least a few, and sometimes many, taxa appeared to be highly resistant to gall formation by one or more of the nematodes. It may be that there was greater genetic diversity in those genera with well-defined subgeneric or sectional categories and that the *Cercis* species represent a more homogeneous group. The lower degree of galling on the provenance seedlings of *C. canadensis* was likely the results of their sub-optimal growth.

Even though most of the plants were heavily galled, there were major differences in the ability of the different nematodes to reproduce on the various *Cercis* species. It would appear that *C. occidentalis*, *C. racemosa*, and *C. siliquastrum* were susceptible to all of the nematodes, but the

Table 1. Response of redbud (Cercis) taxa to inoculation with root-knot nematodes (Meloidogyne spp.) [1]

Species source	M. arenaria Race 1	M. arenaria Race 2	M. hapla	M. incognita	M. javanica
C. canadensis					
Commercial	5(0)	3(0)	4(12)	4(0)	3(0)
Michigan	3(0)	2(0)	3(6)	2(0)	4(0)
N. Carolina	3(0)	2(0)	3(0)	3(0)	3(0)
Pennsylvania	4(0)	4(0)	3(0)	4(0)	2(0)
Tennessee	4(0)	4(0)	4(2)	4(0)	2(0)
Virginia	2(0)	2(0)	4(2)	2(0)	4(0)
C. chinensis	5(0)	4(0)	4(13)	4(0)	4(0)
(C. chingii)	5(0)	4(0)	5(17)	4(0)	5(0)
C. occidentalis	5(2)	5(2)	4(25)	5(7)	5(11)
C. racemosa	5(8)	5(16)	5(16)	5(15)	5(16)
C. siliquastrum	5(34)	5(16)	5(29)	5(17)	5(13)
C. yunnanensis	5(0)	5(0)	4(1)	5(0)	5(0)

1/ First number refers to worst case 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. Number in parentheses is the percentage of galls containing viable egg masses.

reproduction of *M. arenaria* on *C. occidentalis* was not especially high. Only *M. hapla* was capable of reproducing on *C. canadensis* and *C. chinensis* (including *C. chingii*). The limited reproduction of *M. hapla* on weak-growing seedlings from three of the five provenance seedlots of *C. canadensis* provided some confirmation that *M. hapla* would be the major pest of this species.

The high degree of galling and lack of nematode reproduction in many redbud-nematode combinations is reminiscent of the work of Golden and Shafer (3) on the crucifer *Hesperis matronalis* L. They found that although four species and two subspecies of nematodes produced numerous galls on this plant no nematode reproduction occurred.

It is possible that *C. yunnanensis* was resistant to the reproduction of all of the nematodes. The single egg mass found in the analysis of 80 galls produced by *M. hapla* on three plants of this species produced only a few normal-appearing eggs. Interestingly, 469 galls of *M. javanica* were found on one plant of this species. This was the highest number of galls on any plant of any species, but not one egg mass was detected.

Several species of *Cercis* have been shown to be susceptible to Verticillium wilt, and a few reports have dealt with more than the isolation of the pathogenic fungus from symptomatic plants. Furthermore, there has always been some controversy whether the pathogen should be classified as *V. albo-atrum* or *V. dahliae*. For instance, Carter (1) reported the isolation of *V. albo-atrum* from *C. canadensis* in Illinois in 1941, but Smith and Neely (12) considered all of the 51 isolates obtained from woody hosts in Illinois (including *C. canadensis*) to be *V. dahliae*.

With regard to *C. canadensis*, Himelick (4) was able to induce wilt symptoms in six of 10 seedlings that were trunk-inoculated. Smith and Neely (12) determined the relative susceptibilities of six woody species by pathogen recovery, the extent of vascular colonization, and the length of vascular streaking following twig inoculations with nine fungal isolates. They concluded that *C. canadensis* was nearly as susceptible to Verticillium wilt as Norway maple, and more susceptible than American elm, catalpa, tuliptree, green ash, and Russian olive.

Verticillium wilt has also been noted on *C. siliquastrum* in Italy (2) and on *C. chinensis* in Russia (6). More recently, Jacobs et al. (5) tested seedlings of *C. canadensis*, *C. chinensis*, and *C. yunnanensis* Hu and Cheng for variability in resistance to Verticillium wilt, using root dip inoculations with isolates of *V. dahliae*. They found that although the infection rate in *C. canadensis* was significantly lower than that for either Chinese species, the low infection rate of all species suggested that the root dip was marginally effective at inoculating plants.

These nematode data have obvious implications for breeding research, since it is possible that progeny from crosses of *C. racemosa* with *C. canadensis* might be susceptible to all of the nematodes. The use of *C. yunnanensis* in certain crosses may confer nematode resistance to hybrid progenies. However, the susceptibility of *Cercis* spp. to nematodes may only be a major problem in the field if there is a synergistic effect between root-knot nematodes and *Verticillium* spp. Studies to determine this possibility will be undertaken in 1994.

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Résumé. Le gainier du Canada (*Cercis canadensis*) était sensible à un nématode anneleur de racines (*Meloidogyne hapla*) qui produisait des galles et des masses d'œufs viables sur l'arbre hôte. Deux espèces chinoises de gainier, *C. chinensis* et *C. yunnanensis*, étaient elles aussi sensibles à *M. hapla* mais apparemment résistantes aux autres espèces de nématodes. Trois autres espèces, (*C. occidentalis* de l'Ouest des États-Unis, *C. racemosa* de Chine et *C. siliquastrum* d'Europe) étaient autant sensibles à *M. hapla* qu'à *M. arenaria* (deux races), *M. incognita* et *M. javanica*. Ceci constitue le premier rapport concernant la présence de nématodes anneleurs de racines sur le *Cercis*.

Zusammenfassung. Der Judasbaum (Cercis canadensis) ist anfällig für Wurzelnematoden (Meloidogyne hapla), welche an ihrem Wirt Gallen produzieren und zahlliose lebensfähige Eier legen. Zwei chinesische Judasbaumarten C. chinensis und C. yunnanensis, sind auch anfällig für M. hapla aber gegenüber anderen Arten resistent. Drei weitere Arten (C. occidentalis aus den westlichen USA, C. racemosa aus China und C. siliquastrum aus Europa) sind sowohl anfällig für M. hapla als auch für M. arenaria (zwei Rassen), M. incognita und M. javanica. Dies ist der erste Bericht über Wurzelnematoden an Cercis.