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Host Suitability of Twelve Leguminosae Species to Populations of *Meloidogyne hapla* and *M. chitwoodi*[1]

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Abstract: Legumes of the genera *Astragalus* (milkvetch), *Coronilla* (crownvetch), *Lathyrus* (pea vine), *Lotus* (birdsfoot trefoil), *Medicago* (alfalfa), *Melilotus* (clover), *Trifolium* (clover), and *Vicia* (common vetch) were inoculated with a population of *Meloidogyne chitwoodi* from Utah or with one of three *M. hapla* populations from California, Utah, and Wyoming. Thirty-nine percent to 86% of alfalfa (*M. scutellata*) and 10% to 55% of red clover (*T. pratense*) plants survived inoculation with the nematode populations at a greenhouse temperature of 24 ± 3°C. All plants of the other legume species survived all nematode populations, except 4% of the white clover (*T. repens*) plants inoculated with the California *M. hapla* population. Entries were usually more susceptible to the *M. hapla* populations than to *M. chitwoodi*. Galling of host roots differed between nematode populations and species. Root-galling indices (1 = none, 6 = severely galled) ranged from 1 on pea vine inoculated with the California population of *M. hapla* to 6 on yellow sweet clover inoculated with the Wyoming population of *M. hapla*. The nematode reproductive factor (Rf = final nematode population/initial nematode population) ranged from 0 for all nematode populations on pea vine to 35 for the Wyoming population of *M. hapla* on alfalfa (*M. sativa*).

Key words: host suitability, legumes, leguminosae, *Meloidogyne chitwoodi, M. hapla,* pathology, reproduction, root galling, root-knot nematode, resistance, shoot weight, survival, susceptibility.

Approximately 86% of the 153 million hectares of rangeland in the Intermountain Region of the western United States is considered to be in less than good condition, and is estimated to produce only 60% of its potential (21). Nitrogen, an essential constituent of protein necessary for cell protoplasm, must be in an available form for all flora organisms (1,2). Vegetative plant growth on 72 million hectares of rangeland in the Northern Great Plains is limited by a lack of available nitrogen (24). A symbiotic relationship exists between nitrifying bacteria (*Rhizobium* spp.) and Leguminosae that enrich the soil with nitrogen. The use of adapted legumes increases the amount of available nitrogen and improves pasture and rangeland conditions (17,19). Legumes are not only beneficial for making atmospheric nitrogen available for other plants but also aid in land reclamation and are used as an energy supply for wildlife and livestock (16). Several species of legumes are adapted to rangeland conditions and are beneficial to rangeland ecology (19).

Plant-parasitic nematodes, including populations of the northern root-knot nematode (*M. hapla* Chitwood) and the Columbia root-knot nematode (*M. chitwoodi* Golden, O'Bannon, Santo, & Finley), parasitize and suppress the growth of legumes and rangeland vegetation in the United States (4–8,10–12,15,18,22,23). The objective of this study was to compare host suitabilities of 12 Leguminosae species to geographically separated populations of *M. hapla* and *M. chitwoodi.*

Materials and Methods

Nematode populations studied were *M. chitwoodi* isolated from potato, *Solanum tuberosum* L., at Beryl, Utah (13), and three *M. hapla* populations isolated from alfalfa (*Medicago sativa* L.) at Visalia, California (11; lettuce (*Lactuca sativa* L.) at Ogden, Utah; and alfalfa at Laramie, Wyoming (9). Nematode populations were cultured on 'Rutgers' tomato (*Lycopersicon esculentum* Mill.) under greenhouse conditions, and inocula (eggs) were collected with an NaOCl method (14). The *Meloidogyne* populations are differentiated by their relationships to the alfalfa germplasm Nevada

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Synthetic XX (Nev Syn XX). Nev Syn XX is resistant to *M. hapla* from Utah and Wyoming and susceptible to *M. chitwoodi* and *M. hapla* from California (9).

The legumes examined were milk vetch (*Astragalus cicer* L.), sickle pod milk vetch (*A. falcatus* Lam.), crownvetch (*Coronilla varia* L.), pea vine (*Lathyrus* L. sp.), birdsfoot trefoil (*Lotus corniculatus* L.), alfalfa (*Medicago falcata* L.), alfalfa (*M. sativa* L.), alfalfa (*M. scutellata* (L. All.), yellow sweet clover (*Melilotus officinalis* Willd.), white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.), and common vetch (*Vicia sativa* L.).

Seeds were scarified and germinated on filter paper. Twenty-eight days after imbibition seedlings were transplanted into individual 6-cm-diameter plastic containers containing 540 cm^3 steam-pasteurized Kidman fine sandy loam soil (coarse-loamy mixed mesic Calcic Haploxeroll [84% sand, 8% silt, 8% clay; pH 7.4, 1% OM]). An aqueous suspension of eggs of a single *Meloidogyne* population was poured into four holes 10 cm deep in the soil around the hypocotyl base at a rate of 2.0 eggs/cm^3 soil. Uninoculated plants were included as controls. Plants were grown at a soil temperature of 24 ± 3 °C and received 19 hours of light per day; light was supplemented with high-output fluorescent lamps. The experiment was a 4 × 12 × 2 factorial (4 nematode species × 12 plant entries × 2 inoculum densities) in a randomized complete block design with 100 replications (containers), one plant per replicate or single container. Plants were watered daily and fertilized monthly with a complete nutrient solution. Plants were harvested 95 days after inoculation. The dry shoot weight and a root galling index (1 = no galling, 2 = 1% to 10%, 3 = 11% to 20%, 4 = 21% to 50%, 5 = 51% to 80%, 6 = 81% to 100% root tissue galled) were determined. Nematode eggs were extracted from the entire root system of each plant by the NaOCl method (14), and the nematode reproductive factor (Rf = final nematode population/initial nematode population) and resistance classification were calculated for each plant. The criterion for classifying a plant as resistant was Rf < 1 (3). The experiment was repeated, and the data presented are means of the two experiments. Data were analyzed with analysis of variance, and differences among means were compared at $P < 0.05$ using LSD. Each parameter measured was regressed against nematode populations. Percentage data on plant survival were transformed with arcsine $\sqrt{x}$ before analysis.

Results and Discussion

Alfalfa (*M. scutellata*) and red clover (*T. pratense*) were the most susceptible of all the legume species evaluated. Plant survival rates were 86%, 39%, 46%, and 39% for *M. scutellata* and 55%, 40%, 28%, and 10% for red clover when inoculated with *M. chitwoodi* and with *M. hapla* from California, Utah, and Wyoming, respectively. All plants of all other legume species survived inoculation with all nematode populations, except for 4% of the white clover (*T. repens*) plants infested with the California *M. hapla* population.

Based on dry shoot weights, suppression of plant growth differed among entries but not nematode populations (Table 1). Shoot weights of all entries except sickle pod milk vetch (*A. falcatus*), crownvetch (*C. varia*), pea vine (*Lathyrus* sp.), birdsfoot trefoil (*L. corniculatus*), and alfalfa (*M. falcata*) were reduced ($P < 0.05$) by one or more nematode population. Generally, entries were more susceptible ($P < 0.05$) to the *M. hapla* populations than to *M. chitwoodi*.

Root-knot galling differed ($P < 0.05$) among nematode populations and species (Table 2). Overall, galling of plants was greater with *M. hapla* than with *M. chitwoodi*. All legume species were moderately to heavily galled except for pea vine, where little or no galling occurred with any nematode populations. As observed in a previous study (20), pea vine was the most resistant of all legumes. The greatest galling occurred on yellow sweet clover exposed to the Wyoming population of *M. hapla*.

TABLE 1. Effect of a *Meloidogyne chitwoodi* population from Utah (MCUT) and *M. hapla* populations from California (MHCA), Utah (MHUT), and Wyoming (MHWY) on dry shoot weight of 12 legume species.[a]

Plant entry	Dry shoot weight (g)[b]					LSD ($P < 0.05$)
	MCUT	MHCA	MHUT	MHWY	Control	
Astragalus cicer 1[c]	0.81	0.91	0.96	0.95	1.26	0.3
Astragalus cicer 2[c]	0.93	1.06	1.25	1.16	1.32	0.3
Astragalus falcatus 1	0.09	0.09	0.05	0.09	0.11	NS
Astragalus falcatus 2	0.18	0.24	0.22	0.24	0.22	NS
Coronilla varia	0.17	0.16	0.17	0.18	0.22	NS
Lathyrus sp.	1.60	1.66	1.56	1.54	1.60	NS
Lotus corniculatus	0.23	0.25	0.24	0.23	0.27	NS
Medicago falcata	0.60	0.57	0.52	0.56	0.67	NS
Medicago sativa 1	1.49	1.25	1.24	1.29	1.80	0.4
Medicago sativa 2	1.51	1.33	1.35	1.26	1.81	0.3
Medicago scutellata	0.99	0.67	0.70	0.68	1.22	0.3
Melilotus officinalis	2.07	1.72	1.60	1.69	2.55	0.9
Trifolium repens	0.46	0.42	0.47	0.51	0.90	0.4
Trifolium pratense	0.33	0.28	0.27	0.26	0.49	0.1
Vicia sativa	0.49	0.48	0.45	0.41	0.80	0.3
LSD ($P < 0.05$)	0.12	0.17	0.21	0.17	0.23	

[a] Twenty eight-day-old plants inoculated with 2.0 eggs/cm^3 soil and grown for 95 days after inoculation on a greenhouse bench at 24 ± 3 °C.
[b] Each value is the mean of 100 replicates.
[c] Denotes different seed lots.

All Leguminosae species, except pea vine, were hosts (Rf > 1) (3) for *M. chitwoodi* and the three populations of *M. hapla* (Table 3). However, entries differed ($P < 0.05$) for percent-resistant plants (Table 4). The pea vine seed lot was 100% resistant, whereas the white clover seed lot was 100% susceptible to both *M. hapla* and *M. chitwoodi*. There were also genetic differences within seed lots of the other en-

TABLE 2. Root galling of 12 Leguminosae species by a *Meloidogyne chitwoodi* population from Utah (MCUT) and *M. hapla* populations from California (MHCA), Utah (MHUT), and Wyoming (MHWY).[a]

Plant entry	Root-galling indices[b]				LSD ($P < 0.05$)
	MCUT	MHCA	MHUT	MHWY	
Astragalus cicer 1[c]	3.1	4.9	4.9	5.2	0.9
Astragalus cicer 2[c]	4.4	5.1	4.8	5.4	0.6
Astragalus falcatus 1	3.2	3.7	3.4	3.4	NS
Astragalus falcatus 2	3.6	3.4	3.7	3.5	NS
Coronilla varia	3.7	4.3	4.2	4.0	NS
Lathyrus sp.	1.0	1.0	1.2	1.2	NS
Lotus corniculatus	2.5	2.0	2.9	2.2	0.6
Medicago falcata	2.6	4.4	4.4	4.8	0.8
Medicago sativa 1	2.3	4.4	4.0	4.1	0.7
Medicago sativa 2	2.5	4.7	4.8	4.5	0.7
Medicago scutellata	3.0	4.8	4.9	5.1	0.9
Melilotus officinalis	2.9	5.6	5.2	6.0	0.8
Trifolium repens	4.8	5.0	4.8	5.3	NS
Trifolium pratense	3.5	5.1	5.2	5.4	1.0
Vicia sativa	2.8	4.6	4.5	5.0	0.8
LSD ($P < 0.05$)	0.9	1.2	1.3	1.4	

[a] Twenty eight-day-old plants inoculated with 2.0 eggs/cm^3 soil and grown for 95 days after inoculation on a greehouse bench at 24 ± 3 °C. Each value is the mean of 100 replicates.
[b] Root-galling indices (1 = no galling; 6 = 80%–100% root tissue galled). Readings made 120 days after inoculation.
[c] Denotes different seed lots.

TABLE 3. Reproduction of a *Meloidogyne chitwoodi* population from Utah (MCUT) and *M. hapla* populations from California (MHCA), Utah (MHUT), and Wyoming (MHWY) on 12 Leguminosae species.[a]

Plant entry	Nematode reproductive indices (Rf)[b]				LSD ($P < 0.05$)
	MCUT	MHCA	MHUT	MHWY	
Astragalus cicer 1[c]	4	29	31	27	4
Astragalus cicer 2[c]	6	32	29	26	5
Astragalus falcatus 1	8	12	15	13	5
Astragalus falcatus 2	10	11	10	8	NS
Coronilla varia	7	12	12	14	4
Lathyrus sp.	0	0	0	0	—
Lotus corniculatus	4	13	16	17	7
Medicago falcata	8	14	18	13	6
Medicago sativa 1	12	31	34	29	8
Medicago sativa 2	10	29	31	35	8
Medicago scutellata	10	30	30	33	7
Melilotus officinalis	10	29	34	32	7
Trifolium repens	9	30	27	33	6
Trifolium pratense	10	29	27	32	7
Vicia sativa	6	26	24	23	6
LSD ($P < 0.05$)	2	5	5	7	

[a] Twenty eight-day-old plants inoculated with 2.0 egg/cm^3 soil and grown for 95 days after inoculation on a greenhouse bench at 24 ± 3 °C. Each value is the mean of 100 replicates.
[b] Nematode reproductive index Rf (final nematode population/initial nematodes population).
[c] Denotes different seed lots.

tries, which accounts for differences among entries in relation to shoot growth, galling, and reproduction.

A greater percentage of plants were resistant to *M. chitwoodi* than to *M. hapla* for all legume species evaluated, except for sickle pod milk vetch (seed lot 1), pea vine, and birdsfoot trefoil. The percentage of

TABLE 4. Resistance and susceptibility of 12 Leguminosae species to a *Meloidogyne chitwoodi* population from Utah (MCUT) and *M. hapla* populations from California (MHCA), Utah (MHUT), and Wyoming (MHWY).[a]

Plant entry	Percent resistant plants[b]				LSD ($P < 0.05$)
	MCUT	MHCA	MHUT	MHWY	
Astragalus cicer 1[c]	17	9	14	11	6
Astragalus cicer 2[c]	20	0	0	0	2
Astragalus falcatus 1	10	7	14	9	NS
Astragalus falcatus 2	20	15	17	14	NS
Coronilla varia	29	10	7	13	4
Lathyrus sp.	100	100	100	100	NS
Lotus corniculatus	25	38	25	35	7
Medicago falcata	77	12	10	14	11
Medicago sativa 1	50	0	0	0	3
Medicago sativa 2	64	12	15	7	9
Medicago scutellata	14	0	0	0	3
Melilotus officinalis	29	0	0	0	2
Trifolium repens	0	0	0	0	0
Trifolium pratense	45	0	0	0	2
Vicia sativa	17	10	13	9	6
LSD ($P < 0.05$)	14	8	12	7	

[a] Inoculated when 28 days old with 2.0 eggs/cm^3 soil and grown for 95 days after inoculation on a greenhouse bench at 24 ± 3 °C.
[b] Each value is the mean of 100 replicates. Plant classified as resistant when Rf < 1. Nematode reproductive factor = final nematode population/initial nematode population.
[c] Denotes different seed lots.

plants resistant to *M. hapla,* except for pea vine, varied from 0% for milk vetch, yellow sweet clover, alfalfa (*M. sativa* and *M. scutellata*), white clover, and red clover for all *M. hapla* populations to 38% of birdsfoot trefoil plants resistant to the California population.

There were few differences ($P > 0.05$) in Rf among the three populations of *M. hapla* (Table 3). However, reproduction of *M. hapla* was greater than *M. chitwoodi* on all legumes but sickle pod milk vetch. There were differences ($P < 0.05$) in the Rf among the different nematode populations on the different plant selections. Except for pea vine, the maximum and minimum Rf of *M. chitwoodi* were 12 and 4 on alfalfa (*M. sativa*) and milk vetch, respectively. This compared to Rf of 35 and 8 for the Wyoming population of *M. hapla* on alfalfa (*M. sativa*) and sickle pod milk vetch, respectively.

The three *M. hapla* populations did not vary ($P > 0.05$) for Rf or for the severity of galling produced on most legume entries in this study. Conversely, variability among *M. hapla* populations in alfalfa has been found in previous studies (9). The *M. hapla* populations caused root galling on most plant species and had a higher reproductive factor than *M. chitwoodi.* Root galling and nematode reproduction were highly correlated ($r = 0.74$) for *M. hapla* for most of the nematode-plant entry relationships. The correlation ($r = 0.59$) between root galling and nematode reproduction was less evident for *M. chitwoodi.*

Root galling alone is not always a good criterion for determining resistance or susceptibility of a plant to a *Meloidogyne* spp. Although there was a significant correlation between root galling and nematode reproduction in this study, there have been reported incidences where this is not the case. A previous study showed that while there were no differences ($P > 0.05$) in the root-galling indices, there were differences ($P < 0.05$) in the Rf values of four *M. hapla* populations on alfalfa (9). Both root-galling and nematode reproduction must be considered when determining the resistance and susceptibility of a plant selection to a *Meloidogyne* spp. (3).

Leguminosae entries that had relatively low root gall indices and Rf may be useful sources of genetic resistance to *M. hapla* and(or) *M. chitwoodi* in the development of legumes adapted for rangeland conditions. Resistance to *M. hapla* should be considered when breeding and improving legumes for forage production and adaptation. Inasmuch as resistance is the major means of controlling *Meloidogyne* spp., geneticists and plant breeders should be aware that the physiology of nematode populations and races differs by geographical origin. Evaluating a broad range of germplasm and then selecting and increasing the more resistant introductions often has resulted in sufficient improvement for the release of economically important entries of legumes planted as minor crops (19).

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