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Resistance of Diploid Triticeae Species and Accessions to the Columbia Root-knot Nematode, *Meloidogyne chitwoodi*[1]

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Abstract: The Columbia root-knot nematode, *Meloidogyne chitwoodi* race 2, is associated with several plant species, including members of the tribe Triticeae. We evaluated 15 diploid species for *M. chitwoodi* gall and reproductive indices from the following genera: *Agropyron, Pseudoroegneria, Hordeum, Psathyrostachys,* and *Thinopyrum*. Species from the genus *Thinopyrum* (*Thinopyrum bessarabicum*; J genome) and *Psathyrostachys* (*Psathyrostachys fragilis, P. juncea, P. stoloniformis*; N genome) expressed more resistance to *M. chitwoodi* than species within the genera *Agropyron* (*Agropyron cristatum* and *A. mongolicum*; P genome), *Pseudoroegneria* (*Pseudoroegneria spicata, P. stipifolia, A. aegilopoides, P. libanotica*; S genome), and *Hordeum* (*Hordeum bogdanii, H. brevisubulatum, H. californicum,* and *H. chilensis*; H genome), although there was variation among individuals within *P. spicata, P. juncea,* and *P. fragilis*. The variation among genera and within species indicates that it would be possible to select Triticeae grasses for resistance to *M. chitwoodi* in order to identify and introgress genes for resistance into cultivated cereals.

Key words: *Agropyron,* Columbia root-knot nematode, *Elymus,* genome, grass, *Hordeum, Meloidogyne chitwoodi,* nematode, *Psathyrostachys, Pseudoroegneria,* resistance, screening, *Thinopyrum,* Triticeae.

The perennial grasses of the tribe Triticeae are among the worlds' most valuable forages and an important gene source for wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), and rye (*Secale cereale*) breeders. The tribe includes about 250 species from most temperate and subarctic regions of the world (3). Hybridization between and within annual and perennial Triticeae species has been used to transfer disease and insect resistance since the 1930s, when Tsitsin demonstrated that *Thinopyrum ponticum, T. intermedium,* and *T. junceum* hybridized readily with various species of *Triticum* (17). Sharma and Gill (15) published a review on wide hybridization with wheat and its related relatives.

Plant-parasitic nematodes can reduce the productivity of cereals and the longevity and productivity of perennial grasses (4,5). Several species of root-knot nematodes are associated with grasses (1,5,11, 13), including the Columbia root-knot nematode, *Meloidogyne chitwoodi*. This nematode is a serious pest of potato (*Solanum tuberosum*) in the western United States, where potato is often rotated with cereals (6). Development of nematode-resistant cereals would reduce the yield losses in potato production.

The objective of this study was to evaluate diploid perennial Triticeae species for possible sources of resistance to *M. chitwoodi*.

Materials and Methods

Seeds of 35 accessions representing 15 diploid ($2n = 14$) species (five genera) within the perennial Triticeae (Table 1) were obtained from the USDA Agricultural Research Services U.S. Living Collection of Perennial Triticeae Grasses (Forage and Range Research Laboratory, Logan, UT). Within each accession, 58–81 individuals were screened for response to *M. chitwoodi*.

Meloidogyne chitwoodi race 2 from a potato field at Beryl, Utah, was cultured on barley (cv. Steptoe) in the greenhouse at 24 ± 3 C. Eggs were collected by the NaOCl method (9).

Seeds were germinated in moist vermiculite and planted into plastic tubes (6-cm-d, 30 cm long) containing 540 cm^3 steam-sterilized Kidman fine sandy loam (coarse–loamy mixed mesic Calcic Haploxeroll;

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TABLE 1. Root gall and reproductive indices of *Meloidogyne chitwoodi* on diploid Triticeae species and plant introductions (PI).

Species	Genome§	*n*	Root gall rating†		Nematode reproductive index‡	
			Mean	Standard error	Mean	Standard error
Agropyron cristatum	P					
PI229574		58	4.8	1.0	32.7	20.0
PI297870		80	3.6	1.5	14.6	35.5
PI315357		78	2.2	1.0	6.3	10.1
Species mean		216	3.4	1.6	16.5	26.8
A. mongolicum	P					
D2778		76	2.9	1.2	4.0	5.4
PI499392		80	2.3	1.2	4.9	6.9
Species mean		156	2.6	1.2	4.5	6.2
Genome mean	P	372	3.1	1.5	11.4	21.60
A. aegilopoides	S					
PI499637		79	3.5	1.2	13.1	15.4
PI499638		75	3.6	1.3	16.1	13.0
Species mean		154	3.5	1.2	14.5	14.3
Pseudoroegneria libanotica	S					
PI222959		80	3.7	1.2	8.1	7.4
PI229581		73	3.2	1.5	7.1	8.8
PI401338		74	2.1	1.1	3.2	5.8
Species mean		227	3.0	1.4	6.2	7.7
P. spicata	S					
D2844		77	1.5	0.6	0.7	1.1
PI232117		80	1.7	0.8	0.6	1.5
PI236681		79	2.0	0.8	2.8	4.8
'Whitmar'		76	1.6	0.9	0.5	1.7
Species mean		312	1.7	0.8	1.2	2.9
P. stipifolia	S					
PI313860		79	2.7	1.1	5.2	5.7
PI325181		79	2.2	1.1	3.7	6.4
PI440000		81	2.0	1.0	2.3	11.8
Species mean		239	2.3	1.1	3.7	8.5
Genome mean	S	932	2.5	1.3	5.2	9.5
Hordeum bogdanii	H					
PI269406		79	3.2	0.9	73.3	67.3
PI401386		76	4.0	1.1	96.9	66.0
Species mean		155	3.6	1.1	84.9	67.5
H. brevisubulatum	H					
PI531774		77	3.3	1.0	22.9	18.8
H. californicum	H					
PI531779		80	1.2	0.4	0.5	1.5
H. chilensis	H					
PI5317811		79	1.1	0.3	0.1	0.3
Genome mean	H	391	2.5	1.4	38.3	58.0
Psathyrostachys fragilis	N					
PI343190		79	2.7	1.3	2.2	3.1
PI401394		76	2.3	1.1	1.5	9.9
Species mean		155	2.5	1.2	1.8	7.3
Psathyrostachys juncea	N					
PI314668		76	2.3	0.9	3.0	4.8
PI499673		59	1.5	0.7	0.3	0.6
'Bozoisky'		61	1.3	0.5	0.3	0.9
'Vinall'		77	2.1	1.0	1.0	2.7
Species mean		273	1.9	0.9	1.2	3.1
Psathyrostachys stoloniformis	N					
D2562		80	1.8	1.0	0.9	1.9
D3376		80	1.7	0.9	0.4	1.1

TABLE 1. *Continued*

Species	Genome§	*n*	Root gall rating† Mean	Root gall rating† Standard error	Nematode reproductive index‡ Mean	Nematode reproductive index‡ Standard error
Species mean		160	1.7	0.9	0.6	1.6
Genome mean	N	588	2.0	1.0	1.2	4.4
Thinopyrum elongatum	E					
PI531719		81	2.7	1.2	6.2	10.8
PI547326		81	2.7	1.0	8.1	8.6
Genome mean	E	162	2.7	1.1	7.2	9.8
T. bessarabicum	J					
AJC305		72	1.9	1.0	2.1	4.1
PI431711		76	2.3	0.9	3.0	3.6
PI531712		77	1.9	0.9	1.0	2.2
Genome mean	J	225	2.0	0.9	2.0	3.5
Genome LSD ($P = 0.05$)			0.2		4.2	

† Root galling rating: 1 = no galls; 2 = 1–10% root tissue galled; 3 = 11–30%; 4 = 31–50%; 5 = 51–80%; and 6 = 81–100% root tissue galled.

‡ Reproductive index = Pf/Pi, where Pf = the final number of *M. chitwoodi* eggs per plant and Pi = the initial number of eggs per plant.

§ Letter designation given for the basic number of chromosomes for a given genus of organisms.

85% sand, 8% silt, 7% clay; pH 7.1; 0.5% organic matter). Thirty days after planting, each tube was infested with ca. 2,160 eggs from an egg suspension in deionized water, poured into four 10-cm deep holes in the soil around each plant. Plants were arranged in a randomized complete block design with four replications and 20 plants per replication; however, within some replications all 20 plants did not survive. The replications were randomized within a greenhouse maintained at 24 ± 3 C. Supplemental light for a 19-hour daylength was provided by high-output fluorescent lamps. Plants were watered daily and fertilized monthly with a complete nutrient solution (16). All plants were harvested 120 days after inoculation and root gall indices were determined: 1 = no galling; 2 = 1–10%; 3 = 11–20%; 4 = 21–50%; 5 = 51–80%; and 6 = 81–100% root tissue galled. Nematode eggs were extracted from each root system by the NaOCl method (9). Eggs were counted and the nematode reproductive index (Pf/Pi = final nematode population per plant/initial nematode population per plant) was calculated. Data were analyzed as a randomized complete block with PROC GLM (14) designed for unequal sample sizes. Checks were *A. cristatum* (7) and *P. spicata* (8).

RESULTS AND DISCUSSION

Root galls were observed on roots of all accessions. Root-gall indices were relatively low (1.1–4.8); however, there were differences ($P < 0.01$) among accession of the same species, among species, and between genera (Table 1). The lowest gall index was on *Hordeum chilensis* PI531781 from Argentina and the highest index was on *A. cristatum* PI229574, an introduction from Iran. The most variation was expressed in the genus *Hordeum*, in which gall ratings ranged from 1.1. in *H. chilensis* to 4.0 in *H. bogdanii* PI401306.

The genus *Agropyron* sensu stricta contains only two diploid species, *A. cristatum* and *A. mongolicum*. Based on the nematode reproductive index, both taxa were suitable hosts for *M. chitwoodi*. Average root galling and the reproductive index were significantly lower for *A. mongolicum* than for *A. cristatum*. These results are consistent to those previously reported for *A. cristatum* (7). *Agropyron* has been hybridized with *Triticum* (bread wheat) (2), but due to the chromosome-pairing regulators in wheat it may not be possible to transfer genes from *Agropyron* to the cereals without the use of biotechnological techniques. Better sources of resistance are available within the perennial Triticeae.

Pseudoroegneria, a recently constructed genus, consists of about 15 species that were previously included in *Agropyron* or *Elytrigia*. All taxa are diploid ($2n = 14$) and tetraploid ($2n = 28$), and contain only the S genome or some variation of it. We evaluated four diploid species (*A. aegilopoides, P. libanotica, P. stipifolia*, and *P. spicata*). The overall reproductive index within the S genome was similar to that in diploid *T. elongatum*, which contains the E genome. *Pseudoroegneria spicata* (bluebunch wheatgrass), the only native North America taxon of the genus *Pseudoroegneria*, had a low reproductive index compared with *A. aegilopoides, P. libanotica*, and *P. stipifolia*. Within *P. spicata*, accessions D-2844, PI232177, and cv. Whitmar had reproductive indexes below 1.0. This is consistant with reproductive indexes previously reported for *P. spicata* (8) under the same conditions. The inability of *M. chitwoodi* to increase on *P. spicata* indicates that *P. spicata* may contain gene(s) for resistance to the nematode. The distant relationship between the genomes in *Triticum* and *Pseudoroegneria* will make it difficult to transfer the resistance in *P. spicata* by conventional breeding methods.

Hordeum is genomically heterogeneous (15) and accounts for almost half of the total diploid taxa in the perennial Triticeae. The largest variation in nematode reproductive index occurred within this group, ranging from 0.1 in *H. chilensis* PI531781 to 96.9 in *H. bogdanii* PI401386. *Hordeum californicum* PI531779, from California, was not a suitable host for *M. chitwoodi* (a reproductive index of 0.5). Host suitability for *M. chitwoodi* appeared to be highly species-specific within the genus *Hordeum*. Hybrids have been reported between *Hordeum* spp. and *Triticum* spp. (3); however, there was little chromosome pairing in hybrids of *H. chilensis* and six tetraploid taxa of *Triticum* (12). Artificially developed amphiploids and additional lines of *H. chilensis* with *T. aestivum* provide a possible solution to the hybridization problems and may have some promise as new species.

Psathyrostachys is a small genus of about 10 species, all of which contain the basic N genome. All species of *Psathyrostachys* studied to date are diploid ($2n = 14$). *Psathyrostachys* was not significantly more resistant than species represented in the genus *Thinopyrum* (J genome), but its mean reproductive index was lower ($P < 0.05$) than that of species in the genus *Pseudoroegneria, Hordeum, Agropyron*, and *Thinopyrum* (E genome). Within *Psathyrostachys*, accessions of *P. juncea* PI499673 and cv. Bozoisky, and accessions of *P. stoloniformis* D-2562 and D-3376 had reproductive indices of less than 1. The only successful hybrid between this genus and the cereals was a hybrid between *P. fragilis* and *H. vulgare* (10).

Thinopyrum is a recently erected genus that, according to Dewey's (3) definition, encompasses about 20 species that were previously considered in the traditional *Agropyron* or *Elytrigia*. This genus is centered around the diploid J genome of *T. bessarabicum* and another diploid, *T. elongatum*, composed of the E genome. Species of the genus *Thinopyrum* have been of great interest to wheat breeders because *T. ponticum, T. intermedium*, and *T. junceum* hybridize readily with various *Triticum* species (15). The reproductive index of *T. bessarabicum* was significantly ($P < 0.01$) lower than that of *T. elongatum*. Accession PI531712 of *T. bessarabicum* had a reproductive index of 1.0.

The nematode reproductive indices in species found in the genus *Psathyrostachys* and *Thinopyrum* were lower ($P < 0.01$) than those taxa in the genus *Agropyron, Pseudoroegneria*, and *Hordeum*; however, there was variation in resistance among individuals within *Pseudoroegneria spicata, Psathyrostachys juncea*, and *P. fragilis* that contain germplasm resistant to *M. chitwoodi*. The variation among the different genera and within species for resistance to the root-knot nematode indicates that it would be possible to screen and select plants for resistance within the grasses themselves, and to introgress resistant gene(s) from the wild grasses into cultivated cereals.

LITERATURE CITED

1. Birchfield, W. 1965. Host–parasite relations and host studies of a new *Meloidogyne* species in southern U.S.A. Phytopathology 55:1259–1261.

2. Chen, Q., J. Jahier, and Y. Cauderon. 1992. Enhanced meiotic chromosome pairing in intergeneric hybrids between *Triticum aestivum* and diploid inner Mongolian *Agropyron*. Genome 35:98–102.

3. Dewey, D. R. 1984. The genomic system of classification as a guide to intergeneric hybridization with the perennial Triticeae. Pp 209–279 *in* J. P. Gustafson, ed. Gene manipulation in plant improvement. New York: Plenum Publishing.

4. Griffin, G. D. 1992. Comparative effects of two populations of *Meloidogyne chitwoodi* on *Triticum aestivum* and *Hordeum vulgare*. Nematropica 22:65–74.

5. Griffin, G. D. 1984. Nematode parasites of alfalfa, cereals, and grasses. Pp. 243–321 *in* W. Nickle, ed. Plant and insect nematodes. New York: Marcel Dekker.

6. Giffin, G. D. 1985. Host–parasite relationship of *Meloidyne chitwoodi* on potato. Journal of Nematology 17:395–399.

7. Griffin, G. D., and K. H. Asay. 1989. Pathological reaction of crested wheatgrass cultivars to four *Meloidogyne chitwoodi* populations. Journal of Nematology 21:446–452.

8. Griffin, G. D., R. N. Inserra, and N. Vovlas. 1984. Rangeland grasses as hosts of *Meloidogyne chitwoodi*. Journal of Nematology 16:399–402.

9. Hussey, R. A., and K. R. Barker. 1973. A comparison of methods of collecting inocula of *Meloidogyne* spp. including a new technique. Plant Disease Reporter 57:1025–1028.

10. Jacobsen, N., and R. Bothmer. 1981. Interspecific hybridization in the genus *Hordeum* L., Proceedings of the 4th International Barley Genetic Symposium, pp. 710–715.

11. O'Bannon, J. H., G. S. Santo, and A. P. Nyczepir. 1982. Host range of the Columbia root-knot nematode. Plant Disease 66:1045–1048.

12. Padilla, J. A., and A. Martin. 1983. New hybrids between *Hordeum chilense* and tetraploid wheats. Cereal Research Communication. 11:5–7.

13. Riggs, R. D., J. L. Dale, and M. L. Hamblen. 1962. Reaction of bermudagrass varieties and lines to root-knot nematodes. Phytopathology 52:587–588.

14. SAS Institute. 1985. SAS user's guide: Statistics, version 5 ed. Cary, NC: SAS Institute.

15. Sharma, H. C., and B. S. Gill. 1983. Current status of wide hybridization in wheat. Euphytica 32: 17–31.

16. Silvius, J. E., D. F. Kremer, and D. R. Lee. 1978. Carbon assimilation and translocation in soybean leaves at different stages of development. Plant Physiology 62:54–58.

17. Tsitsin, N. V. 1960. The significance of wide hybridization in the evolution and production of new species and forms of plants and animals. Pp. 2–30 *in* N. V. Tzitsin, ed. Wide hybridization in plants. Jerusalem: Israel Program for Science (Translation).