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Resistance of maize to *Meloidogyne arenaria* and *Meloidogyne javanica* *

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Summary. A diallel cross of eight maize, *Zea mays* L., inbred lines was analyzed for reaction to two species of root-knot nematodes, *Meloidogyne arenaria* (Neal) Chitwood and *M. javanica* (Treub) Chitwood. Egg production following inoculation of F_1 hybrid seedlings with nematode eggs was determined in a greenhouse experiment. Data were analyzed using Griffing's Method 4, Model I. General combining ability was a significant source of variation in egg production of both *M. arenaria* and *M. javanica*; specific combining ability was not a significant source of variation for either. The correlation between egg production of the two nematode species on the 28 F_1 hybrids was highly significant. Hybrids with Mp313 or SC213 as one parent were the most resistant to both species. This indicates that germ plasm is available for developing inbred lines and hybrids with resistance to both *M. arenaria* race 2 and *M. javanica*.

Key words: Maize – *Meloidogyne arenaria* – *Meloidogyne javanica* – Root-knot nematode – *Zea mays* L.

Introduction

Maize, *Zea mays* L., is attacked by several species of root-knot nematodes, *Meloidogyne* spp. (Baldwin and Barker 1970; Johnson et al. 1974; Norton 1984). Symptoms of infection vary and range from barely detectable damage to severe stunting of plants and galling of roots. This variability in expression of symptoms has resulted in conflicting reports on the severity of damage to maize (Baldwin and Barker 1970; Clayton et al. 1944; Kinloch 1983; Kirkpatrick and Sasser 1984).

Host plant resistance is the only practical method of controlling *Meloidogyne* spp. on maize. The cost of nematicides and application, as well as the environmental hazards associated with nematicides, limit the use of these chemicals. The use of nematode-resistant hybrids in crop rotations could provide growers with an alternative control strategy. Growers with fields severely infested with *Meloidogyne* spp. would benefit immensely by planting maize hybrids with root-knot nematode resistance. By reducing the rate of nematode reproduction, damage to the maize crop and subsequent susceptible crops would be limited.

Limited progress has been made in identifying maize hybrids and inbreds with resistance to nematodes. Greenhouse evaluations of 64 commercially available maize hybrids for suitability as hosts to *M. incognita* (Kofoid and White) Chitwood, *M. arenaria* (Neal) Chitwood, and *M. javanica* (Treub) Chitwood indicated that, although all hybrids were excellent hosts for *M. incognita*, a few were not suitable hosts for *M. arenaria* and *M. javanica* (Windham and Williams 1987, 1988 b). In other evaluations, several inbred lines also exhibited resistance to both *M. arenaria* and *M. javanica* (Windham and Williams 1988 a, b).

This investigation was undertaken to determine how inbred lines of maize with resistance to *M. arenaria* and *M. javanica* performed in a diallel cross, in order to obtain information on the importance of general and specific combining abilities in the inheritance of resistance to *M. arenaria* and *M. javanica*.

Materials and methods

An eight-parent diallel cross of maize (without parents or reciprocals) was evaluated for egg production by *M. arenaria* and *M. javanica* in greenhouse experiments. In earlier experiments, in-

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bred parents Mp313, SC213, and T220 exhibited resistance to both *M. arenaria* and *M. javanica*; GA209, Mp706, and SC246 were susceptible to both; and Tx601 and Ky21, which were not evaluated for *M. javanica*, were also susceptible to *M. arenaria* (Windham and Williams 1988 a, b).

Seed of the 28 F_1 hybrids constituting the diallel cross were planted in Todd Planter Flats (Model 300, Speedling, Inc., Sun City/FL) containing a potting mixture of methyl-bromide-treated, sandy loam soil and river sand (80% sand, 6% clay, 14% silt). Each flat contained 32 inverted-pyramid-shaped cells (76 x 76 x 76 mm) with one plant per cell. Separate experiments were conducted for each nematode species. The experiment evaluated for *M. arenaria* was planted Oct. 3, 1989 and maintained at a mean temperature of 26 °C; the experiment evaluated for *M. javanica* was planted Feb. 7, 1990 and maintained at approximately 28 °C. Hybrids were arranged in a randomized complete block design with 20 replications within each experiment.

Populations of *M. arenaria* race 2 and *M. javanica* were obtained from the Plant Pathology Department, North Carollina State University, Raleigh/NC. Inoculum was increased in the greenhouse on tomato (*Lycopersicon esculentum* Mill. cv Floradel), and eggs were extracted from the tomato roots with NaOCl (Hussey and Barker 1973). Seedlings were inoculated 7–10 days after planting by pipetting a water suspension containing approximately 3,000 nematode eggs into each cell.

Sixty days after maize seedlings were inoculated, roots were washed free of soil, blotted with paper towels, weighed, and cut into 10-mm segments. Eggs were extracted from the roots with NaOCI, stained with acid fuchsin, and counted. The number of eggs per gram of fresh root was calculated as a measure of reproduction for each nematode species.

An analysis of variance of the data for each nematode species was performed, and variation among hybrids was partitioned into general and specific combining ability components using Griffing's (1956) Experimental Method 4, Model I. Hybrid means and general combining ability effects were compared by Fisher's Protected LSD.

Results and discussion

Without exception, fewer eggs per gram of root were produced on hybrids with either Mp313 or SC213 as one parent, regardless of nematode species (Table 1). The correlation between number of eggs produced by *M. arenaria* and *M. javanica* over all hybrids was also highly significant ($r = 0.88$). Egg production on each of the 28 F_1 hybrids of the diallel cross was higher for *M. arenaria* than *M. javanica*.

Partitioning of the variation among hybrids into general and specific combining ability components indicates that general combining ability was a highly significant source of variation for both *M. arenaria* and *M. javanica*; however, specific combining ability was not significant for either (Table 2).

Estimates of general combining ability effects for eggs per gram of fresh root are given in Table 3. The large negative values for Mp313 and SC213 indicate that these inbred lines imparted to their hybrids the highest levels of resistance to both *M. arenaria* and *M. javanica*. These inbred lines, along with T220, had previously been identified as resistant to both species (Windham and Williams 1988 a, 1988 b).

Table 1. Number of *Meloidogyne arenaria* race 2 and *M. javanica* eggs per gram fresh root of F_1 hybrid maize seedlings 60 days after inoculation

Hybrid	*M. arenaria*	*M. javanica*
Mp706 x Tx601	2,479	647
Ky21 x Tx601	2,410	808
GA209 x Ky21	2,265	458
SC246 x Tx601	2,058	1,417
GA209 x Mp706	1,890	458
Ky21 x Mp706	1,810	403
Ky21 x SC246	1,427	543
GA209 x Tx601	1,424	687
T220 x GA209	1,172	243
GA209 x SC246	1,092	545
T220 x SC246	1,039	411
Mp706 x SC246	953	555
T220 x Tx601	933	208
T220 x Mp706	910	318
T220 x Ky21	897	220
SC213 x Ky21	598	103
Mp313 x SC246	532	73
SC213 x SC246	439	31
Mp313 x Tx601	415	182
Mp313 x T220	335	53
Mp313 x Ky21	320	78
SC213 x T220	294	16
SC213 x Tx601	292	131
SC213 x Mp706	283	119
Mp313 x GA209	246	53
SC213 x GA209	237	27
Mp313 x SC213	201	11
Mp313 x Mp706	198	60
Mean	970	316
LSD (0.05)	1,207	530

Table 2. Combining ability analyses for reaction of a maize diallel cross to *Meloidogyne arenaria* race 2 and *M. javanica* under greenhouse conditions

Source	Degrees of freedom	Mean square	
		M. arenaria	*M. javanica*
Hybrids	27	2035518 **	10834993 **
General combining ability	20	5849763 **	31797772 **
Specific combining ability	7	700532	3498020
Error	513	727566	3048333

** Significant at $P = 0.01$

Mp313 and SC213, although sources of resistance for *M. arenaria* and *M. javanica*, are not resistant to the more widely distributed *M. incognita* (Windham and Williams 1988 a). Apparently, the factors causing resistance to *M. arenaria* and *M. javanica* that are present in these inbreds are not effective against *M. incognita*.

Although egg production on greenhouse-grown maize plants appears to be a potentially useful method of

Table 3. Estimates of general combining ability effects for number of *Meloidogyne arenaria* race 2 and *M. javanica* eggs per gram fresh root 60 days after inoculation of a diallel cross

Inbred parent	*M. arenaria*	*M. javanica*
Tx601	537	311
Ky21	490	66
Mp706	289	57
GA209	256	43
SC246	126	226
T220	−201	−124
SC213	−740	−296
Mp313	−757	−284
LSD (0.05)	492	216

evaluating the levels of resistance to *M. arenaria* and *M. javanica*, results obtained in the greenhouse should be substantiated through field testing before a long-term breeding program is undertaken. Our results indicate that Mp313 and SC213 appear to be potentially useful sources of resistance to both *M. arenaria* and *M. javanica*. The high correlation between resistance to the two species suggests that selection for resistance to one species would probably increase the level of resistance to the other species as well. The significance of general combining ability components of variation among this group of inbred lines further indicates that breeding methods that take advantage of additive types of gene action should be most effective in breeding for resistance to either *M. arenaria* race 2 or *M. javanica*.

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