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Reaction of Pigeonpea Cultivars and Germplasm Accessions to the Root-knot Nematode, *Meloidogyne javanica*[1]

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Abstract: *Meloidogyne javanica* is an important nematode pest of pigeonpea. Thirty-four pigeonpea cultivars and 227 germplasm accessions were evaluated for resistance to *M. javanica* based on number of galls, egg masses, size of galls, and area of root covered with galls. Galls were not formed on 75% of the cultivars, and no egg masses were observed on the roots of four cultivars (UPAS 120, Pant A3, CO 1, and BDN 2); however, shoot mass of 64% of the cultivars was reduced by *M. javanica*. Pant A3, ANM 504, and BDN 2 were identified as highly resistant to *M. javanica*. Plant weight of these cultivars was not reduced ($P = 0.05$) in the nematode-infested soil. Cultivars with low gall and egg mass ratings and significantly reduced vegetative biomass in nematode-infested soil were considered to have low tolerance to the nematode. Galls and egg masses were found on all the germplasm accessions; galls were usually more common than egg masses. None of the germplasm accessions were resistant to *M. javanica*, but 33 accessions were moderately resistant. Large variations in gall number, gall size, and egg mass number were observed. ICP 24 and ICP 99, two moderately resistant accessions, manifested low plant-to-plant variation.

Key words: *Cajanus cajan* cultivar, damage index, germplasm, *Meloidogyne javanica*, nematode, pigeonpea, resistance, tolerance.

Pigeonpea, *Cajanus cajan*, is one of the major grain legumes of subsistence farming systems in the Indian subcontinent and in other regions of the semi-arid tropics. The root-knot nematode, *Meloidogyne javanica*, is an important nematode pest of pigeonpea (9,11). Infestations of this nematode result in yellowish leaves and poor plant growth. The nematode has a wide host range, which reduces the effectiveness of crop rotations for its control. Nematicides to control nematode diseases are either too expensive or unavailable to farmers in subsistence farming systems. Therefore, *M. javanica*-resistant cultivars would be useful if they were available. The aim of this study was to examine the reactions to *M. javanica* of available released pigeonpea cultivars, and to identify promising sources of resistance within a set of pigeonpea germplasm.

Materials and Methods

The evaluation tests were conducted in a greenhouse between November 1989 and May 1992 (maximum temperature 22 to 32 C, and minimum temperature 20 to 23 C). Seeds of 14 short-, 14 medium-, and 6 long-duration pigeonpea cultivars and 12 short-, 175 medium-, and 40 long-duration germplasm accessions were obtained from the Genetic Resources Program of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India. The short-, medium-, and long-duration designations indicate the time required by a pigeonpea genotype to mature. The short-duration genotypes mature in 3–5 months, medium-duration in 5–6 months, and long-duration in 6–9 months. Four seeds of each of the 35 cultivars were sown in each of four 15-cm-d pots containing autoclaved riverbed sand and black cotton soil (38% sand, 20% silt, 41% clay; pH 8.0) mixture (4:1, v:v). An *M. javanica* isolate, originally collected from pigeonpea, was maintained on tomato (*Lycopersicon esculentum*) cv. Rutgers. The nematode eggs were extracted from the roots of 8-week-old tomato plants by treating with sodium hypochlorite (4). Five thousand nematode eggs in aqueous suspension were placed at planting in the same depression where seed was sown. Four seeds of each cultivar were also sown

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in four nematode-free pots. The pots were arranged in a randomized complete block design, and the treatments of nematode-free and nematode-infested soils for a cultivar were paired. All the pots were irrigated regularly and supplemented with Arnon's nutrient solution and 250 ppm nitrogen as ammonium nitrate once per week (1).

Eight weeks after seedling emergence, roots were carefully separated from soil, washed with tap water, and treated with 0.25% trypan blue to stain the egg masses for counting (8). The roots were graded for gall number, gall size, and the percentage area of root galled. Roots were evaluated on a 1–9 scale for gall index (GI); 1 = no galls, 2 = 1–5 galls, 3 = 6–10 galls, 4 = 11–20 galls, 5 = 21–30 galls, 6 = 31–50 galls, 7 = 51–70 galls, 8 = 71–100 galls, and 9 = >100 galls per plant. Numbers of egg masses (EI) were rated according to the 1–9 scale developed for gall number (1 = no egg masses, 9 = >100 egg masses). Root and shoot weights of each cultivar in nematode-free and nematode-infested soils were recorded after the plants were oven-dried at 60 C for ca. 1 week and were compared with paired *t*-tests. Genotypes without any significant (P = 0.05) reduction in shoot weight in nematode-infested soil were considered tolerant.

Pigeonpea accessions were evaluated in the same manner as cultivars were evaluated; however, damage caused by the nematodes was studied in greater detail. Roots of each plant were indexed for number of galls, size of galls, extent of galled area of the root, and egg masses. The scales for GI and EI were as described for cultivar evaluation, whereas those for gall size (GS) and extent of galled area of the root (GA) were as follows. For gall size: 1 = no galls; 3 = very small galls, about 10% increase in root area at galled region over nongalled normal root area; 5 = small galls, about 30% increase; 7 = medium galls, about 31–50% increase; and 9 = big galls, >50% increase (10). For extent of galled area: 1 = no galls; 3 = 1–10% root area galled; 5 = 11–30 %; 7 = 31–50%; and 9 = >50% root area galled. To assess root damage, a damage index (DI) was calculated by dividing the sum of GI, GS, and GA by 3 (10). Accessions with DI $\leqq$1.0 were considered highly resistant, DI $\leqq$3 were resistant, DI 5 were moderately resistant, DI $\leqq$7 were susceptible, and DI $\leqq$9 were highly susceptible (10). Pigeonpea cultivar C 11 (ICP 7118) was used as a susceptible control in all the tests.

Results

Galls were not formed on about 75% of the cultivars, and no egg masses were observed on the roots of three short-duration cultivars (UPAS 120, Pant A3, CO 1) and a medium-duration (BDN 2) cultivar (Table 1). For approximately 75% of the cultivars, EI were higher than GI. HY 5, a short-duration cultivar, and C 11 and LRG 30, two medium-duration cultivars, were the only genotypes with GI and EI ratings of 9.0. There was no obvious relationship either between GI or EI and plant weight. Shoot weight of about 64% of the cultivars in the three maturity groups was reduced in nematode-infested soil. Root weight of 54% of the short-, 14% of the medium-, and 16% of the long-duration cultivars was reduced by the nematode. All the short-duration cultivars except HY 5 and ICPL 87 had a rating of 1.0 for GI. Pusa Ageti, DSLR 55, HY 4, BDN 1, JA 3, CO 2, T 15-15, B 7, CO 3, C 28, T 17, Mukta, Code No. 8, UPAS 120, P 1258, BR 65, CO 1, and ICPL 87 had low (less than 3.0) GI and EI, but their shoot weights were significantly reduced. Pant A3, ANM 504, and BDN 2 were highly resistant, and their plant weight was not reduced (P = 0.05) in nematode-infested soil. Khargaon 2, Sharda, T 7, and No. 148 were susceptible.

The nematode reproduced and formed galls on all 227 germplasm accessions. Ten out of 12 short-duration accessions were susceptible to root damage with DI $\geqq$ 5 (Table 2). ICP 12 and ICP 24 had average DI between 3 and 5 but ICP 12 had larger plant-to-plant variation in GI and DI than

TABLE 1. Reaction of pigeonpea cultivars to *Meloidogyne javanica*.

ICRISAT germplasm accession number (ICP number)†	Cultivar	Dry shoot weight (g)		Dry root weight (g)		GI‡	EI§
		Uninfected control	Infected with *M. javanica*	Uninfected control	Infected with *M. javanica*		
			Short-duration pigeonpea				
26	T 21	1.98	1.55	1.09	0.95	1.0	2.2
28	Pusa Ageti	2.42	1.14*	1.47	0.77*	1.0	1.8
6971	UPAS 120	2.67	1.46*	1.09	0.88	1.0	1.0
6974	Pant A3	2.81	1.58	0.87	0.89	1.0	1.0
7035	DSLR 55	4.04	2.09*	1.66	1.06*	1.0	1.2
7191	HY 4	3.10	1.83*	1.24	0.80*	1.0	1.3
7220	Prabhat	2.41	1.85	1.01	0.77*	1.0	1.8
7222	HYB 2	2.63	1.99	1.22	1.23	1.0	1.2
7608	CO 1	2.63	1.67*	1.35	1.09	1.0	1.0
7609	CO 2	2.51	1.35*	1.45	1.09*	1.0	1.3
7647	BR 183	2.51	1.71	1.42	0.91*	1.0	2.1
8520	HY 5	2.16	1.36*	1.00	1.13	9.0	9.0
9878	CO 3	2.60	1.44*	1.57	0.81*	1.0	1.8
ICPL 87		3.93	1.97*	1.45	0.89*	2.0	2.0
			Medium-duration pigeonpea				
1207	Khargaon 2	2.20	1.31*	1.10	1.10	1.0	4.3
2624	ST 1	2.03	1.31	1.29	1.00	1.0	1.5
2626	Sharda	2.47	1.27*	0.91	0.87	1.0	3.1
2627	Mukta	2.57	1.44*	1.08	0.92	2.0	2.0
7118	C 11	1.74	1.52	1.25	1.13	9.0	9.0
7119	HY 3C	2.44	2.17	1.37	1.04	1.9	1.9
7120	No. 148	2.28	1.31*	1.27	1.00	4.5	4.5
7182	BDN 1	2.83	1.39*	1.29	0.89*	1.0	1.8
7202	BR 65	2.30	1.43*	1.18	1.16	1.3	1.3
7623	BDN 2	2.10	1.56	1.44	1.02	1.0	1.0
7724	T 15-15	2.50	1.70*	1.51	0.98*	1.0	1.9
7739	C 28	2.76	1.55*	1.46	1.02	1.0	1.3
7862	S. A. 1	2.45	1.83	1.71	0.75	1.0	1.5
8518	LRG 30	2.46	1.53*	1.38	1.11	9.0	9.0
			Long-duration pigeonpea				
1641	T 17	1.92	1.22*	1.13	1.07	1.0	1.4
2603	2 E	1.92	1.38	1.32	1.25	1.0	2.0
6344	T 7	2.40	1.66*	1.12	0.92	1.0	3.5
6920	Code No. 8	4.10	1.76*	1.32	1.01	1.0	1.2
7193	JA 3	3.20	1.64*	1.37	1.02*	1.0	1.7
7221	Gwalior 3	2.26	1.78	1.44	1.13	1.0	1.5
7760	B 7	2.44	1.35*	1.76	1.35*	1.8	1.8
8151	ANM 504	2.34	1.51	1.42	0.94	1.0	2.0

Data are means of 16 plants. * = significant difference ($P \leq 0.05$) between infected and uninfected plants of each cultivar.
† ICRISAT refers to the International Crops Research Institute for the Semi-Arid Tropics.
‡ GI = Gall index, where 1 = no galls, 2 = 1–5 galls, 3 = 6–10 galls, 4 = 11–20 galls, 5 = 21–30 galls, 6 = 31–50 galls, 7 = 51–70 galls, 8 = 71–100 galls, and 9 = >100 galls per plant.
§ EI = Egg mass index, where 1 = no egg masses, 2 = 1–5 egg masses, 3 = 6–10 egg masses, 4 = 11–20 egg masses, 5 = 21–30 egg masses, 6 = 31–50 egg masses, 7 = 51–70 egg masses, 8 = 71–100 egg masses, and 9 = >100 egg masses per plant.

ICP 24 (Table 2). EI were usually lower than GI across the three maturity groups. The susceptible check ICP 7118 had GI = 8–9, GS = 6–7, GA = 5–9, EI = 7–8, and DI = 6–8. DI were greater than 5.0 on more than 85% of the medium-duration accessions.

Variations in GI, EI, and DI were high in 25 accessions that had average DI ≦5. ICP 79 had little plant-to-plant variation for these damage parameters. Seven long-duration accessions had average DI ≦5 and only ICP 99 had low plant-to-plant variation. Gall size and extent of root area

TABLE 2. Average egg mass (EI) and damage (DI) indices on pigeonpea germplasm accessions caused by *Meloidogyne javanica*.

ICRISAT germplasm accession number†	Number of plants examined	EI‡		DI§	
		Mean	SE	Mean	SE
		Short-duration			
4	14	4.4	0.35	5.7	0.38
5	16	4.5	0.26	6.0	0.34
12	5	3.8	0.66	4.3	0.72
13	16	4.3	0.18	5.6	0.25
14	12	5.0	0.37	6.2	0.34
17	6	4.7	0.33	5.1	0.35
22	6	4.8	0.79	6.0	0.45
24	12	3.2	0.21	3.8	0.19
25	9	4.9	0.20	5.9	0.12
28	11	4.4	0.31	5.4	0.31
185	14	4.3	0.19	5.6	0.24
352	13	5.3	0.26	6.2	0.32
		Medium-duration			
1	17	4.3	0.17	5.4	0.19
3	10	5.0	0.39	5.9	0.36
6	15	4.0	0.33	4.9	0.42
9	7	4.3	0.42	5.3	0.69
11	14	3.8	0.21	5.5	0.31
26	6	4.3	0.33	4.7	0.47
27	11	3.7	0.31	4.5	0.39
29	11	3.8	0.18	4.5	0.23
31	15	4.5	0.32	5.4	0.33
33	5	5.0	0.63	5.3	0.68
35	12	4.0	0.21	4.8	0.27
37	8	4.6	0.46	5.3	0.61
38	6	5.5	0.50	6.8	0.32
40	15	4.7	0.28	5.8	0.28
41	9	6.0	0.50	6.5	0.27
46	13	4.9	0.37	6.0	0.27
48	13	4.6	0.29	5.8	0.19
49	12	6.1	0.40	6.7	0.26
50	10	4.5	0.50	5.3	0.51
56	12	4.5	0.31	4.9	0.36
57	12	5.3	0.41	6.1	0.40
59	8	4.0	0.53	4.7	0.47
60	8	3.7	0.41	3.8	0.37
62	15	5.0	0.36	6.3	0.23
63	7	3.8	0.26	4.6	0.47
65	10	3.4	0.43	4.5	0.44
66	12	4.2	0.30	5.2	0.35
67	12	3.5	0.35	5.2	0.19
68	10	4.1	0.43	6.4	0.24
69	7	4.8	0.45	6.8	0.32
70	10	3.9	0.28	6.1	0.27
71	7	4.1	0.14	5.0	0.16
72	7	4.0	0.49	3.2	0.59
77	14	3.4	0.34	4.6	0.19
78	15	4.9	0.27	6.3	0.21
79	10	3.4	0.30	3.5	0.28
82	15	5.0	0.33	5.6	0.32
83	14	4.8	0.33	5.5	0.35
84	6	4.7	0.61	5.4	0.61
87	13	4.4	0.24	6.0	0.34
88	8	4.9	0.48	5.7	0.48

TABLE 2. *Continued*

ICRISAT germplasm accession number†	Number of plants examined	EI‡		DI§	
		Mean	SE	Mean	SE
91	6	4.8	0.65	5.7	0.58
92	12	4.2	0.44	5.3	0.25
95	12	4.2	0.38	5.7	0.39
100	14	3.6	0.14	4.6	0.27
103	8	4.5	0.42	5.3	0.53
104	6	5.5	0.22	6.8	0.35
109	6	4.2	0.17	5.3	0.62
110	15	5.3	0.27	6.3	0.29
111	6	4.5	0.43	4.5	0.34
112	11	4.6	0.24	6.0	0.33
115	7	4.7	0.28	6.2	0.22
117	6	5.0	0.45	6.6	0.47
121	15	4.3	0.30	5.4	0.35
122	8	3.5	0.38	4.5	0.41
126	12	3.7	0.25	4.7	0.42
127	11	3.4	0.34	4.4	0.44
128	14	4.3	0.25	5.0	0.27
130	9	3.9	0.31	4.2	0.26
131	7	4.3	0.42	5.7	0.36
132	14	4.3	0.22	5.6	0.36
135	12	3.9	0.08	5.8	0.25
136	12	3.7	0.13	6.4	0.25
139	14	5.1	0.27	6.6	0.25
141	10	3.8	0.55	4.7	0.52
147	12	3.7	0.14	4.7	0.31
148	15	5.4	0.29	7.1	0.21
150	15	5.4	0.23	6.9	0.20
151	15	5.8	0.26	7.8	0.09
154	14	3.9	0.07	5.7	0.23
155	12	4.3	0.37	5.7	0.31
156	15	4.8	0.26	5.9	0.29
164	15	4.4	0.23	7.1	0.19
165	15	3.8	0.11	6.8	0.25
168	9	7.4	0.38	7.8	0.15
170	15	4.1	0.34	5.7	0.39
171	14	5.2	0.30	7.3	0.18
173	14	4.1	0.27	5.6	0.36
175	15	4.3	0.23	5.3	0.35
178	15	5.2	0.30	6.7	0.24
180	15	5.1	0.32	6.3	0.34
182	15	4.6	0.21	5.3	0.28
184	14	5.0	0.30	6.0	0.30
187	12	5.0	0.32	7.4	0.22
189	13	5.3	0.31	6.7	0.33
193	14	5.6	0.29	7.1	0.28
194	12	5.7	0.22	7.3	0.22
195	8	3.9	0.35	6.8	0.23
198	13	4.8	0.28	7.3	0.15
199	14	5.2	0.36	5.9	0.30
204	15	5.4	0.24	6.3	0.19
206	15	5.5	0.24	6.4	0.25
210	12	5.3	0.26	6.3	0.24
212	12	5.3	0.35	7.6	0.20
216	14	3.9	0.34	6.4	0.37
218	13	4.8	0.37	6.9	0.30
219	14	5.7	0.19	7.9	0.16
220	15	5.9	0.07	7.6	0.20

TABLE 2. *Continued*

ICRISAT germplasm accession number†	Number of plants examined	EI‡		DI§	
		Mean	SE	Mean	SE
224	14	5.2	0.26	7.3	0.30
230	11	6.3	0.14	7.7	0.15
231	13	5.5	0.31	6.3	0.33
232	15	5.3	0.25	6.2	0.24
233	12	5.7	0.25	6.8	0.21
234	15	4.8	0.22	5.4	0.25
240	14	3.8	0.14	5.1	0.19
247	9	5.5	0.41	6.5	0.38
248	12	4.4	0.29	5.4	0.24
250	12	5.4	0.23	6.0	0.26
251	14	4.6	0.39	3.9	0.15
252	12	4.5	0.26	3.7	0.12
255	5	5.8	0.49	4.3	0.51
264	7	4.1	0.55	5.4	0.58
267	5	6.2	0.20	6.1	0.55
268	10	6.2	0.13	7.2	0.33
270	9	5.1	0.35	7.3	0.41
274	13	5.9	0.18	7.1	0.23
275	11	4.7	0.38	6.2	0.24
283	10	4.5	0.31	5.7	0.30
285	9	4.4	0.38	5.1	0.24
288	9	4.4	0.29	5.1	0.36
290	9	4.5	0.38	5.3	0.26
292	15	4.4	0.25	5.4	0.21
296	14	4.4	0.20	5.6	0.21
299	12	4.8	0.21	5.5	0.15
306	15	4.8	0.26	6.1	0.27
309	7	5.6	0.30	7.1	0.56
312	12	4.7	0.31	6.7	0.27
314	9	4.7	0.37	6.2	0.28
315	5	3.6	0.60	3.4	0.16
323	12	5.8	0.27	7.7	0.15
325	9	6.3	0.33	7.4	0.25
327	7	6.0	0.00	8.0	0.24
330	9	5.9	0.51	7.9	0.16
332	8	5.5	0.26	7.1	0.28
335	14	5.8	0.15	7.9	0.12
338	14	5.2	0.30	7.0	0.25
339	10	6.0	0.15	8.0	0.17
342	13	5.4	0.31	6.1	0.24
344	14	5.9	0.41	7.1	0.29
348	14	6.6	0.27	7.1	0.26
349	12	4.9	0.29	5.4	0.30
350	13	4.8	0.25	5.8	0.26
353	13	5.9	0.40	7.1	0.27
355	6	7.0	0.73	7.2	0.22
357	8	3.7	0.25	4.1	0.38
359	12	6.2	0.35	7.5	0.25
369	12	5.7	0.35	7.1	0.17
373	14	4.9	0.27	5.8	0.23
375	10	5.8	0.20	6.6	0.35
377	15	5.7	0.20	7.0	0.22
379	12	5.5	0.26	7.0	0.33
380	14	4.8	0.27	5.7	0.24
382	15	5.2	0.37	5.5	0.27
383	14	5.8	0.33	6.8	0.31
385	13	6.4	0.29	7.2	0.10

TABLE 2. *Continued*

ICRISAT germplasm accession number†	Number of plants examined	EI‡		DI§	
		Mean	SE	Mean	SE
388	14	4.8	0.24	5.5	0.22
390	13	4.4	0.21	5.6	0.23
391	15	6.3	0.12	7.9	0.12
393	15	5.7	0.25	7.5	0.17
395	15	4.8	0.33	7.1	0.19
397	13	3.6	0.29	5.5	0.23
400	12	5.2	0.33	6.8	0.15
402	15	5.3	0.25	7.3	0.20
404	15	5.4	0.23	6.7	0.22
406	14	5.1	0.27	5.2	0.22
410	15	5.5	0.27	6.9	0.20
412	12	5.6	0.38	6.9	0.25
416	14	6.4	0.29	7.5	0.14
418	11	5.7	0.43	6.6	0.38
420	12	6.6	0.23	7.5	0.18
423	12	6.0	0.21	6.9	0.21
424	15	5.9	0.32	6.8	0.24
426	10	5.4	0.37	5.8	0.26
427	8	5.0	0.46	6.4	0.37
428	13	5.5	0.33	6.8	0.34
		Long-duration			
2	12	4.4	0.31	5.2	0.31
19	5	4.0	0.63	4.8	0.44
32	5	5.2	0.37	6.7	0.42
36	13	4.5	0.27	5.8	0.31
43	8	5.0	0.27	5.7	0.36
45	9	4.2	0.22	4.8	0.44
51	14	4.8	0.25	5.9	0.28
52	10	4.7	0.79	5.9	0.20
58	6	4.3	0.21	5.2	0.30
81	4	3.5	0.29	4.7	0.87
98	14	5.1	0.28	5.7	0.41
99	12	3.5	0.26	3.1	0.08
106	5	3.6	0.51	4.3	0.56
107	10	4.7	0.33	5.7	0.37
113	6	6.5	0.43	7.7	0.33
163	15	4.7	0.30	7.0	0.19
167	15	4.5	0.24	5.5	0.22
202	15	6.3	0.23	7.5	0.14
208	13	4.1	0.34	5.0	0.21
213	14	4.6	0.27	7.0	0.13
214	15	5.1	0.31	7.4	0.21
222	15	5.1	0.25	6.7	0.28
227	13	4.6	0.33	6.7	0.31
228	8	3.6	0.37	3.8	0.36
235	15	4.9	0.35	6.5	0.24
238	14	4.7	0.30	5.9	0.28
242	7	6.5	0.37	7.3	0.32
246	12	5.3	0.33	6.2	0.25
257	6	5.0	0.45	7.1	0.54
266	8	2.9	0.29	3.7	0.45
294	12	4.2	0.25	5.3	0.25
297	15	4.7	0.32	5.8	0.34
301	13	6.3	0.35	6.9	0.24
305	14	5.0	0.32	7.3	0.23
308	10	5.3	0.30	7.2	0.32

TABLE 2. *Continued*

ICRISAT germplasm accession number†	Number of plants examined	EI‡		DI§	
		Mean	SE	Mean	SE
321	13	4.9	0.29	7.2	0.19
334	11	5.2	0.32	7.1	0.19
341	11	6.6	0.53	7.5	0.18
387	14	5.1	0.37	5.8	0.33

Data are means of number of plants examined. SE = standard error.
† Accession numbers assigned by the International Crops Research Institute for the Semi-Arid Tropics.
‡ EI = Egg mass index, where 1 = no egg masses, 2 = 1–5 egg masses, 3 = 6–10 egg masses, 4 = 11–20 egg masses, 5 = 21–30 egg masses, 6 = 31–50 egg masses, 7 = 51–70 egg masses, 8 = 71–100 egg masses, and 9 = >100 egg masses per plant.
§ DI ≤ 1.0 = highly resistant, DI ≤ 2–3 = resistant, DI ≤ 4–5 = moderately resistant, DI ≤ 6–7 = susceptible, and DI ≤ 8–9 = highly susceptible. DI for each accession was calculated as mean of size of the gall (GS), area of the root galled (GA), and gall (GI) indices.

galled in the tested lines were typically smaller than those of the susceptible check. ICP 257, ICP 321, ICP 334, and ICP 341 were the only accessions with more than 50% of the roots covered with galls (data not shown).

Discussion

Despite the fact that pigeonpea cultivars with resistance to root-knot nematodes have not been developed, some of the released cultivars exhibited resistance to *M. javanica*. Lower GI and EI of the released cultivars, when compared with those of the germplasm accessions, are presumable indicators of selection of genotypes with no symptoms on roots by the pigeonpea breeders; however, some genotypes are damaged without production of galls and egg masses. Thus, breeding programs for development of high-yielding pigeonpea cultivars with tolerance to *M. javanica* should be encouraged to reduce losses in pigeonpea production.

Cook and Evans (2) indicated that differences in tolerance cannot be reliably assessed in pots and should be assessed in field trials. We believe that pot studies help to identify genotypes with low levels of tolerance, and evidence of tolerance in greenhouse tests is suggestive of the ability of a genotype to grow well in the field despite parasitism by the nematode. Further investigations are essential to verify this possibility. In our study, a short-duration cultivar Pant A3 has been identified as tolerant as well as resistant to *M. javanica*. This cultivar was highly resistant to a mixed population of *M. incognita* race 2 and *M. javanica* in Nepal, and to *M. incognita* in northern India (3,5).

This study documents the differences in pigeonpea reaction to *M. javanica*. For example, LRG 30, which was highly susceptible to *M. javanica* in our study, was reported resistant to a *M. javanica* population at Aligarh in northern India (12). Similarly, pigeonpea accession ICP 11295 was susceptible to certain isolates of *M. javanica* and *M. incognita*, and to the concomitant infection by these species (6,7) but was resistant to combined infection with other isolates of the same two species (13). Damage to pigeonpea tends to increase when *M. javanica* and *M. incognita* infect together (11). Some resistant genotypes such as ICP 8860, ICP 8863, ICP 11289, and ICP 11299 are moderately to heavily galled when both species are present (11). From a pragmatic viewpoint, these results underline the importance of evaluating breeding lines with mixtures of the root-knot nematode populations, regardless of the species, in order to achieve broad-spectrum durable resistance.

We observed large variations in damage ratings within a genotype. Natural outcrossing of pigeonpea, collection of germplasm as a bulk sample from farmers' fields, and maintenance of germplasm as a bulk population in the gene bank are some major reasons for large variability. Therefore, pigeonpea accessions with resistance to *M. javanica* should be purified before use as sources of resistance. Conscientious probes within the gene bank, which has more than 12,000 accessions of pigeonpea, are required for identification of sources of resistance to root-knot nematodes.

References

1. Arnon, D. I. 1938. Micro elements in culture solution experiment with higher plants. American Journal of Botany 25:322–325.

2. Cook, R., and K. Evans. 1987. Resistance and tolerance. *Pp.* 179–231 *in* R. H. Brown and B. R. Kerry, eds. Principles and practices of nematode control in crops. Sydney: Academic Press.

3. Hassan, A., and A. M. Khan. 1983. Resistance of pigeonpea cultivars to root-knot nematode, *Meloidogyne incognita*. International Pigeonpea Newsletter 2: 56.

4. Hussey, R. S., 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.

5. Manandhar, H. K., and P. Amatya. 1992. Evaluation of pigeonpea genotypes in a *Meloidogyne*-infested field in Nepal. International Pigeonpea Newsletter 16:19.

6. Patel, B. A., J. C. Chavda, S. T. Patel, and D. J. Patel. 1987. Susceptibility of some pigeonpea lines to root-knot nematodes (*Meloidogyne incognita* and *M. javanica*). International Pigeonpea Newsletter 6:55–57.

7. Sasser, J. N., and K. M. Hartman. 1985. Evaluation of some pigeonpea lines for resistance to the root-knot nematode, *Meloidogyne* spp. International Pigeonpea Newsletter 4:44–45.

8. Sharma, S. B., and P. Ashokkumar. 1991. A technique to evaluate pigeonpea for resistance to *Rotylenchulus reniformis*. Annals of Applied Biology 119: 323–330.

9. Sharma, S. B., and D. McDonald. 1990. Global status of nematode problems of groundnut, pigeonpea, chickpea, sorghum and pearl millet and suggestions for future work. Crop Protection 9:453–458.

10. Sharma, S. B., P. Remanandan, and D. McDonald. 1993. Resistance to *Meloidogyne javanica* and *Rotylenchulus reniformis* in wild relatives of pigeonpea. Supplement to the Journal of Nematology 25:824–829.

11. Sharma, S. B., D. H. Smith, and D. McDonald. 1992. Nematode constraints of chickpea and pigeonpea production in the semi-arid tropics. Plant Disease 75:868–874.

12. Siddiqui, Z. A., S. I. Husain, and M. Fazal. 1991. Response of twenty varieties of pigeonpea (*Cajanus cajan* L.) against *Meloidogyne javanica*. Current Nematology 2:139–142.

13. Thaka, N. A., and C. C. Patel. 1985. Susceptibility of some pigeonpea varieties to root-knot nematodes, *Meloidogyne incognita* and *M. javanica*. International Pigeonpea Newsletter 4:43–44.