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Tolerance in chickpea to *Meloidogyne javanica*

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Summary – Forty-seven chickpea cultivars were appraised for resistance and tolerance to the root-knot nematode, *Meloidogyne javanica* by assessing their growth in nematode-infested, and nematode-free soils. Based on the number of galls, gall size, root area covered with galls and the number of egg masses produced, all the cultivars were susceptible. Nematode infection caused stunting, yellowing, premature drying, and shedding of leaves. Regression analysis showed that plant height, and shoot, root, and pod mass decreased with increasing levels of nematode infestation. Flowering in two late-maturing cultivars, Pant G 114 and Phule G 1, was delayed in nematode-infested soil while in early maturity cultivars flowering was either advanced or not influenced by nematode infection. Ratio of dry shoot mass in infested and in nematode-free soils revealed that cultivars Pant G 114, Phule G 1, GNG 146 and Annigiri had low level of tolerance to *M. javanica*. The tolerance threshold of cultivars Bheema, N 31 and N 59 was about 4.0 eggs g^{-1} soil. Calcium uptake by tolerant cultivar N 31 from nematode-infested soil was greater than that by intolerant cultivar Phule G 1. Performance of the promising tolerant cultivars N 31, N 59, ICCC 42 and a promising breeding line ICCV 90043 was better than other chickpea genotypes in a farmer's field infested with mixed population of *M. javanica* and *M. incognita*.

Résumé –***Tolérance à* Meloidogyne javanica *chez le pois chiche*** – Quarante-sept cultivars de pois chiche ont été testés pour leur résistance ou leur tolérance envers *Meloidogyne javanica* en notant leur croissance dans des sols infestés et des sols sans nématodes. En se fondant sur le nombre de galles, la taille de celles-ci, la surface des racines occupée par les galles et le nombre de masses d'œufs produites, tous les cultivars paraissent sensibles. L'infestation par le nématode provoque un nanisme, un jaunissement, un dessèchement précoce et une chute des feuilles. Une analyse de régression démontre que la hauteur des plants, le poids des pieds, celui des racines et celui des gousses diminuent lorsque l'infestation augmente. La floraison de deux cultivars tardifs, Pant G 114 et Phule G 1, est retardée dans les sols infestés tandis que chez les cultivars précoces cette floraison est soit avancée soit indifférente à l'infestation par le nématode. Le rapport du poids des racines dans les sols infestés et non infestés - seuil de tolérance - démontre que les cultivars Pant G 114, Phule G 1, GNG 146 et Annigini n'ont qu'un faible niveau de tolérance à *M. javanica*. Le niveau de tolérance des cultivars Bheema, N 31 et N 39 est d'environ 4,0 œufs/gr^{-1} de sol. Dans un sol infesté, l'absorption de calcium par le cultivar tolérant N 31 est plus élevée que par le cultivar non tolérant Phule G 1. Dans un champ infesté par une population mixte de *M. javanica* et *M. incognita*, les performances des cultivars tolérants prometteurs N 31, N 59, ICCC 42 et de la lignée de croisement ICCV 90043 se sont révélées meilleures que celles des autres génotypes de pois chiche.

Key words : *Cicer arietinum*, chickpea, legumes, *Meloidogyne javanica*, *Meloidogyne* spp., resistance, tolerance.

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop in the world after beans (*Phaseolus vulgaris* L.) and peas (*Pisum sativum* L.) (Saxena, 1990). It is grown in 33 countries and is a significant component of cropping systems of subsistence farmers in the Indian subcontinent, West Asia and North Africa. Many species of plant-parasitic nematodes have been found associated with chickpea in seventeen countries and they cause an estimated 13.7 % annual loss (Sasser, 1987; Nene *et al.*, 1989). The root-knot nematodes (*Meloidogyne incognita* and *M. javanica*) are the most prominent nematode pests of chickpea in the tropics (Sharma & McDonald, 1990). These nematodes cause galling of the roots, and aerial parts of the plants manifest reduced vigor, stunting, and early senescence (Sharma *et al.*, 1992). Management options to reduce the nematode-caused damage are limited in chickpea. No commercial chickpea cultivar has been developed with resistance to *Meloidogyne* spp. This paper characterizes reactions of selected chickpea cultivars to *M. javanica* and identifies those that are tolerant to this nematode population.

Materials and methods

PRELIMINARY EVALUATION

A population of *M. javanica* was maintained on tomato (*Lycopersicon esculentum* Mill.) cv. Rutgers in a greenhouse at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra Pradesh, India. Seeds of 47 chickpea cultivars were obtained from the Genetic Resources Program and Crop Physiology Unit of ICRISAT. Seeds were sown in a mixture of autoclaved sand + black soil (3:1, v/v) in 15-cm-diameter pots. Each cv. was grown in four pots, each containing four seeds. Eggs of *M. javanica* were extracted from tomato roots (Hussey & Barker, 1973), and 2500 eggs in water suspension were placed in the depressions where seeds were sown. Similarly, seeds of these cultivars were also sown in pots containing a nematode-free mixture of sand + black soil. The pots were arranged in a randomized block design with treatments of nematode-free and nematode-infested soil paired for each cultivar. Pots were irrigated daily and Arnon's nutrient solution was added to the soil at 7-day intervals (Arnon, 1938). Plant height, dry shoot mass, dry root mass, number of galls and egg masses, extent of galled area of root, and gall size, were measured 60 days after seedling emergence. Roots of each plant were rated for number of galls, size of galls, extent of galled area, and egg masses on 1 to 9 indices. Gall index (GI) : 1 = 0 galls, 2 = 1-5, 3 = 6-10, 4 = 11-20, 5 = 21-30, 6 = 31-50, 7 = 51-70, 8 = 71-100, 9 = > 100 galls. Gall size (GS) : 1 = no galls, 3 = small galls, 5 = medium, 7 = large, and 9 = very large galls. Percentage galled area (GA) : 1 = no galls, 3 = 1-10 % root area galled, 5 = 11-30 %, 7 = 31-50 %, and 9 = > 50 % root area galled. Numbers of egg masses (EI) were rated using the scale developed for gall index. To assess the root damage of a plant, a damage index (DI) was calculated by averaging of GI, GS, and GA. DI of a plant is an indicator of its degree of susceptibility (or resistance) to root damage by the nematode. Cultivars with DI = 1.0 were considered highly resistant, 1.0 < DI $\leq$ 3.0 as resistant, 3 <DI $\leq$ 5.0 as moderately resistant, 5 <DI $\leq$ 7.9 as susceptible, and 7 <DI $\geq$ 9.0 as highly susceptible (Sharma *et al.*, 1993 *b*). EI of a plant is an indicator of its suitability to nematode reproduction. Greater EI usually but not always results in greater DI. Abundant nematode reproduction and (or) severe root damage correspond to susceptibility. Tolerance is the ability of a plant to grow without any perceptible reduction in plant growth and yield despite severe root damage and (or) abundant reproduction of the nematode. Chickpea cv. K 850 was used as a susceptible check (EI = 9; DI = 9). Root and shoot masses and plant height in nematode-free soil and in nematode-infested soil were compared using paired t-tests.

Advanced evaluation

Based on the results of preliminary evaluation and results of a similar test (Sharma *et al.*, 1993 *b*), eleven promising cultivars and the elite breeding line ICCV 90043 were selected for further investigation. Seeds of these genotypes were sown in a mixture of autoclaved sand + black soil (3:1, v/v) in 15-cm-diameter pots and were inoculated with 0.0, 0.4, 2.0, 4.0, and 8.0 *M. javanica* eggs g^{-1} soil. The soil pH at sowing was 8.1, electrical conductivity = 0.17 d S m^{-1}, available mineral nitrogen (N) = 9.9 mg kg^{-1}, Olsen phosphorus (P) = 1.5 mg kg^{-1}, exchangeable potassium (K) = 51 mg kg^{-1}, DPTA extractable zinc (Zn) = 0.20 mg kg^{-1}, iron (Fe) = 3.24 mg kg^{-1}, manganese (Mn) = 21.3 mg kg^{-1}, exchangeable magnesium (Mg) 96 mg kg^{-1}, and exchangeable calcium (Ca) = 1995 mg kg^{-1} soil. The pots were arranged in split-plot design with cultivars as main plots and nematode inoculum levels as subplots. All plants were harvested at physiological maturity, and data on days to flowering and podding, plant height, shoot and root masses, GI, GS, GA, and EI were recorded. The data were subjected to an analysis of variance. Correlation coefficients were calculated between initial nematode densities of *M. javanica* and biomass of the chickpea genotypes, and GI, GA, and GS. Effect of the nematode densities on chickpea biomass was examined by linear and quadratic regression analyses, and by using the Seinhorst' equation (Seinhorst, 1965) : $Y = m + (1-m)z^{P-T}$ for $P > T$, where Y = relative yield, m = minimum yield, z = the slope determining variable, P = nematode density g^{-1} soil, and T = the tolerance threshold (the nematode population density below which suppression in yield is not measurable). Estimates of m, T and z were derived using a computer algorithm (Ferris *et al.*, 1981). For determination of protein content, seed samples from plants grown in nematode-infested (0.4, 2.0, and 4.0 eggs g^{-1} soil), and nematode free soils were ground to a fine powder in a Udy cyclone mill using 0.4 mm screen, and nitrogen content was determined using a Technicon Auto Analyzer (Singh & Jambunathan, 1980); nitrogen values were converted into protein values by multiplying by a factor of 6.25. The root and shoot samples were analyzed for K, Na, Mg, Zn, Cu, Fe, and Mn following digestion in ternary mixture of acids (HNO_3-H_2SO_4-$HCeO_4$) at 180-200 °C in a digestion flask (Jackson, 1967). The digested materials after dilutions were examined for the mineral constituents by the atomic absorption spectrophotometer.

Field evaluation

The twelve genotypes selected from the above studies were further evaluated in a farmer's field heavily infested (7.7-10.5 juveniles g^{-1} soil) with mixed population of *M. incognita* race 1 and *M. javanica* at Pedda Mangalaram village, 40 km south of ICRISAT Center. The genotypes were sown in October in plots with two 9-m long rows 45 cm apart with plants 10-cm apart along the rows. Pant G 114 was included as a susceptible control. No fertilizer or organic manures were added to soil and the plots were irrigated two-times during the crop growth period. Plant growth was visually assessed a every 5 weeks until harvest in January. Data on plant stand, number of stunted and dried plants, plants with pods, pods per plant, galls and egg masses, shoot biomass, size of galls and extent of galled area of root were recorded.

Result

Preliminary evaluation

All of the chickpea genotypes were suitable or highly suitable for *M. javanica* reproduction (EI 9.0) and susceptible to nematode-caused root damage (DI 6.9-9.0). All of the cultivars had GI equal to 9.0, but they differed in GS and GA. GS was low on JG 1, RSG 2, Phule G 1, GNG 146, RSW 11, Bheema, N 31, N 59, ICCV 2 and ICCC 40. All of the genotypes had more than 30 % of root area covered with galls; 40 % of the tested cultivars had extensive root galling with more than 50 % area covered with galls. Only RSG 2, N 31, N 59, ICCC 40 and ICCC 42 had DI between 6 and 7 (Table 1). Nematode parasitism caused stunted growth, yellowing, premature drying and shedding of leaves and occasional bronzing of leaves. Cultivars differed greatly in expression of premature chlorosis. Yellowing of foliage of L 550 and RSW 10, and bronzing of leaves in Ujjain 24 and JG 62 was profound. N 31, N 59, ICCC 42, and Bheema had moderate foliar symptoms of nematode-induced stress. Nematode infection reduced (P = 0.05) the plant height of Ujjain 24, G 543, H 208, K 468, RSW 10, RSW 11, BDN 9-3, Chaffa, DO 8, JG 62, ICCV 2, and ICCC 42. Dry shoot mass of 79 % of the cultivars was reduced ($P = 0.05$) by nematode infection. Ratio of dry shoot mass in infested and in nematode-free soils showed that Bheema, N 59, N 31, ICCC 42, and Pant G 114 were relatively tolerant to nematode-caused damage. Dry root mass increased with nematode parasitism due to formation of galls, and infected root mass was greater than the uninfected root mass in 20 % genotypes.

Advanced evaluation

Plant height, number of leaves, pod, shoot and root masses of genotypes were significantly affected by the varying densities of *M. javanica*. Dry shoot, root and pod masses of all the cultivars, except dry shoot mass of N 31 and dry root mass of CPS 1 and Bheema were negatively correlated with densities of *M. javanica* at sowing time (Table 2). GI, GA, and GS were positively correlated with initial nematode densities and correlation coefficients were normally greater for GS and GA than for GI. P values were generally highly significant for all the parameters except for dry shoot mass of N 31 and root masses of Bheema and CPS 1. R^2 values of plant height, root and shoot masses were between 51 and 78 for Pant G 114 but less than 38 for N 31 and N 59. Attempts to fit data to quadratic models did not provide improved fit over the linear regression models for all the variables. The Seinhorst' model denoted that tolerance thresholds ranged from at-sowing time density of 0.05 to 4.3 eggs g^{-1} soil (Table 3). Estimates of m were 0.6 and higher for Annigri, Bheema, Raja Gouda, N 31, N 59, and CPS 1 but these cultivars differed in their tolerance thresholds. On the basis of tolerance thresholds, the genotypes could be broadly divided into three groups : T less than 1.0 (Pant G 114, Phule G 1, GNG 146, Annigiri), T about 2.0 (Raja Gouda, ICCC 40, ICCC 42, ICCV 90043, CPS 1), and T about 4.0 (Bheema, N 31, N 59). Days to flower of two long-duration cultivars, Pant G 114 and Phule G 1, increased in the nematode-infested soil. Cultivars that required 50 or less days to flower either flowered earlier in nematode-infested soil than in nematode-free soil or took the same time in both soils.

Amounts of K, Mn, and Zn in shoot and K, Ca, Mg, Na, and Mn in root of chickpea plants were negatively correlated with nematode densities in soil. Although amounts of Mg, Na, and Cu in shoot, and Cu in root were positively correlated with the nematode densities in soil (data not shown). N 31 (tolerant) and Phule G 1 (intolerant) differed in uptake of mineral nutrients; N 31 had greater ($P = 0.01$) concentrations of K, Ca, and Na and lower concentrations of Zn in shoot than in Phule G 1. However, amounts of K and Mg were greater and Na was lower in roots of intolerant cultivar (Table 4). Amounts of P, Na and Fe in the two cultivars did not differ. The amount of Ca in the intolerant cultivar in infested soil was 7.3 % greater than in nematode-free soil, while in nematode tolerant cultivar the amount of Ca was 21.1 % greater in infested soil than in the nematode-free soil. Amount of Zn in plants grown in nematode-infested soil was 12-15 % lower than that in plants grown in nematode-free soil of both the cultivars. Interactions between nematode infestation and cultivar for uptake of K in root was significant (P = 0.05) and its amount increased with an increase in nematode infestation level in tolerant cultivar. No such trend was apparent in nematode-susceptible cultivar. The protein content of cultivars in nematode free soils and in soils infested with 0.4 eggs were typically similar; however, in soils infested with 2.0 or more eggs g^{-1} soil, the protein content of intolerant cultivar increased by 15 %. A slight increase (5 %) in protein contents of Annigri, ICCC 40, ICCC 42, ICCV 90043, and CPS 1 was observed. There was no such increase in seed protein content of Bheema, N 31, Raja Gouda and N 59 (Table 5). A marked increase in protein content of CPS 1 and a decrease in protein content of ICCV 90043 were observed with increase in nematode infestation level to 4.0 eggs g^{-1} soil.

Field evaluation

Plant growth was highly variable and patchy because of high nematode infestation levels in the farmer's field. Roots of all the genotypes were heavily galled due to nematode infection. Plants were chlorotic and several plants almost dried before reaching physiological maturity. Pant G 114 had 73 % stunted or dried plants. Num-

Table 1. *Reaction of chickpea cultivars to* Meloidogyne javanica.

ICC no.	Cultivar name	Plant height (cm)		Dry shoot mass (g)		Dry root mass (g)		Damage index
		Control	*M. javanica*	Control	*M. javanica*	Control	*M. javanica*	
4923	BEG 482	12.8	11.3	2.2	1.2*	1.7*	2.5	9.0
4930	C 214	14.1	11.4	2.4	0.9*	2.5	3.5	8.1
4948	G 130	12.3	11.3	2.1	1.2*	2.2	2.8	8.2
4950	G 543	17.0	10.9*	2.3	1.1*	2.4	4.2*	8.6
4954	H 208	15.0	10.0*	2.5	0.7*	2.7	2.1	8.3
4956	H 355	12.8	11.2	2.8	1.1*	2.9	2.1	9.0
4961	JG 221	23.7	16.6	3.8	1.9*	1.9	4.0	8.6
4963	K 468	14.2	11.2*	2.5	1.1*	1.7	3.8*	7.7
4967	L 144	15.5	13.6	3.3	1.9*	3.0	4.0	8.1
4973	L 550	15.2	13.1	2.7	1.3*	2.5	3.7	8.3
5215	Gwalior 2 A	14.8	12.8	2.8	1.3*	2.0	2.8	8.6
6036	JG 1	23.4	19.7	2.8	1.6*	1.5	2.2*	7.4
6098	JG 74	18.8	16.8	3.1	1.5*	1.8	3.1*	8.6
6132	Ujjain 21	21.0	20.0	3.3	1.5*	1.7	2.7*	8.2
6135	Ujjain 24	18.7	11.8*	2.9	1.5*	2.0	2.3	7.3
8276	BR 77	12.0	11.4	2.2	1.0*	1.7	3.6*	8.2
8322	CO 1	23.8	22.3	2.5	1.4*	1.5	3.5*	7.9
8331	Dohad Yellow	22.1	19.8	2.1	1.4*	1.7	1.6	7.9
8933	K 315	18.2	13.8	2.2	1.0*	1.9	2.7	8.3
10136	Pant G 114	12.0	12.2	1.5	1.1	2.0	3.2*	8.9
10656	ST 4	17.9	17.7	1.8	1.1*	1.7	2.5	8.6
11105	PSG 2	12.9	10.7	1.6	0.8*	2.2	2.5	7.0
11508	GL 769	12.2	10.6	1.6	0.9*	2.2	3.3	8.3
12196	Phule G 1	21.8	19.9	2.4	1.8	1.6	4.2*	7.4
12314	GNG 16	12.7	11.3	1.8	1.1*	2.4	3.7*	7.8
13819	GNG 146	12.2	11.9	1.7	1.0	2.2	3.1	7.7
14344	Avrodhi	14.5	10.5*	2.0	1.3	2.3	2.4	8.6
14604	RSW 10	21.8	11.9*	4.1	1.1*	2.3	3.0	9.0
14605	RSW 11	21.9	16.1*	2.8	1.0*	2.8	2.6	7.7
11141	BDN 9-3	23.0	19.8*	2.0	1.4*	1.1*	1.9	8.3
	Bheema	24.7	22.6	1.5	1.5	1.2	1.9	7.2
4934	Chaffa	22.0	17.2*	2.1	1.2*	1.2	1.6	7.6
5091	DO-8	18.1	13.0*	2.8	1.3*	3.0	2.3	8.7
4962	JG 62	21.2	15.6*	2.4	0.9*	2.0	2.2	7.7
5003	K 850	16.5	16.0	2.4	1.7*	3.6	4.6	8.4
	Land race	21.3	18.2	3.0	1.6*	2.5	3.0	8.3
	Andol	21.8	18.3	2.4	1.5*	2.5	3.0	6.8
	Raja Gouda	20.0	16.3	1.7	1.3	2.2	2.1	8.3
8932	N 31	27.0	26.6	2.8	2.2	1.7	3.0	6.9
11152	N 59	27.2	26.8	2.2	2.1	1.9	2.3	7.0
6009	Warangal	12.2	16.3	2.3	1.4*	2.6	3.7*	8.3
ICCV 2		24.2	20.1*	2.2	1.7	1.9	2.1	7.1
ICCV 5		24.5	21.8	3.0	2.0*	2.5	4.4	7.3
ICCV 37		25.8	23.5	2.4	1.5*	2.0	2.3	8.1
ICCC 40		17.9	18.2	2.4	1.6	2.3	2.5	6.6
ICCC 42		19.8	15.3*	2.4	1.7	2.7	4.1	6.7
4918	Annigiri	23.0	19.2	2.4	1.9*	2.2	2.9	9.0

* Indicates significant difference ($P = 0.05$).

Table 2. *Correlation between plant height, dry shoot, root and pod masses, gall index, gall size and extent of galling of root and at sowing time densities of* Meloidogyne javanica *on twelve chickpea cultivars.*

	Pant G 114	Phule G 1	GNG 146	Annigiri	Bheema	Raja-Gouda	N 31	N 59	ICCC 40	ICCC 42	ICCV 9043	CPS 1
Plant height	-0.82**	-0.60**	-0.71**	-0.53**	-0.59**	-0.76**	-0.61**	-0.62**	-0.49**	-0.73**	-0.64**	-0.43**
Dry shoot mass	-0. 88**	-0.67**	-0.79**	-0.57**	-0.58**	-0.70**	-0.31**	-0.56	-0.70**	-0.76**	-0.78**	-0.52**
Dry root mass	-0.73**	-0.65**	-0.55**	-0.63**	-0.08	-0.71**	-0.52**	-0.45*	-0.68**	-0.63**	-0.64**	-0.38**
Pod mass	-0.63**	-0.70**	-0.46**	-0.71**	-0.77**	-0.73**	-0.92**	-0.88**	-0.73**	-0.75**	-0.73**	-0.77**
Gall index	0.46**	0.53**	0.49**	0.56**	0.54**	0.49**	0.49**	0.55**	0.53**	0.50**	0.49**	0.54**
Gall size	0.60**	0.83**	0.65**	0.66**	0.79**	0.67**	0.89**	0.84**	0.83**	0.90**	0.64**	0.77**
% galling	0.42**	0.68**	0.46**	0.66**	0.78**	0.64**	0.80**	0.73**	0.68**	0.64**	0.50**	0.68**

Asterisks denote significance at $P < 0.05$ (*), and $P < 0.01$ (**).

Table 3. *Relationship between initial densities of* Meloidogyne javanica *and biomass of chickpea genotypes (estimates of* m, z, *and* T).

Genotype	m	z	T	R^2
Pant G 114	0.34	0.99	0.24	0.90
Phule G 1	0.56	0.99	0.10	0.64
GNG 146	0.31	0.99	0.10	0.76
Annigiri	0.70	0.99	0.15	0.35
Bheema	0.71	0.99	4.16	0.30
Raja Gouda	0.60	0.99	1.68	0.49
N 31	0.78	0.99	4.28	0.17
N 59	0.70	0.99	4.04	0.46
ICCC 40	0.56	0.99	1.24	0.61
ICCC 42	0.53	0.99	1.64	0.47
ICCV 90043	0.553	0.96	2.08	0.74
CPS 1	0.68	0.96	2.08	0.43

m = minimum yield, z = the slope determining variable, and T = the tolerance limit.

ber of plants m^{-2} of Pant G 114 were 11, Annigiri 12, Bheema 14, Raja Gouda 15, N 31 11, N 59 12, ICCC 42 13, ICCV 90043 14, ICCC 40 8 and K 850 13. Plant growth of Pant G 114, and Annigiri was variable even after 40 days of sowing. Raja Gouda and K 850 grew well till 70 days; later the plants expressed symptoms of stress and only 35 % of plants were with pods while N 31, N 59, ICCC 42 and ICCV 90043 had between 51 and 66 % plants with pods after 100 days of sowing. Shoot mass (ha^{-1}) of Pant G 114 was 370 kg; Annigiri, 741 kg; Bheema, 1272 kg; Raja Gouda, 1173 kg; N 31, 1975 kg; N 59, 2098 kg; ICCC 42, 1975 kg; ICCV 90043, 2025 kg; ICCC 40, 1673 kg; and K 850, 1630 kg.

Table 4. *Amount (μg) of nutrients taken up by* Meloidogyne javanica *intolerant and tolerant chickpea cultivars.*

Nutrient	Phule G 1	N 31	LSD (P = 0.05)
		Shoot	
K	3.14	3.84	0.454
Mg	0.41	0.42	NS
Ca	2.63	3.43	0.386
Mn	127.1	125.3	NS
Zn	37.1	26.8	4.94
Cu	4.92	5.92	NS
Na	0.15	0.47	0.141
		Root	
K	0.63	0.45	0.105
Mg	0.81	0.71	0.064
Ca	2.71	2.74	NS
Zn	24.9	23.2	NS
Mn	242.0	289.0	NS
Cu	22.8	23.8	NS
Na	0.36	0.52	0.88

Data are average of nutrient uptake in infested and uninfested soils.

Table 5. *Protein content (%) of chickpea genotypes grown in nematode-free and* Meloidogyne javanica *infested soils.*

Genotype	Nematode density g^{-1} soil		
	0.0	2.0	4.0
Phule G 1	24.6	28.1	28.6
Pant G 114	24.0	–	–
GNG 146	27.9	–	–
Annigiri	23.7	24.1	25.0
Bheema	22.6	22.0	22.1
Raja Gouda	23.3	22.9	24.8
N 31	22.9	22.4	23.1
N 59	24.8	23.7	25.1
ICCC 40	23.4	24.2	22.3
ICCC 42	22.7	23.3	24.2
ICCV 90043	27.3	27.8	24.8
CPS 1	23.6	24.4	30.5

– = No seed was produced.

Discussion

The research in this paper is unique in that for the first time it reveals the existence of tolerance to nematodes in chickpea cultivars. Tolerance in chickpea genotypes is a trait useful for good plant performance in *M. javanica* infested soils because of the non-availability of nematode resistant cultivars. This study showed that commercial cultivars lacked resistance, and differed in their tolerance to *M. javanica.* N 31, N 59, ICCC 42, ICCV 90043 were recognized as promising tolerant genotypes and they performed better than other cultivars even in soil infested with two *Meloidogyne* species. Pant G 114, Phule G 1, GNG 146 and Annigiri are likely to suffer considerable damage in soils even lightly infested with *M. javanica.* Poor growth of these cultivars in nematode-infested soil is anticipated particularly under rainfed production systems because *M. javanica* disrupts the vascular system of the plants and creates a water deficit (Meon *et al.,* 1978). N 31, N 59 and ICCV 90043 are early maturing genotypes and have faster initial growth than the late maturing cultivars. ICCC 42 is drought tolerant. Drought tolerance and nematode tolerance are probably related to each other as Klar and Franco (1979) found that nematode-tolerant potato cultivars were drought tolerant. It is likely that the promising chickpea cultivars have tolerance to more than one factors and there may be several mechanisms of tolerance in these genotypes (Wallace, 1987). The tolerant (N 31) and intolerant (Phule G 1) cultivars generally had greater concentration of Ca when grown in nematode-infested soil than in nematode-free soil but the tolerant cultivar had much greater concentration of Ca. The relationship between Ca uptake and tolerance to *M. javanica* in chickpea deserves further study. Distribution of other cations in the roots and shoot may be dependant on the ionic imbalance mainly due to ionic uptake of Ca. Evans and Franco (1979) found that Ca uptake in potato genotypes was useful in indicating the degree of tolerance to the potato cyst nematode. Increase in protein content (%) in the intolerant lines was possibly due to decrease in number of seeds per plant as a result of nematode infection. Additional investigation to determine the effects of nematode infection on the protein content of tolerant and intolerant cultivars would be useful.

Tolerant cultivars have an advantage over resistant cultivars in that they limit yield losses without exerting selection pressure on the nematode for the development of more aggressive populations. We suggest multilocation trials with the identified promising genotypes in nematodes infested soils in different agroecological regions. Evaluation of chickpea germplasm lines in the genebank for resistance to the root-knot nematodes is necessary to identify promising sources of resistance as well as tolerance to the root-knot nematodes. Tolerance of damage is independent of resistance, but resistance may confer tolerance if it decreases the incidence of nematode attack or parasitism (Cook, 1974; Trudgill, 1991).

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