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SPATIAL AND TEMPORAL DISTRIBUTION OF PLANT-PARASITIC NEMATODES ON PIGEONPEA IN ALFISOLS AND VERTISOLS†

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ABSTRACT

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Populations of *Heterodera cajani*, *Rotylenchulus reniformis*, and other plant-parasitic nematodes associated with field-grown pigeonpea (*Cajanus cajan* (L.) Millsp.) were monitored monthly for 12 months at three depths in alfisol and vertisol soils. *Heterodera cajani* and *R. reniformis* were the predominant nematodes in the vertisol and the alfisol, respectively. *Hoplolaimus seinhorsti* and *R. reniformis* in alfisol, and *H. cajani*, *Helicotylenchus retusus*, and *R. reniformis* in vertisol, were 0–45 cm deep throughout the year. Populations of *Pratylenchus zeae* and *H. seinhorsti* declined with sampling depth. Cysts of *H. cajani*, however, were found at a soil depth of 75–90 cm. Highest population densities of *R. reniformis* and *H. cajani* occurred at crop maturity and harvest (January–February). Summer fallow (February–June) reduced *R. reniformis* populations 70% and 36% at 0–15 cm and 15–30 cm depths, respectively. Summer fallow reduced densities of *H. cajani* juveniles by 45% at 0–15 cm but densities at 15–30 cm and 30–45 cm were not affected. The egg and juvenile population in the cysts was reduced by 18% at 0–15 cm and 11% at 15–30 cm. However, *H. retusus*, *H. seinhorsti*, *H. cajani*, and *R. reniformis* survived in soil inside buried pots with no plants for 305 days.

Key words: alfisol, *Cajanus cajan*, *Helicotylenchus retusus*, *Heterodera cajani*, *Hoplolaimus seinhorsti*, nematode spacial distribution, pigeonpea, population dynamics, *Pratylenchus zeae*, *Rotylenchulus reniformis*, survival, vertisol.

RESUMEN

Sharma, S. B. y Y. L. Nene. 1992. Distribución espacial v temporal de nematodos fitoparásitos en el gandul (*Cajanus cajan*) en suelos de alfisol y vertisol. Nematrópica 22:13–20.

Poblaciones de *Heterodera cajani*, *Rotylenchulus reniformis* y otros nematodos fitoparásitos asociados con el gandul (*Cajanus cajan* (L.) Millsp.) fueron medidas mensualmente por 12 meses a tres profundidades en suelos de alfisol y vertisol. *Heterodera cajani* y *R. reniformis* fueron los nematodos predominantes en el vertisol y alfisol, respectivamente. *Hoplolaimus seinhorsti* y *R. reniformis* en el alfisol y *H. cajani*, *Helicotylenchus retusus* y *R. reniformis* en el vertisol, se encontraron a 0–45 cm de profundidad durante todo el año. Poblaciones de *Pratylenchus zeae* y *H. seinhorsti* decrecieron con la profundidad de muestreo. Quistes de *H. cajani*, sin embargo, se encontraron en el suelo a una profundidad de 75–90 cm. Las densidades poblacionales más altas de *R. reniformis* y *H. cajani* se encontraron durante la maduración y cosecha del cultivo (enero-febrero). El barbecho de verano (febrero-junio) redujo las poblaciones de juveniles de *H. cajani* en un 45% en los primeros 15 cm, pero las densidades no fueron afectadas a 15–30 y 30–45 cm de profundidad. Poblaciones de huevos y juveniles dentro de los quistes disminuyeron en un 18% en los 0–15 cm y en un 11% en los 15–30 cm. Sin embargo, *H. retusus*, *H. seinhorsti*, *H. cajani* y *R. reniformis* sobrevivieron por 305 días en suelo sin plantas dentro de macetas enterradas.

Palabras clave: alfisol, *Cajanus cajan*, gandul, *Helicotylenchus retusus*, *Heterodera cajani*, *Hoplolaimus seinhorsti*, dinámica de poblaciones, distribución espacial de nematodos, *Pratylenchus zeae*, *Rotylenchulus reniformis*, supervivenica, vertisol.

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INTRODUCTION

In India, alfisols ("red soils") occur mostly in the southern states of Andhra Pradesh, Karnataka, and Tamil Nadu. The vertisols ("black cotton soils") and associated soils of the Deccan, which are the major resources for dryland articulture in India, extend through six states of the northern peninsula from Gwalior in the north to Raichur in the south (15). Pigeonpea (*Cajanus cajan* (L.) Millsp.) is cultivated extensively on alfisols and vertisols in India and is attacked by many species of plant-parasitic nematodes. *Heterodera cajani* Koshy and *Rotylenchulus reniformis* Lindford & Oliveira are particularly important pests of pigeonpea (10). They reduce pigeonpea biomass and increase susceptibility to *Fusarium udum* Butler (11,12). Information regarding the population dynamics of plant-parasitic nematodes associated with pigeonpea in India will be useful in developing control strategies. Therefore, we investigated the spatial and temporal distribution patterns of *R. reniformis*, *H. cajani*, and other nematodes in pigeonpea fields with alfisol and vertisol soils (13).

MATERIALS AND METHODS

A 1.1-ha field with an alfisol soil and a 1.2-ha field with a vertisol soil were selected at the research farm of the ICRISAT Center at Patancheru, Andhra Pradesh (17°N 78°E, 545 m elevation), India. Both fields had been planted to pigeonpea every year for at least 10 years. The alfisol was a hyperthermic deep, Udic Rhodustalf, sandy clay loam (59.6% sand, 7.2% silt, 33.2% clay) with pH = 5.9, electrical conductivity = 0.10 dS/m, organic matter = 0.20%, and available phosphorus = 2.1 mg/kg. The vertisol was a very fine montmorillonitic, calcareous, hyperthermic, Typic Pellustert, silty clay loam (38.8% sand, 20.0% silt, and 41.2% clay) with pH = 7.9, electrical conductivity = 0.15 dS/m, organic matter = 0.38%, and available phosporus = 1.6 mg/kg. Previously, pigeonpea had been sown during the rainy season in June and the fields were fallow after the crop was harvested in February.

Spatial and temporal distribution: In June of 1984 and 1985, during the rainy season, pigeonpea was planted in each field in rows spaced 75 cm apart. Diammonium phosphate (100 kg/ha) and zinc sulfate (40 kg/ha) were applied before planting. Weeds were removed manually during the initial 45 days of crop growth. Crops were harvested in February and fields were left fallow until June. Fields were not irrigated. Rainfall was 99 mm in September of 1984, 80 mm in October, and 89 mm in June of 1985. In all other months, rainfall was less than 20 mm and was less than 2 mm in December, January, and February.

Every month from September 1984 to August 1985, 200-cm^3 soil samples were collected with a 75-cm long × 2.5-cm-diam tube auger at depths of 0–15, 15–30, and 30–45 cm from 15 randomly selected sites in each field. Nematodes were extracted from each sample by a decanting and sieving technique (4) using nested 80-mesh (180μm pore) and 400-mesh (38 μm pore) sieves. Cysts of *H. cajani* were collected on the 80-mesh sieve. Material collected on the 400-mesh sieve was transferred to modified Bearmann funnels to extract vermiform nematodes (9). Nematode counts were log-transformed for analysis of variance. For each sampling date, the sampling sites were divided into five groups of nine samples each based on position in the field. Means and variances were computed for each group and used to test for spatial aggregation according to Taylor's power law (16).

Nematode survival: In September 1984, soil at each field was mixed and placed in eight 30-cm-diam, 30-cm-deep earthen pots. The bottom of each earthen pot was removed and replaced with a wire screen. The pots were filled with soil 15 cm deep, and a second wire screen was placed on the soil. The pots were completely filled with soil and buried with the rims slightly above the soil surface. Twelve random 200-cm^3 soil samples were taken before filling in the pots. After 130 days and again after 305 days, four pots were removed and a 200-cm^3 sample from the upper and lower half of each pot was taken. Nematodes were extracted from samples as previously described. The remainder of the soil in each half of each pot was bioassayed in a 10-cm-diam earthen pot in which a seedling of pigeonpea cv. ICP 8863 was sown and grown for 70 days. Nematodes were extracted from soil in each bioassay pot and counted as previously described.

Deep sampling for Heterodera cajani *cysts in March 1989:* Soil samples were collected from another pigeonpea field with a vertisol soil in which a long-duration pigeonpea (ICPL 8094) had been sown in June 1987. Samples were collected at the depths of 0–15, 15–30, 30–45, 45–60, 60–75, 75–90, 90–105, and 105–120 cm from six randomly selected sites. Cysts of *H. cajani* were extracted as described.

RESULTS

Nematode species detected: Rotylenchulus reniformis was the predominant species in the alfisol field; *H. cajani* and *R. reniformis* were predominant in the vertisol field. Other nematodes present in both soils were *Helicotylenchus retusus* Siddiqi & Brown, *Hoplolaimus seinhorsti* Luc, *Meloidogyne javanica* Treub, *Pratylenchus zeae* Graham, and *Tylenchorhynchus vulgaris* Upadhyay, Sethi & Swarup. The latter three species were present only in very low numbers.

Spatial and temporal distributions: Hoplolaimus seinhorsti and *R. reniformis* (in alfisol), and *H. cajani, R. reniformis*, and *H. retusus* (in vertisol), were found 0–45 cm deep throughout the period of study (Tables 1,2). For all species, coefficients of variation increased with sampling depth. All coefficients of Taylor's regression for *R. reniformis* in alfisol, and *H. cajani* eggs and J2 in vertisol were greater than 1.0, indicating aggregated population distributions of all depths.

When averaged over the 12 sampling dates, the population density of every species in vertisol at 30–45 cm was significantly less than at 0–30 cm (Table 3). *Heterodera cajani* J2 were the least influenced by depth, with a mean density at 30–45 cm that was 81% of that at 0–15 cm. In alfisol, *R. reniformis* was the least influenced by depth, with a mean density at 30–45 cm that was 77% of that at 0–15 cm. *Hoplolaimus seinhorsti, H. retusus*, and *P. zeae* were sensitive to depth in alfisol, and their average population densities at 0–15 cm were about five times as great as at 30–45 cm.

The average population density of *R. reniformis* in the vertisol field was only 25% of the average density in the alfisol field, even though both fields had been cropped to pigeonpea for 10 years, and population density decreased proportionally with depth more in vertisol than in alfisol. Populations of *H. retusus* decreased more with depth in alfisol than in vertisol.

In alfisol, highest total populations (0–45 cm deep) of *H. seinhorsti, H. retusus*, and *R. reniformis* were recorded at crop harvest (February). Populations of these

Table 1. Population densities of plant-parasitic nematodes in a pigeonpea field with alfisol soil, 1984–1985.[z]

	Rotylenchulus reniformis Sample depth (cm)			*Hoplolaimus seinhorsti* Sample depth (cm)			*Helicotylenchus retusus* Sample depth (cm)		
Month	0–15	15–30	30–45	0–15	15–30	30–45	0–15	15–30	30–35
Sep	517	543	538	143	67	37	12	2	0
Oct	965	378	287	105	25	2	7	0	0
Nov	993	790	312	162	198	27	32	32	2
Dec	697	638	432	180	97	8	12	3	0
Jan	703	942	743	90	95	32	27	22	2
Feb	1164	1106	439	261	297	119	36	25	11
Mar	640	452	347	125	57	23	28	17	5
Apr	625	623	380	211	103	28	37	12	12
May	328	728	540	90	106	41	0	7	0
Jun	348	702	667	55	72	3	25	17	2
Jul	578	910	700	80	47	7	27	7	3
Aug	288	502	487	93	107	43	18	40	20
				Log_{10} transformed data					
Sep	2.60	2.62	2.56	1.99	1.33	0.60	0.34	0.09	0.00
Oct	2.92	2.47	2.14	1.52	0.52	0.09	0.23	0.00	0.00
Nov	2.82	2.69	2.37	2.13	1.70	0.52	1.01	0.73	0.09
Dec	2.76	2.68	2.41	2.10	1.69	0.23	0.51	0.19	0.00
Jan	2.74	2.90	2.76	1.56	1.58	0.74	0.79	0.76	0.09
Feb	2.96	3.00	2.61	2.38	2.40	1.16	1.27	0.78	0.50
Mar	2.70	2.43	2.27	1.91	1.46	0.70	1.07	0.64	0.21
Apr	2.76	2.73	2.38	2.09	1.28	0.71	1.03	0.44	0.15
May	2.46	2.80	2.63	1.76	1.84	0.96	0.00	0.22	0.00
Jun	2.48	2.72	2.65	1.40	1.22	0.19	1.04	0.64	0.09
Jul	2.70	2.88	2.71	1.75	0.99	0.13	0.96	0.22	0.11
Aug	2.37	2.57	2.31	1.67	1.39	1.01	0.88	1.20	0.67
LSD ($P = 0.05$)	0.22	0.28	0.39	0.45	0.63	0.54	0.54	0.50	0.32

[z]Nematodes per 200 cm^3 soil.

nematodes dropped by 81%, 42%, and 37%, respectively, during post harvest (Febraury–June). *Rotylenchulus reniformis* densities at 0–15, 15–30, and 30–45 cm did not change significantly during the sowing, seedling, and pre-flowering stages (June–September). In October, however, *R. reniformis* density at 0–15 cm increased by 87%. In vertisol, the highest total populations of eggs and J2 of *H. cajani* were recorded at crop maturity and crop harvest. Nematode densities 30–45 cm deep were similar to those at 0–30 cm from post harvest (May) until the seedling stage (August).

Rates of decline in nematode populations during post-harvest summer fallow after February till sowing of pigeonpea in June were depth dependent. The *R. reniformis* density in alfisol was reduced by 70% at 0–15 cm but only by 36% at 15–30 cm. The *H. cajani* J2 population was reduced by 45% at the 0–15 cm depth, while densities at 15–30 cm and

Table 2. Population densities of plant-parasitic nematodes in a pigeonpea field with vertisol soil, 1984–1985.[1]

Month	*Heterodera cajani* eggs + J2 Sample depth (cm)			*Rotylenchulus reniformis* Sample depth (cm)			*Helicotylenchus retusus* Sample depth (cm)		
	0–15	15–30	30–45	0–15	15–30	30–45	0–15	15–30	30–35
Sep	350	380	154	80	13	2	65	18	22
Oct	481	718	201	122	142	57	53	47	3
Nov	845	691	394	318	282	168	68	47	38
Dec	860	535	275	367	263	48	88	112	53
Jan	907	625	755	335	125	102	47	75	53
Feb	746	736	579	82	57	47	103	65	60
Mar	559	617	382	157	175	130	33	50	50
Apr	633	504	343	147	107	145	30	38	32
May	656	720	720	148	357	123	37	83	67
Jun	615	657	718	125	243	78	60	102	72
Jul	377	422	613	202	213	208	45	38	42
Aug	501	594	540	112	175	133	33	43	49
				Log_{10} transformed data					
Sep	2.50	2.47	2.09	1.60	0.60	0.09	1.07	0.66	0.77
Oct	2.60	2.70	2.07	2.00	2.00	1.15	0.91	1.00	0.11
Nov	2.89	2.76	2.47	1.45	2.01	1.72	1.60	1.07	0.64
Dec	2.81	2.69	2.36	2.29	2.16	1.26	1.80	1.89	1.43
Jan	2.92	2.71	2.73	1.41	1.80	1.71	1.36	1.39	1.22
Feb	2.84	2.85	2.71	1.68	1.48	1.29	1.93	1.59	1.17
Mar	2.62	2.69	2.49	1.47	1.39	1.29	1.03	1.21	1.12
Apr	2.75	2.65	2.35	1.55	1.29	1.42	1.14	1.15	0.71
May	2.76	2.80	2.76	1.91	2.27	1.75	1.22	1.70	0.37
Jun	2.71	2.77	2.72	1.97	1.96	1.69	1.62	1.66	1.41
Jul	2.55	2.56	2.68	2.00	1.98	1.81	1.46	1.16	1.28
Aug	2.62	2.66	2.53	1.85	1.92	1.80	1.08	0.96	1.11
LSD ($P = 0.05$)	0.18	0.19	0.32	0.52	0.56	0.56	0.54	0.60	0.63

[1]Nematodes per 200 cm^3 soil.

30–45 cm were not affected. The egg and J2 population in the cysts was reduced by 18% at 0–15 cm but by only 11% at 15–30 cm. Population decline during summer fallow was also soil type dependent. The total density of plant-parasitic nematodes at 0–15 cm was reduced by 70% in alfisol but only by 15% in vertisol. Population reductions were associated only with the fallow condition of the fields; there was no apparent correlation with rainfall for any species during the 12-month period.

Nematode survival: Heterodera cajani, H. seinhorsti, H. retusus, and *R. reniformis* survived in pots without plants for 305 days. However, there was a 91% reduction in number of *H. cajani* cysts after 305 days of fallow. The *R. reniformis* population was below a level detectable by direct extraction in vertisol and was reduced by 57% in alfisol. Population densities were greater at 15–30 cm than at 0–15 cm. Bioassays indicated *H. cajani, R. reniformis, H. retusus*, and *H. seinhorsti* could

Table 3. Average population densities of different nematode species at three soil depths in pigeonpea fields with alfisol and vertisol from September 1984 to August 1985.

Nematode	Average nematode density per 200 cm³ soil			LSD
	0–15 cm	15–30 cm	30–45 cm	(P = 0.05)
		Alfisol		
Rotylenchulus reniformis	636 (2.68)	679 (2.70)	491 (2.48)	(0.09)
Hoplolaimus seinhorsti	129 (1.84)	99 (1.42)	28 (0.57)	(0.17)
Helicotylenchus retusus	21 (0.74)	15 (0.48)	4 (0.15)	(0.13)
Pratylenchus zeae	10 (0.41)	6 (0.28)	2 (0.06)	(0.10)
		Vertisol		
Heterodera cajani cysts	13 (1.09)	12 (1.06)	10 (0.97)	(0.05)
H. cajani J2	159 (2.00)	171 (2.00)	129 (1.58)	(0.10)
H. cajani eggs + J2	627 (2.71)	600 (2.69)	481 (2.50)	(0.07)
Rotylenchulus reniformis	183 (1.85)	179 (1.74)	103 (1.42)	(0.16)
Helicotylenchus retusus	55 (1.35)	60 (1.29)	45 (1.03)	(0.17)

Data were $\log_{10}$ (X + 1) transformed for analysis. Figures in parentheses are log values.

parasitize pigeonpea roots and reproduce after 130 days of fallow. During the bioassays, populations of *Heterodera cajani* J2 increased eight-fold while *R. reniformis* increased six-fold in soil from the 0–15 cm depth and 20 times in soil from the 15–30 cm depth.

Soil samples collected 120 cm deep from a long-duration pigeonpea planting in a vertisol contained *H. cajani* cysts down to 90 cm. The number of cysts per 200 cm³ soil averaged 34.0, 23.7, 19.0, 6.5, 3.0, and 1.5 at the 0–15, 15–30, 30–45, 45–60, 60–75, and 75–90 cm depths, respectively.

DISCUSSION

Population densities of *R. reniformis* in alfisol and *H. cajani* in vertisol were higher at flowering, podding, and crop maturity (November–February) than at summer fallow, sowing, and preflowering (March–October). Both fields had been cropped to pigeonpea for 10 years before the study was started, yet there were striking differences between the relative densities of the species present in the two soils. Populations of *H. cajani* were low in alfisol whereas *R. reniformis* populations were low in vertisol but high in the alfisol. *Hoplolaimus seinhorsti*, similarly, preferred alfisol to vertisol. These effects may be due to differences in soil texture. Soils with high sand contents are more suitable than silty soils for movement of large nematodes (2,17); soil texture also influences water retention, gas exchange, and antagonistic microbiota. Extensive sampling of the pigeonpea growing areas are needed to verify these observations. It is not surprising that *H. cajani* and *R. reniformis* exhibited aggregated distributions. This is a common characteristic of plant-parasitic nematodes, particularly in row crop fields, where root growth patterns markedly influence nematode distributions (1,3,5,7,8,16).

The *H. cajani* cysts 75–90 cm deep may have been produced at that depth. Although most roots of pigeonpea are concentrated in the upper 30 cm, they can reach a depth of more than 100 cm. Nematodes in vertisols could be carried by top soil falling through the deep cracks that form during dry seasons. These cracks may penetrate more than 50 cm.

In both soils, several species survived in the absence of a host for many months. Juveniles of *H. cajani* are enclosed in protective cysts and exhibit dormancy, emerging only gradually even under optimum conditions (14). The other nematodes that survived 305 days have no apparent protective structure and it is probable that they survive by anhydrobiosis. *Scutellonema cavenessi* Sher survies in an anhydrobiotic state in soil throughout the summer months in Senegal (6).

Throughout most of the semi-arid region of India where pigeonpea is produced, sampling for nematodes deeper than 15 cm is very difficult most months of the year because of soil compaction. Although populations of *R. reniformis* in alfisol and *H. cajani* in vertisol fluctuate during the course of the year, samples that give a good enough estimate of the population density to decide whether or not to use nematode control measures could be taken 0–15 cm deep during the rainy season when soil moisture is optimal for taking samples in vertisol, but probably need to be taken deeper in alfisol.

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