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Plant-parasitic Nematode Densities in Cereal and Legume Based Cropping Systems on Vertisols

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Abstract. Densities of plant-parasitic nematodes in traditional, low-input cropping systems were three times lower than in high input cropping systems. Sorghum/pigeonpea (intercropped), soybean/pigeonpea (intercropped) and green gram (*Vigna radiata*) were identified as systems very condusive to the build up of *Heterodera cajani*. Very high population densities (>3500 nematodes 100 cm^3 soil) of *Rotylenchulus reniformis* were recorded on sunflower. The densities of plant-parasitic nematodes did not increase significantly in plots that were either fallowed or sown with pearl millet (*Pennisetum glaucum*)in the rainy season. A summer fallow period between February to June reduced the soil densities of all plant-parasitic nematodes by 42%; *R. reniformis* population was reduced by 80%. *Heterodera cajani*, *Tylenchorhynchus* sp. and total plant-parasitic nematode densities were significantly higher in plots treated with inorganic fertilizers than in plots treated with farmyard manure. *R. reniformis* densities were higher in irrigated than in rainfed fields.
Keywords: Crop fallow, cropping systems, fertilizers, *Heterodera cajani*, irrigation, *Rotylenchulus reniformis*.

INTRODUCTION

Plant-parasitic nematodes are significant constraints to grain legume production in the semi-arid tropics. Pigeonpea cyst nematode, *Heterodera cajani* and the reniform nematode, *Rotylenchulus reniformis* cause important diseases in grain legume (Sharma *et al.*, 1992). *H. cajani* is widespread in this region and produces several generations in each crop season (Koshy and Swarup, 1971). *R. reniformis* attacks many crop species in 38 countries and causes 'dirty root' disease in pigeonpea [*Cajanus cajan* (L.) Millsp.] (Holdeman *et al.*, 1977). It causes variable growth of pigeonpea in India where a preplanting density of 1.0 *R. reniformis* cm^{-3} soil can significantly reduce biomass production in susceptible pigeonpea cultivars (Sharma and Nene, 1988). *Helicotylenchus indicus*, *H. retusus*, *Hoplolaimus seinhorsti*, *Pratylenchus* sp. are identified from Alfisol fields and *Tylenchorhynchus* sp., the other potentially important nematode, was found in Vertisol fields (Sharma *et al.*, 1985).

Soil temperatures that favour nematode activity and development, long growing seasons, and continuous cultivation of susceptible crops can lead to substantial production losses due to nematodes (Sharma, 1988). Farmers in developing tropical countries have limited resources and management options. The use of nematicides to manage nematodes is not practical because of their high cost and possible health hazards. A cropping system approach could be an attrative nematode management option under these conditions. It is a relatively low-cost, low-input method of optimising existing agricultural practices with respect to limiting losses due to nematodes (Noe, 1988). Crop rotations have long been regarded as a successful means of reducing nematode populations (Ross, 1962; Chawla and Prasad, 1973; Nusbaum and Ferris, 1973).

Therefore, the influence of different cropping practices on population densities of plant-parasitic nematodes was studied in diverse cropping systems on Vertisol fields at the Asian Center of ICRISAT at Patancheru, from 1991 to 1993.

MATERIALS AND METHODS

Field trials were conducted in three Vertisol watershed fields (BW1, BW3B, and BW4C) at Patancheru, ICRISAT. The cropping sequences followed in these fields are given in Table 1.

The long-term effects of high and low fertilizer applications [FYM (Farm Yard Manure) vs. NPK)], traditional versus non-traditional cropping sequences and varieties, and flat versus broad-bed and furrow (BBF) land form were studied by comparing nematode densities in BW1 and BW4C fields. BW1 was used for 15 years prior to 1989 as a demonstration area for ICRISAT's Vertisol technology package while BW4C was used to demonstrate farmer's traditionl practices. BW1 received regular NPK inputs while BW4C received only FYM in alternate years. The cropping patterns in BW1 were characterized as intensive (intercropping or sequential cropping) while those in BM4C were extesive (only postrainy season cropping). BW1 utilized the BBF land form while BW4C was kept flat (traditional). Traditional cultivars were used in BW4C while only improved cultivars were used in BW1.

Table 1. Cropping sequences followed in BW1, BW4C, and BW3B fields, 1991-1993 at ICRISAT Asian Center, Patancheru, India.

Field number and cropping sequence number	Crops and seasons				
	Rainy June 1991-Oct. 1991	Postrainy Nov. 1991-Feb. 1992	Fallow Feb. 1992 May 1992	Rainy June 1992 Oct. 1992	Postrainy Nov. 1992 Feb. 1993
BW1					
1	Fallow	Sorghum[1]	Fallow	Fallow	Chickpea[1]
2	Fallow	Chickpea[1]	Fallow	Fallow	Sorghum[1]
3	Fallow	Sorghum[2]	Fallow	Fallow	Chickpea[2]
4	Fallow	Chickpea[2]	Fallow	Fallow	Sorghum[2]
5	Maize	Chickpea[2]	Fallow	Maize	Safflower
6	Maize	Safflower	Fallow	Maize	Chickpea[2]
7	Sorghum/[3] pigeonpea	Sorghum/ pigeonpea	Fallow	Green gram	Sunflower
8	Green gram	Sunflower	Fallow	Sorghum/ pigeonpea	Sorghum/ pigeonpea
9	Soybean/ pigeonpea	Soybean/ pigeonpea	Fallow	Millet	Safflower
10	Millet	Safflower	Fallow	Soybean/ pigeonpea	Soybean/ pigeonpea
11	Millet	Chickpea[2]	Fallow	Green gram	Safflower
12	Green gram	Safflower	Fallow	Millet	Chickpea[2]
BW4C					
1	Fallow	Sorghum[1]	Fallow	Fallow	Chickpea[1]
2	Fallow	Chickpea[1]	Fallow	Fallow	Sorghum[1]
3	Fallow	Sorghum[2]	Fallow	Fallow	Chickpea[2]
4	Fallow	Chickpea[2]	Fallow	Fallow	Sorghum[2]
7	Sorghum/ pigeonpea	Sorghum/ pigeonpea	Fallow	Green gram	Sunflower
8	Green gram	Sunflower	Fallow	Sorghum/ pigeonpea	Sorghum/ pigeonpea
10	Millet	Safflower	Fallow	Millet	Chickpea[2]
11	Millet	Chickpea[2]	Fallow	Millet	Safflower
BW3B					
1	Fallow	Sorghum[1]	Fallow	Fallow	Chickpea[1]
2	Fallow	Chickpea[1]	Fallow	Fallow	Sorghum[1]
3	Fallow	Sorghum[2]	Fallow	Fallow	Chickpea[2]
4	Fallow	Chickpea[2]	Fallow	Fallow	Sorghum[2]
5	Maize	Chickpea[2]	Fallow	Maize	Safflower
6	Maize	Safflower	Fallow	Maize	Chickpea[2]
7	Sorghum/ pigeonpea	Sorghum/ pigeonpea	Fallow	Green gram	Sunflower
8	Green gram	Sunflower	Fallow	Sorghum/ pigeonpea	Sorghum/ pigeonpea

[1] Traditional cultivar; [2] Improved cultivar; [3] Intercrop.

In 1989, those cropping systems used in BW4C were used in BW1 while selected cropping systems were added to BW4C (Table 1). This was done as a split plot design which then allowed for plots in each area that were managed in the same manner as the previous 15 years. In order to assess the long term effects of traditional (BW4C) and newer (BW1) cropping systems, soil samples were collected in June, 1991 from both sites. Ten soil cores were collected at random from each plot with a 75-cm long × 2.5-cm-diameter tube auger at a depth of 0-20 cm. The soil cores were thoroughly mixed and nematodes extracted from a 100 cm^3 subsample by suspending it in water, pouring through 850, 180, and 38-μm-pore nested sieves, and placing the residue from the 38-μm-pore sieve in modified Baermann funnels (Schindler, 1961). Nematode cysts were collected on a 180-μm-pore sieve (Sharma and Nene, 1986). Two aliquots from each subsample were counted.

The effect of different cropping sequences and fertility levels on nematode populations were studied in BW1. Twelve cropping systems, each replicated three times, were arranged in a split-plot design (Table 1). The main plots comprised of different crop combinations.

To compare fertility levels (FYM vs. NPK), main plots were subdivided with one half of each plot receiving 10 t ha^{-1} of FYM every alternate year while the other half received a basal application of 18 kg ha^{-1} nitrogen and 20 kg ha^{-1} phosphate prior to sowing an addition of 46 kg N ha^{-1} was applied for cereal crops as a urea top dressing in each season.

To estimate nematode populations, plots were sampled at the sowing and harvest of each crop starting in June, 1991. Soil sampling was continued for four crop seasons. Twenty soil cores (10 from the subplot receiving organic fertilizers and 10 from another subplot receiving only FYM were randomly collected from a depth of 0-20 cm.

The effect of irrigation on nematode populations was studied by comparing BW1 and BW3B. BW3B is a 1.6 ha field located adjacent to a catchment tank and receives supplemental irrigation. Eight cropping systems common to both locations were arranged in a split plot design (Table 1). BW1 was rainfed, whereas BW3B received supplementary irrigation. Other crop husbandry practices were common to both fields. Nematode populations were compared in eight cropping systems (Table 1). Two fertility levels (FYM and NPK) as described above were used in both fields. Soil samples were collected from June, 1991 to March 1993. To estimate nematode populations 20 soil cores were collected from each plot and analyzed.

Nematode counts were log 10 (nematode number+0.5) transformed for analysis of variance, and treatment means compared by the least significant differences techniques at a 5% level of significance.

RESULTS

Influence of traditional and newer cropping systems on densities of plant-parasitic nematodes

Densities of *Heterodera cajani* and total plant-parasitic nematodes were significantly higher ($P<0.05$) in the newer cropping systems than in the traditional systems (Table 2). Mean nematode densities were higher in the newer cropping systems than in traditional systems; *H. cajani* 73.0 times higher, *R. reniformis* 4.3 times higher and total plant-parasitic nematodess 3.0 times higher. Sorghum [*Sorghum bicolor* (L.) Moench]/pigeonpea intercropped and green gram [*Vigna radiata* (L.) Wilczek] + sunflower (*Helianthus annuus* L.) sequentially cropped plots had 6-114 times higher densities of *R. reniformis* than the other cropping systems. Cropping systems did not influence the densities of *H. cajani*. Systems containing intercropped sorghum/pigeonpea, and green gram supported the greatest number of plant-parasitic nematodes, while the fallow+sorghum, and fallow+chickpea systems had the lowest densities of plant-parasitic nematodes.

Effect of different cropping sequences and fertility levels on densities of plant-parasitic nematodes

Heterodera cajani densities remained higher in the sorghum/pigeonpea (intercropped), soybean/pigeonpea (intercropped), and green gram systems than in the other systems (Table 3). In October, 1992, *H. cajani* densities as high as 818 eggs and juveniles 100 cm^{-3} soil were observed on green gram. However, subsequent rotation with safflower resulted in an 80% reduction in this nematode density. Crop rotation with pearl millet and summer fallow reduced *H. cajani* densities by 13%. *R. reniformis* densities were very high on sorghum/pigeonpea (intercropped), green gram and sunflower (Table 3). Sunflower was the most favoured host of *R. reniformis* and supported about 3500 *R. reniformis* 100 cm^{-3} soil. Soybean/pigeonpea (intercropped) increased *R. reniformis* densities to as high as 478 nematodes cm^{-3} in February 1992 but summer fallow, and rotating with millet significantly reduced these densities. Summer fallow in 1992 caused an 80% decline in *R. reniformis* densities. Low densities of this nematode were noticed on millet in June 1991 (cropping sequence 10 and 11) but subsequent cultivation of safflower, chickpea, soybean/pigeonpea (intercropped), and green gram between 1991 and 1993 caused significant increases in the nematode population. Other cropping sequences had relatively low *R. reniformis* densities.

Densities of *Pratylenchus* sp. and *Helicotylenchus retusus* were generally low, and densities of total plant-

Table 2. Traditional and newer cropping systems effects on the densities of plant-parasitic nematodes examined in two fields (BW1 and BW4C) in 1991 at ICRISAT Asian Center, Patancheru, India.

	Number of nematodes cm^{-3} soil[1]								
	Heterodera cajani (eggs+juveniles)			*Rotylenchulus reniformis*			Total plant parasitic nematodes		
Crops	BW1[2]	BW4C	Mean	BW1	BW4C	Mean	BW1	BW4C	Mean
Fallow+Sorghum[3]	246	0	123	0	13	7	288	66	177
	(2.16)	(-0.30)	(0.93)	(-0.30)	(-0.34)	(0.02)	(2.39)	(1.79)	(2.09)
Fallow+Chickpea[3]	348	0	174	0	13	7	412	148	280
	(2.52)	(-0.30)	(1.11)	(-0.30)	(0.77)	(0.24)	(2.60)	(2.13)	(2.36)
Fallow+Sorghum[4]	149	0	75	15	0	7	271	123	197
	(1.46)	(-0.30)	(0.58)	(0.35)	(-0.30)	(0.02)	(2.36)	(2.09)	(2.23)
Fallow+Sorghum[4]	301	0	151	8	0	4	439	200	320
	(2.35)	(-0.30)	(1.02)	(0.27)	(-0.30)	(-0.02)	(2.60)	(2.28)	(2.44)
Sorghum/Pigeonpea	184	0	92	1029	90	560	1314	278	796
	(2.25)	(-0.30)	(0.98)	(2.64)	(1.28)	(1.96)	(3.01)	(2.43)	(2.72)
Green gram+Sunflower	465	43	254	427	276	352	985	537	761
	(2.49)	(0.50)	(1.50)	(2.58)	(2.36)	(2.47)	(2.99)	(2.68)	(2.84)
Millet+Safflower	751	0	376	109	0	55	969	169	569
	(2.74)	(-0.30)	(1.22)	(1.34)	(-0.30)	(0.52)	(2.91)	(2.18)	(2.54)
Millet+Chickpea	468	0	234	133	7	70	640	233	437
	(2.60)	(-0.30)	(1.15)	(1.16)	(0.58)	(0.87)	(2.74)	(2.25)	(2.50)
Mean	365	5		215	50		665	219	
	(2.32)	(-0.20)		(0.97)	(0.55)		(2.70)	(2.23)	
LSD P, 0.05 Field (F)			(0.34)			NS			(0.16)
Cropping sequence (CS)			NS			(0.97)			(0.32)
F × CS			NS			NS			NS

[1] Figures in parentheses are log 10 (nematode number+0.5) transformed values.
[2] BW1 - New cropping system; BW4C - Traditional cropping system.
[3] Traditional cultivar.
[4] Improved cultivar.

Table 3. Population densities of *Heterodera cajani*, *Rotylenchulus reniformis* and total plant-parasitic nematodes in different cropping systems between June, 1991 and March, 1993 in BW1 field at ICRISAT Asian Center, Patancheru, India.

Cropping sequence	Nematode densities[1]									
	Date June 1991	Crop	Date Oct. 1991	Crop	Date Feb. 1992	Date June 1992	Crop	Date Oct. 1992	Crop	Date March 1993
Heterodera cajani										
	246 (2.16)	F	102 (1.31)	S[3]	344 (2.47)	242 (2.31)	F	214 (2.29)	CP[3]	45 (0.82)
	348 (2.52)	F	182 (2.12)	CP[3]	337 (2.46)	303 (2.51)	F	293 (2.43)	S[3]	32 (0.73)
	149 (1.46)	F	72 (1.72)	S[4]	195 (2.03)	123 (1.72)	F	97 (1.67)	CP[4]	12 (0.73)
	301 (2.35)	F	189 (1.52)	CP[4]	232 (1.90)	182 (1.70)	F	129 (1.99)	S[4]	60 (1.16)
	147 (2.12)	M	127 (1.50)	CP[4]	98 (1.61)	344 (2.47)	M	120 (1.97)	SF	27 (0.71)
	510 (2.28)	M	158 (1.83)	SF	89 (1.87)	216 (2.30)	M	110 (1.69)	CP[4]	96 (1.54)
	184 (2.25)	S/PP	193 (2.14)	S/PP	586 (2.60)	261 (2.30)	GG	233 (2.34)	SN	78 (1.56)
	465 (2.49)	GG	112 (1.96)	SN	195 (2.14)	371 (2.38)	S/PP	397 (2.45)	S/PP	196 (2.23)
	163 (1.48)	SB/PP	420 (2.27)	SB/PP	689 (2.74)	337 (2.48)	PM	440 (2.57)	SF	230 (2.36)
	751 (2.74)	PM	66 (0.88)	SF	255 (2.38)	325 (2.51)	SB/PP	349 (2.45)	SB/PP	203 (2.24)
	468 (2.60)	PM	97 (1.56)	CP[4]	429 (2.53)	259 (2.34)	GG	818 (2.84)	SF	145 (1.74)
	399 (2.39)	GG	93 (1.89)	SF	265 (2.31)	252 (2.27)	PM	95 (1.23)	CP[4]	71 (0.92)
LSD 5%	NS		(0.82)		(0.64)	NS		(0.69)		(1.13)
Rotylenchulus reniformis										
	0 (-0.30)	F	19 (0.60)	S[3]	13 (0.76)	7 (0.23)	F	7 (0.02)	CP[3]	66 (1.09)
	0 (-0.30)	F	3 (0.14)	CP[3]	37 (0.40)	16 (0.28)	F	21 (0.40)	S[3]	0 (-0.30)
	15 (0.35)	F	14 (0.54)	S[4]	10 (0.27)	3 (-0.03)	F	0 (-0.30)	CP[4]	21 (0.37)
	8 (0.27)	F	2 (-0.08)	CP[4]	10 (0.29)	3 (-0.03)	F	0 (-0.30)	S[4]	32 (0.44)
	82 (1.81)	M	271 (1.41)	CP[4]	68 (1.10)	44 (-0.03)	M	8 (0.25)	SF	33 (0.41)
	35 (0.95)	M	691 (1.72)	SF	31 (0.74)	2 (-0.07)	M	19 (0.64)	CP[4]	4 (-0.02)
	1029 (2.64)	S/PP	1317 (2.93)	S/PP	350 (1.56)	160 (2.09)	GG	441 (1.77)	SN	1480 (3.02)
	427 (2.58)	GG	565 (2.68)	SN	3513 (3.50)	272 (2.22)	S/PP	692 (2.68)	S/PP	1209 (2.95)
	28 (0.9)	SB/PP	13 (0.29)	SB/PP	478 (1.92)	122 (1.30)	PM	88 (1.13)	SF	104 (0.97)
	109 (1.34)	PM	90 (1.15)	SF	248 (1.44)	107 (0.90)	SB/PP	271 (1.20)	SB/PP	317 (1.57)
	133 (1.16)	PM	41 (1.04)	CP[4]	414 (2.09)	283 (1.60)	GG	254 (1.72)	SF	242 (1.62)
	65 (1.70)	GG	284 (2.15)	SF	227 (2.01)	78 (1.22)	PM	163 (1.77)	CP[4]	371 (1.67)
LSD 5%	(1.33)		(1.03)		(1.25)	(1.21)		(1.21)		(1.61)
Total plant-parasitic nematodes										
	288 (2.39)	F	148 (1.96)	S[3]	530 (2.71)	382 (2.53)	F	278 (2.42)	CP[3]	219 (2.21)
	412 (2.60)	F	219 (2.21)	CP[3]	479 (2.67)	413 (2.60)	F	383 (2.55)	S[3]	186 (1.87)
	271 (2.36)	F	146 (2.15)	S[4]	582 (2.73)	485 (2.64)	F	330 (2.46)	CP[4]	270 (2.42)
	439 (2.60)	F	302 (2.44)	CP[4]	564 (2.67)	604 (2.67)	F	287 (2.43)	S[4]	433 (2.58)
	321 (2.49)	M	557 (2.68)	CP[4]	416 (2.54)	526 (2.70)	M	827 (2.88)	SF	264 (2.34)
	746 (2.76)	M	1000 (2.93)	SF	410 (2.58)	482 (2.67)	M	729 (2.85)	CP[4]	273 (2.39)
	1314 (3.01)	S/PP	1684 (3.17)	S/PP	1070 (2.99)	668 (2.78)	GG	854 (2.92)	SN	1633 (3.11)
	985 (2.99)	GG	775 (2.85)	SN	3728 (3.54)	738 (2.82)	S/PP	1547 (3.17)	S/PP	1466 (3.08)
	241 (2.19)	SB/PP	686 (2.75)	SB/PP	1217 (3.07)	489 (2.66)	PM	558 (2.71)	SF	374 (2.56)
	969 (2.91)	PM	247 (2.28)	SF	560 (2.69)	481 (2.66)	SB/PP	703 (2.77)	SB/PP	535 (2.59)
	640 (2.74)	PM	208 (2.23)	CP[4]	886 (2.91)	713 (2.81)	GG	1285 (3.10)	SF	482 (2.52)
	488 (2.56)	GG	423 (2.52)	SF	574 (2.67)	467 (2.66)	PM	333 (2.45)	CP[4]	504 (2.50)
LSD 5%	NS		(0.32)		(0.27)	NS		(0.21)		(0.50)

[1] Number of nematodes 100 cm^{-3} soil. Figures in parentheses are log 10 (nematode number + 0.5) transformed values.
[2] Refer to Table 1 for cropping sequence; F = Fallow, S = Sorghum, CP = Chickpea, PP = Pigeonpea, GG = Green gram, SF = Safflower, M = Maize, SN = Sunflower.
[3] Traditional cultivar. [4] Improved cultivar.

Table 4. Effect of traditional fertilizer (FYM) and inorganic fertilizers (NPK) on the number of plant-parasitic nematodes and saprophytes in 100 cm^3 soil measured in BW1 field during 1991 and 1992 at ICRISAT Asian Center, Patancheru, India.

Treatment (fertilizer)	Total *Heterodera cajani**	Total *Tylenchorhynchus*	Total plant parasites	Total saprophytes
Organic (FYM)	90	38	456	589
	(1.14)[1]	(0.51)	(2.40)	(2.69)
Inorganic (NPK)	109	83	651	489
	(1.58)	(1.09)	(2.63)	(2.53)
LSD (P=0.05)	(0.39)	(0.47)	(0.22)	NS

* Total *H. cajani* includes eggs+juveniles.
[1] Figures in parentheses are log 10 (nematode number+0.5) transformed values.

parasitic nematodes increased about one and a half times after two years of rotation containing sorghum/pigeonpea intercropped, green gram, or soybean/pigeonpea intercropped (Table 3). Other cropping sequences caused a reduction in total plant-parasitic nematode densities. The population of saprophytic nematodes increased in all cropping sequences with a greater rate of increase in plots where sorghum/pigeonpea intercropped, soybean/pigeonpea intercropped, and green gram + sunflower sequentially cropped were grown.

Heterodera cajani, Tylenchorhynchus sp., and total plant-parasitic nematode densities were significantly ($P<0.05$) higher in plots receiving inorganic fertilizers than in those receiving only FYM (Table 4). Densities of saprophytic nematodes were 1.2 times greater in the FYM treatment than in the NPK treatment.

Influence of irrigation on densities of plant-parasitic nematodes

Rotylenchulus reniformis densitiess were significantly ($P<0.05$) higher in treatments receiving supplemental irrigation than in the same cropping systems under rainfed conditions (Table 5). Higher densities were recorded in the sorghum/pigeonpea intercropped and green gram+sunflower sequential systems. The interaction between cropping sequence and irrigation was significant, and nematode densities were higher in the maize+chickpea and maize+safflower sequential cropping treatments in the irrigated (BW3B) field than in the rainfed (BW1) field with the same crop combinations.

Table 5. Effect of irrigation on population densities of *Rotylenchulus reniformis* in different cropping sequences measured in BW1 and BW3B fields in 1991 to 1993 at ICRISAT Asian Center, Patancheru, India.

Cropping sequence	Number of nematodes in 100 cm^{-3} soil: Rainfed (BW1)	Irrigated (BW3B)	Mean
F-S[1]-F-CP[1]	66	271	168
	(1.09)[3]	(1.14)	(1.12)
F-CP[1]-F-S[1]	0	13	7
	(-0.30)	(0.54)	(0.12)
F-S[2]-F-CP[2]	21	0	10
	(0.37)	(-0.30)	(0.30)
F-CP[2]-F-S[2]	32	34	33
	(0.44)	(0.93)	(0.69)
M-CP[2]-M-SF	33	1021	527
	(0.41)	(2.17)	(1.29)
M-SF-M-CP[2]	4	273	139
	(-0.02)	(1.97)	(0.98)
S/PP-GG+SN	1480	1493	1486
	(3.03)	(2.98)	(3.00)
GG+SN-S/PP	1209	1112	1161
	(2.95)	(3.02)	(2.99)
Mean	356	527	
	(1.00)	(1.56)	
LSD, P<0.05			
Field (F)	(0.25)		
Cropping sequence (CS)	(0.78)		
F × CS	(1.04)		

F = Fallow, S = Sorghum, CP = Chickpea, PP = Pigeonpea, GG = Green gram, SF = Safflower, M = Maize, SN = Sunflower.
[1] Traditional cultivar, [2] Improved cultivar, [3] Figures in parentheses are log 10 (nematode number+0.5) transformed values.

DISCUSSION

Cereals were less-preferred hosts of plant-parasitic nematodes than legumes, and densities of these nematodes declined sharply in crop rotations, particularly in those that had pearl millet as a component crop. Rotations of pigeonpea with sorghum, pearl millet, rice, and maize have been suggested as a strategy to suppress the deletarious effects of *H. cajani*, and *R. reniformis* on pigeanpea yields (Sharma *et al.*, 1992). Our results support the use of sorghum and pearl millet for this purpose.

High temperatures and low moisture conditions during the summer fallow were found to be very effective in reducing nematode populations. Sharma and Nene (1990) also reported a 66-88% reduction in the densities of plant-parasitic nematodes from fields that were fallowed in the summer months from April to June. Soil moisture governs the movement, infectivity, development and reproduction of plant-parasitic nematodes. Sharp reductions in *R. reniformis* densities in the rainfed system could be due either to high mortality, or a transformation of eggs into an anhydrobiotic state under drought conditions. Drought can severily inhibit nematode egg hatching and indirectly affect nematode populations by adversely affecting root growth (Den Toom; 1988; Goodell and Ferris, 1989). In traditional cropping systems fallowing is the major factor resposible for suppressing population densities of plant-parasitic nematodes. Another factor associated with the low population densities of plant-parasitic nematodes in traditional cropping systems is the fertility level. Plots treated with FYM had lower populations of plant-parasitic nematodes than did plots treated with NPK. Similar results have been reported earlier (Oostenbrink, 1954; Laan, 1956).

Inorganic fertilizers, the use of high yielding varieties, supplemental irrigation, and growing crops in both rainy and postrainy seasons may be the principal reasons for the plant-parasitic nematode population increases in the newer cropping systems. Increased root biomass and the resultant increased availability of nematode feeding sites could be the major reasons why nematode densities were higher in the newer high-input systems than in the traditional systems.

These studies highlight the benefits of including pearl millet in cropping systems and of summer crop fallow in nematode management. They indicate that the productivity of newer production system technologies can be enhanced by the inclusion of a nematode-management component. The development of high yielding, nematode resistant or tolerant cultivars suitable for newer production system is advocated.

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