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Evaluation of pigeon pea varieties against root knot nematode and assessment of yield loss in field condition

Anukiran Sahu[1], D. K. Nayak[2], Sujit Kumar Behera[2], Avanish Kumar Singh[3*], Bansa Singh[4], Rupak Jena[5]

[1]Department of Entomology, Bihar Agricultural University, Sabour, Bhagalpur-813210, India
[2]Department of Nematology, OUAT, Bhubaneswar,751003, India
[3]Department of Horticulture (Vegetable Science), Bihar Agricultural University, Sabour, Bhagalpur-813210, India
[4]Indian Institute of Pulse Research, Kanpur, India
[5]Crop Protection division, National Rice Research Institute, Cuttack, India

ABSTRACT

Background: *Root-knot nematode, M. incognita is a sedentary endoparasite affecting the root system of plant. Infection of nematode cause immense loss of quality of crop and yield by restricting the free flow of nutrients. In this context studies were conducted at Department of Nematology, OUAT, Bhubaneswar.*

Methods: *The present investigation carried out during the kharif season of 2020-2022 to screen and evaluate against M. incognita along with assessment of yield loss in field condition using the paired plot technique.*

Results: *Out of 20 screened varieties, 14 were resistant, IPA-15-1 was moderately resistant, three were susceptible, and variety IPA-79 and CO-6 were highly susceptible. The highest shoot length and fresh weight were found in variety kathi kandula local with 87.1 cm and 24.39 g respectively, while decline in shoot length and fresh weight was greater in variety CO-6 with 72.0 cm and 15.75 g, respectively. Variety IPA-14-7 showed a decrease in root length measuring 28.22 cm. Under carbofuran treated condition, yield was significantly increased 46.89% and avoidable yield loss was 30.98%. Hence identified resistant varieties will serve as resistant gene donors for developing resistant cultivars of pigeon pea to increase the yield of the crop.*

Keywords: *Pigeon pea, Resistant, Root-knot nematode, M. incognita, Yield loss, Varietal evalaution*

INTRODUCTION

Pigeon pea, *Cajanus cajan* (L.) is a major food legume grown in tropical and subtropical region. It is widely farmed in 25 countries and grown on 7.03 million hectares, with a production of 4.89 million tons and an average yield of 695 kg/ha globally[1]. India leads the world in terms of pigeon pea output and area. About 92% of pigeon pea production is from India alone[2]. Pigeon peas are grown in India on 5.6 million ha, yielding 3.27 million tonnes [1]. But the yield as well as quality of the produce is not so promising due to various biotic stresses. Crop is highly vulnerable to different nematodes causing 13% yield loss globally[3]. Among nematodes, root-knot nematode infection causes characteristic galls on the roots of susceptible host plants and decrease the plant growth. Weak and low-yielding plants result from the damaged root structure's considerable reduction in nutrition and water intake[4]. Earlier reasearcher screened 30 genotypes of pigeon pea found that 19 were highly resistant, 2 were resistant and 3 were moderately resistant to the root-knot nematode[5]. Although earlier many genotypes had been screened against root knot nematode Therefore, the present experiment was conducted for identification of suitable resistant variety against the nematode to increase the yield of the crop.

Corresponding Author: **Avanish Kumar Singh*

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MATERIALS AND METHODS

Experimental site and Source of germplasm

The research was carried out in the net house of the Department of Nematology, Odisha university of agriculture and technology, Bhubaneswar during the kharif season during 2020-22. Seeds of Pigeon pea (*Cajanus cajan* L.) varieties were obtained from CPR, Berhampur, Indian Institute of Pulse Research (IIPR), Kanpur and various areas of Odisha to test their reactions against test nematode, *Meloidogyne incognita.*

Preparation of soil mixture and maintenance and culturing of nematode

The soil was mixed in a ratio of 2:1:1 with sand and FYM, which was packed in a gunny bag and autoclaved at 1.1 kg / cm^2 pressure for 1 hour for two days and 15 cm diameter earthen pots were surface sterilized in 1% formalin, leaving air dry. Then pots were filled with sterilized aerated soil. Pure culture of *M. incognita* was maintained in the greenhouse on the tomato susceptible cultivar Super Strain B for use as a source of egg-masses, free eggs and second stage juveniles. A single eggmass was used to establish a nematode population. The identification of species depended on second stage juvenile measurements and the perineal pattern method of adult females[6] [7]. Collection of juveniles was continued for 7 to 8 days and used subsequently for experimental purpose. Egg masses of equal size needed to study the effect of the tested oils on *M. incognita* egg hatching were hand-picked with fine forceps from small galls on the infected tomato roots obtained from previously maintained pure culture. The collected egg-masses were surface sterilized in 1:500 V/V aqueous solution of sodium hypochlorite for 5 min [8].

Screening of pigeon pea cultivars against root-knot nematode, *Meloidogyne incognita*

Twenty varieties of pigeon pea procured were used for testing and scoring against test nematode, *M. incognita* for resistance/ susceptibility. Pots were arranged in the net house in Complete Randomized Design with three replications. Seeds were sown and sprinkled with water passed through 500 mesh sieve. Thinning was done at 3-4 leaves stage of the seedlings (15 days after sowing), leaving a single healthy seedling in each pot. Root-knot nematodes were released @ 1000 J_2/ pot into the root zone of the plant 15 days after sowing. Forty-five days after inoculation each plant was removed from the potting soil carefully and Roots were washed by a gentle stream of water and the numbers of galls produced on each plant's roots were counted. Pigeon pea varieties were categorized as per the Root-knot Index Scale given below [9].

Table 1. Root-knot Index 1-5 Scale (Taylor and Sasser, 1978)

Gall index	Observations	Reactions
1	No egg mass/galls/plant	Highly Resistant (HR)
2	1-10 egg masses/galls/plant	Resistant(R)
3	11-30 egg mass/galls/plant	Moderately Resistant (MR)
4	31-100 egg mass/galls/plant	Susceptible(S)
5	> 100 egg masses/galls/plant	Highly Susceptible (HS)

Avoidable yield loss calculation

An experiment was conducted in the sick plot, which was split into two portions, untreated and treated, each with ten subplots of 3 m x 2 m each, replication. In the treated condition, before sowing pigeon pea seeds, gentle watering and carbofuran (Furadon 3G) @ 2 kg a.i/ha was applied to the plot. The crop was raised following all agronomic guidelines. The observations on the yield parameters were made in both the treated and untreated plots 130 days after the experiment started.

Statistical Analysis

S.E (m)± for treatment = √EMS/R

CD at 0.05= √2× S.E (m) × t (0.05) at error d.f.

where, d.f.= degree of freedom

r= replication

EMS= Error means sum of square

S.E(m)± = Standard error mean

CD (0.05) = Critical difference at 5% level

From first set of paired plots Table-4, the values in the columns are determined as follows:

• t value= Mean difference in yield
Standard error of mean

Standard error of mean SE(m) = SD/√n

where n= no. of paired plots

SD = Standard deviation $(\sqrt{\Sigma d^2/n-1}$

• Percent avoidable losses =

Yield in treated plots(X_1) -Yield in untreated plots (X_2) x100
Yield in treated plots(X_1)

• Per cent increase in yield =

Yield in treated plots(X_1) - Yield in untreated plots(X_2) x 100
Yield in untreated plots (X_2)

RESULTS AND DISCUSSION

Screening and evaluation of pigeon pea varieties against Root knot nematode, *M. incognita:*

Root knot nematode infection was recorded at 45 days after inoculation with nematode using root knot index scale 1-5(Taylor and Sasser, 1978) and results are shown in Table 2 and 3. Out of the 20 screened pigeon pea varieties, 14 were found to be resistant (R), with the lowest no. of galls (3 galls per plant), while one variety, IPA-15-1, was found to be moderately resistant (MR), with 16 no. of galls per plant, three varieties were found to be susceptible (S), with the 42–83 galls per plant, and two varieties, IPA-79 and CO-6, were found to be highly susceptible (S). The findings of the study are in line with previous studies with pigeon pea [10] [11] [12]. Another researcher also evaluated different pigeon pea genotypes against *M. javanica* found that five genotypes viz., DPPA 85-12, DPPA 85-8, DPPA 85-1, DPPA 85-13 and IPA 15-1 showing moderately resistant reaction of the total 24 genotypes examined[13]. High root gall index (4 to 5) for two pigeon pea varieties rendered them as good host of *M. incognita* whereas the lowest root gall index (2) was found in the resistant pigeon pea varieties of UPAS-120 and IPA-15-1.) The nematode resistant plants are characterized by failure of the nematodes to produce functional feeding sites in the host after invasion and to develop hypersensitive responses by[14].

It is interesting to see that the shoot and root growth parameters decreased as root knot nematode susceptibility increased. Furthermore, it was discovered that the plant's growth parameters were less hampered in resistant variety. The highest average shoot length and fresh shoot weight were found in pigeon pea local variety kathi kandula local with 87.1 cm and 24.39 g respectively. The maximum average shoot length and fresh weight were 82.4 cm and 22.69 g, respectively, found in early variety UPAS-120, while the decline in shoot length and fresh weight was more severe in highly susceptible variety CO-6 with 72.0 cm and 15.75 g respectively. The moderately resistant variety ICPL-151 had the highest dry shoot weight (9.88 g), whereas the susceptible variety IPA-14-7 had the lowest dry shoot weight (7.71 g). Fresh shoot weight and length of susceptible varieties were found to be negatively impacted by the root knot nematode *M. incognita*. Nematode infection also affects the root growth parameters severely. The maximum average root length of the pigeon pea in variety UPAS-120 was 36.38 cm. Variety IPA-14-7 showed decrease in root length that was more pronounced than that of other susceptible cultivars, measuring 28.22 cm. The maximum fresh root weight and dry root weight for all susceptible and resistant varieties, respectively, were 3.87 g and 1.82 g for kathi kandula local, 2.15 g and 0.99 g for var. CO-6. The result of different growth parameters showed that nematode infection negatively affects growth parameters, which was expected because the nematode draws the nutrients by forming the giant cell and blocking the free flow of nutrients through xylem tissue. Similar findings have also been noted by [15] an initial inoculum level of 100 juveniles of *M. incognita* per plant caused a significant reduction in growth characters of pulse. Earlier research in brinjal [16] found that root-knot nematode causes damage to varieties by decreasing plant growth parameters over uninoculated healthy plant varieties. Shoot length was significantly reduced in infected plants, as was shoot fresh weight, but root fresh weight showed a significant increase in mung bean due to infection by *M. javanica* [17]. The final nematode population in both soil and root was also varied among different varieties. Maximum population of nematode found in highly susceptible varieties like CO-6 (1974), IPA-79 (1875), susceptible varieties such as IPA-14-7 (1581), IPA-15-2 (1476) and DPPA-85-16 (1498) and least population in resistant varieties UPAS-120 (698) and Kathi kandula Local (712).

This occurrence of variation in susceptibility among twenty pigeon pea variety to *M. incognita* might be due to genetic differences which are similar to the result reported by[18] also reported that different varieties of Pigeon pea (*Cajanus cajan*) showed varied reactions to *M. incognita* and *Rotylenchulus reniformis* in plant weight, number of pods per plant, chlorophyll content of leaves and bulk density of stem parts. They also observed that it was directly correlated with the multiplication of the nematodes, highest being in susceptible varieties with minimal or no change in resistant varieties.

Table 2. Screening of pigeon pea varieties against root-knot nematode, Meloidogyne incognita

Sl. No.	Varieties	No. of galls	Root-knot index	Reaction
1	UPAS -120	4	2	R
2	BDN-1	5	2	R
3	ICPL-87	7	2	R
4	BDN-2	8	2	R
5	GC-11-39	5	2	R
6	WRP-1	5	2	R
7	MANAK	6	2	R
8	ICPL-11298	7	2	R
9	PUSA-991	9	2	R
10	ICPL-151	8	2	R
11	CO-6	106	5	HS
12	DPPA-85-16	42	4	S
13	IPA-15-1	16	3	MR
14	RAJIBLOCHAN	6	2	R
15	KATHI KANDULA LOCAL	3	2	R
16	NAYAGADA LOCAL	7	2	R
17	IPA-15-2	67	4	S
18	IPA 14-7	83	4	S
19	IPA -79	103	5	HS
20	IPA- 9	6	2	R
	CD (0.05)	4.05		
	SE(m) ±	1.94		

Table 3. Evaluation of pigeon pea varieties against root-knot nematode, Meloidogyne incognita

Sl. No.	Varieties	Shoot length (cm)	Fresh shoot wt. (g)	Dry shoot wt. (g)	Root length (cm)	Fresh root wt. (g)	Dry root wt. (g)	Final Nematode population (Soil and Root)
1	UPAS -120	82.4	22.69	8.66	36.38	3.71	1.38	698 (2.84)*
2	BDN-1	79.1	21.21	9.73	36.12	2.77	1.44	753(2.87)*
3	ICPL-87	77.2	20.34	8.60	32.10	3.21	1.45	918(2.96)*
4	BDN-2	74.4	20.24	8.07	36.56	3.63	1.67	1025(3.01)*
5	GC-11-39	76.5	19.80	9.09	35.31	3.07	1.28	886(2.94)*
6	WRP-1	75.6	18.90	8.05	33.42	2.61	1.08	798(2.89)*
7	MANAK	76.2	18.06	8.28	31.39	2.40	1.03	834(2.92)*
8	ICPL-11298	78.3	18.69	8.17	33.48	2.89	1.32	976(2.98)*
9	PUSA-991	74.4	18.41	8.62	35.39	3.68	1.77	1208(3.08)*
10	ICPL-151	75.2	17.78	9.88	32.20	3.22	1.44	1177(3.07)*
11	CO-6	72.0	15.75	8.83	29.32	2.15	0.99	1974(3.29)*
12	DPPA-85-16	73.1	16.51	8.39	30.25	2.26	1.62	1498(3.17)*
13	IPA-15-1	77.9	17.57	8.28	35.25	3.17	1.41	1348(3.12)*
14	RAJIBLOCHAN	84.5	21.32	8.13	34.41	3.65	1.70	876 (2.94)*
15	KATHI KANDULA LOCAL	87.1	24.39	8.32	36.41	3.87	1.82	712 (2.85)*
16	NAYAGADA LOCAL	86.2	19.05	8.94	31.01	2.50	1.27	943 (2.97)*
17	IPA-15-2	74.6	17.24	8.90	31.47	3.48	1.69	1476(3.16)*
18	IPA 14-7	74.4	17.03	7.71	28.22	2.61	1.10	1581(3.19)*
19	IPA- 79	72.9	16.83	7.90	29.02	2.39	0.99	1875(3.27)*
20	IPA -9	79.7	17.08	7.80	35.12	2.64	1.14	865 (2.93)*
	SE(m) ±	**3.91**	**0.21**	**0.18**	**1.92**	**0.10**	**0.08**	0.01
	CD (0.05)	**8.15**	**0.43**	**0.37**	**4.01**	**0.20**	**0.16**	0.02

** Figures in parentheses are log transformed value*

Assessment of avoidable yield loss

The study on assessment of yield losses due to *M. incognita* on susceptible pigeon pea genotype revealed that the application of carbofuran 3G @ 2 kg a.i. ha^{-1} significantly increased the yield of the crop by 46.89 % with significant reduction in *M. incognita* population (Table -4) during 2021 and 2022. It was found that an infestation of root-knot nematodes on the crop inflicted an avoidable yield loss of 30.98 per cent (Table- 4). According to statistical analysis of the data, performance of the susceptible variety treated with Carbofuran 3G at 2 kg a.i. ha^{-1} was considerably better for two years than the untreated control. This result is similar line with [19] marked the application of chemical treatment significantly reduced the number of galls, egg masses, eggs & juveniles per egg mass and final nematode population by 79.03, 81.10, 30.91 and 56.54%, respectively and avoidable yield losses were recorded to the tune of 66.84% on cucumber by *M. incognita* in poly-house. Similar study by [20] revealed that preventable yield losses due to root-knot nematode in ridge gourd were up to 74.52 percent under field conditions. Another reasearcher [21] also founded that in treated condition, cowpea yield was significantly increased ranging from 10.93 to 14.58% with 37.19 to 38.17% reduction of nematode population. The range of avoidable yield loss was 9.85 to 12.72%. The root-knot nematode infection caused stunting in genotype were likely to blame for the declining yield that had not been treated. Compared to the untreated plants, the treated plants began vigorous vegetative development. Nematicide carbofuran affects the oviposition of nematode which restrict nematode entry into the root. This may indicate that carbofuran directly affects nematodes in the soil, affecting egg hatching and larval migration into the root and increase in plant growth.

Table 4. Effect of nematicide treatment on yield performance of pigeon pea (var. CO-6) under sick plot condition of M. incognita (Average of two years data)

Paired plots no.	Yield/plot (g)		Difference	D	d^2	t-value	Avoidable yield loss (%)	Increase in yield (%)
	Treated (X_1)	Untreated (X_2)	X_1-X_2					
1	32.5	23.5	9	0.74	0.55	84.07	27.69	38.3
2	27	20.5	6.5	-1.76	3.10	60.71	24.07	31.7
3	24.6	15.5	9.1	0.84	0.71	85.00	36.99	58.7
4	22.5	13	9.5	1.24	1.54	88.74	42.22	73.1
5	30.5	22.5	8	-0.26	0.07	74.72	26.23	35.6
6	25	17.5	7.5	-0.76	0.58	70.05	30.00	42.9
7	21.5	13.5	8	-0.26	0.07	74.72	37.21	59.3
8	29.5	20.5	9	0.74	0.55	84.07	30.51	43.9
9	26	19	7	-1.26	1.59	65.38	26.92	36.8
10	27.5	18.5	9	0.74	0.55	84.07	32.73	48.6
SUM	**266.6**	**184**	**82.6**				314.57	468.9
AVERAGE	**26.66**	**18.4**	**8.26**				**30.98**	**46.89**

Fig. 1 Yield loss trial of pigeon pea var. CO-6 in kharif -2021

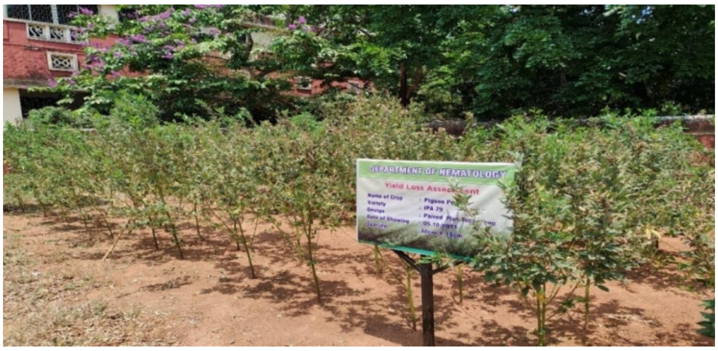

Fig. 2 Yield loss trial of pigeon pea var. CO-6 in kharif -2022

CONCLUSION

The study found significant variations within pigeon pea cultivars in terms of *M. incognita* reproduction, growth, and resistance response. Resistant and moderately resistant cultivars displayed slower and lower nematode proliferation than susceptible cultivars. The moderately resistant cultivars were less susceptible to nematode damage, making them good checks for breeding operations focused at creating nematode-resistant cultivars. Using of moderately resistant cultivars in fields infected with root-knot nematodes can limit nematode reproduction, minimize environmental contamination, preserve biodiversity, and improve management efficiency and cost-effectiveness. The findings of this study gave the idea about avoidable yield loss in susceptible varieties by application of carbofuran which control the nematode population. Application of carbofuran in the susceptible check, the yield of treated plot increased as compared to untreated plot by intrupting the nematode reproduction and hatching so ultimately the yield in the treated plot was increased as compared to the untreated plot.

FUTURE SCOPE

Root-knot nematode is a sedentary endoparasite and resistance can be affected within the soil to the root environment. The information generated from this investigation can be manipulated through advanced biotechnological research for suitable management strategies. The findings of this study gave the clear idea about avoidable yield loss in susceptible variety and that is important implications for future research who wish to increase agricultural yields by utilising genotypes of pigeon pea that are resistant to nematodes.

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CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

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