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RESEARCH ARTICLE

Mining of resistance source for root-knot nematode (*Meloidogyne incognita*) in bitter gourd

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Abstract

Bitter gourd (*Momordica charantia* L.) is nutritionally and medicinally rich cucurbit crop and widely cultivated during summer and *kharif* season in India but suffer a lot with several biotic and abiotic stresses. Among biotic stresses, root-knot nematodes are one of the most damaging pests which cause 13.5% yield loss amounting to 252.82 million rupees annually. Use of resistant sources and development of new cultivars, is an eco-friendly approach to combat nematode incidence in this crop. In this endeavour, morphologically distinct twenty genotypes of *M. charantia* was screened against root-knot nematode (*Meloidogyne incognita*) by challenged inoculation of 2000 J_2/kg of soil under screen house condition. The results revealed that, among twenty genotypes, two genotypes IC-44438 and IC-44428 were found resistant, three genotypes IC-212504, VRBTG-10 and VRBTG11-1 were moderately resistance and remaining were noted to be susceptible to *M. incognita*. The promising bitter gourd genotypes were again reconfirmed for their resistance against *M. incognita* by comparing with a susceptible check 'Kalyanpur Baramasi'. Hence, the identified resistant genotypes i.e. IC-44438 and IC-44428 from the present study can serve as useful genetic material to plant breeders for developing root-knot nematode resistant bitter gourd varieties or hybrids to combat root knot nematode incidence in prone areas.

Keywords: Bitter gourd, genotypes, *Meloidogyne incognita*, root gall index, screening, resistance.

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Introduction

Bitter gourd (*Momordica charantia* L.) is an important cucurbitaceous vegetable crop known for its nutritional, medicinal, antidiabetic and other curative properties. Fruits that have a unique bitter taste (due to momordicine compounds) are considered a rich source of vitamins, minerals and antioxidant compounds. However, this crop is highly prone to root-knot nematodes (RKNs), which cause a 13.5% yield loss, amounting to 252.82 million rupees annually (Kumar et al., 2020). Among economically important root-knot nematode species, *Meloidogyne incognita* is a widely spread and destructive nematode species that causes severe yield loss and shows high pathogenic potential on bitter gourd (Anwar & McKenry, 2010; Singh et al., 2012). Traditionally, nematicides represented the most effective method of managing nematode infestation. However, these chemicals were banned/ withdrawn from the market due to their high cost, toxicity, and health and environmental issues (Sorribas et al., 2005; Collange et al., 2011). In addition, organic vegetable production discourages the use of nematicides and inspires researchers to develop alternative strategies to combat this potential nematode pest. From this perspective, breeding for nematode-resistant cultivars seems to be the only effective, inexpensive and environmentally safe alternative for combatting root-knot nematodes in bitter gourd. Behera et al. (2004) revealed that different species of bitter gourd, *viz. Momordica charantia, M. denudate, M. subangulata,* and *M. dioica*, represent huge sources of resistance against several pathogens. Therefore, identifying host resistance against this pest in the genotypes of established cultivars or in related wild species is a prerequisite for edifice breeding programs. Thus, in the present study, phenotypic screening of bitter gourd genotypes was undertaken by challenged inoculation with *M. incognita* under screen house conditions to identify nematode resistance sources.

Materials and Methods

Bitter gourd genotypes

Twenty bitter gourd genotypes belonging to the species *Momordica charantia* (VRBTG-5 to VRBTG-25) along with the highly susceptible check 'Kalyanpur Baramasi' were obtained from the germplasm collections of ICAR-IIVR, Varanasi (U.P.). The selected genotypes were used for phenotypic screening for root-knot nematode (*Meloidogyne incognita*) resistance under screen house conditions.

Nematode inoculum

A pureculture of *M. incognita* was maintained on susceptible tomato plants under pot conditions at the nematology screen house of the ICAR-Indian Institute of Vegetable Research, Varanasi (U.P.).With the help of forceps, egg masses were picked from heavily infected tomato roots and placed on tissue paper. The selected egg masses were maintained on wire mesh and placed on a Petri plate containing distilled water (Persson, 1974). Then, in intervals of 24 h, juveniles were extracted from the Petri plate and concentrated in a beaker. The fresh second-stage infective juveniles (J_2) were counted under a stereomicroscope with the help of a counting dish and used for inoculation.

Screening of bitter gourd genotypes for Meloidogyne incognita resistance

Twenty genotypes of *M. charantia* were sown in pots containing 1.0 kg of sterilized silt loam soil and sand in a 3:1 ratio. At 15 days after sowing, each bitter gourd plant (one plant per pot) received 2000 second-stage infective juveniles (J_2) around the plant rhizosphere. There were three replicates for each bitter gourd genotype in a completely randomized design, and plants were maintained for 90 days with good agronomic practices. After 90 days, bitter gourd plants were uprooted and gently washed under tap water to remove the adhering soil. Roots were dried using butter paper. After that, observations of nematode disease parameters were recorded, such as the number of egg masses per root system,the number of root galls per plant, which was counted with the help of a magnifying lens, and the final nematode population in the soil (100 cc), which was calculated using Cobb's sieving and decanting method (Cobb, 1918). Root knot indices were determined with the Gall Index Scale (1-5) provided by Gaur et al.(2001), where 1 = 0 galls (Highly Resistant), 2.0 = 1-10 galls (Resistant), 3.0 = 11-30 galls (Moderately Resistant), 4.0 = 31-100 galls (Susceptible), and 5.0 = more than 100 galls (Highly Susceptible). The reaction of bitter gourd genotypes against *M. incognita* was categorized based on the mean number of root galls per root system (Gall Index Scale),which indicates the marking of susceptibility and resistance against root knot nematodes. In addition, these genotypes were also evaluated for yield and other horticultural traits during the same period under field conditions. Promising bitter gourd genotypes obtained from a previous study were again reconfirmed for their resistance against *M. incognita* by comparison with the highly susceptible check 'Kalyanpur Baramasi' by following the above mentioned protocol during 2018.

Statistical analysis

Prior to analysis, square root transformation was used to normalize the data for the number of egg masses per root system, number of root galls per plant and final nematode population in the soil. Analysis of variance was performed for the number of egg masses per root system, number of root galls per plant, final nematode population in soil and root gall indexusing the software Statistical Tool for Agricultural Research (STAR) version 2.0.1 2014 (Biometrics and Breeding Informatics, PBGB Division, International Rice Research Institute, Los Banos, Laguna). When the ANOVA results were significant ($P < 0.05$), comparisons of relevant means were performed using Tukey's honest significant difference (HSD) test at the 5% level of significance.

Results and Discussion

Bitter gourd is highly prone to root-knot nematodes in Indian conditions. However, to date there is only scanty information on resistant genotype(s)/ varieties are available against root-knot nematodes in public domain for its effective management (Montalvo & Esnard, 1994; Hallman et al., 2018). Improving a crop resistance against plant parasitic nematodes through breeding programme is an environmentally safe approach to for their management and also to minimize the crop losses. In this endeavour, the phenotypic screening of bitter gourd genotypes

Figure 1: Resistance reaction in bitter gourd genotypes A. IC-44428 and C. IC-44438 against *Meloidogyne incognita* compared with highly susceptible check B. VRBTG-27.

against *M. incognita*in the present study revealed that the two genotypes *viz.* IC-44428 and IC-44438 were found to resistant against *M. incognita,* with a mean egg mass of 1.3 and 2.0 per root system, final nematode population of 214 J_2 and 226 J_2 per 100 cc soil and root gall number of 4.7 and 4.3 per root system, and the lowest gall indices of 2.0 and 2.0, respectively (Table 1; Figure 1). However, three genotypes,*viz.,* VRBTG-10, IC-212504 and VRBTG-11-1, showed

Table 1: Reaction of bitter gourd genotypes to *Meloidogyneincognita* under challenged inoculation in pot conditions

S. No.	*Genotypes*	*Number of galls per root system*	*Root gall index (1-5 scale)*	*Egg mass per root system*	*Final nematode population in soil*	*Resistant reaction*
1.	VRBTG-5-1	31.3 ± 1.18^{ghi}	3.67^{cd}	23 ± 2.6^{cdef}	417 ± 16.0^{fgh}	S
2.	VRBTG-11-1	23.0 ± 1.7^{hi}	3.0^{de}	12.6 ± 1.4^{def}	354.6 ± 13.8^{ghij}	MR
3.	VRBTG-47-2	74.0 ± 4.03^{f}	4.0^{bc}	45 ± 6.3^{c}	491.3 ± 14.7^{defg}	S
4.	VRBTG 29-1	45.7 ± 3.07^{g}	4.0^{bc}	27.3 ± 1.9^{cdef}	438 ± 21.5^{efgh}	S
5.	IC-44428	04.7 ± 1.78^{j}	2.0^{f}	1.3 ± 1.0^{f}	214.3 ± 11.0^{j}	R
6.	BBGS-09-1	37.0 ± 1.42^{gh}	4.0^{bc}	15 ± 1.69^{cdef}	378.7 ± 23.4^{fghi}	S
7.	IC-44438	04.3 ± 0.98^{j}	2.0^{f}	2 ± 0.47^{f}	226.3 ± 12.1^{j}	R
8.	VRBTG-43	43.0 ± 4.33^{gh}	4.0^{bc}	19.3 ± 0.7^{cdef}	406.3 ± 19.7^{fgh}	S
9.	IC-212504	23.7 ± 1.79^{hi}	3.0^{de}	9.6 ± 1.0^{ef}	297.7 ± 20.0^{hij}	MR
10.	VRBTG-10	12.0 ± 1.42^{ij}	2.67^{ef}	3.3 ± 0.3^{f}	229.3 ± 10.8^{ij}	MR
11.	VRBTG-15	32.7 ± 3.14^{ghi}	4.0^{bc}	12.3 ± 1.8^{def}	386.7 ± 16.1^{fghi}	S
12.	VRBTG-1-1	33.3 ± 1.97^{ghi}	3.67^{cd}	20.3 ± 1.9^{cdef}	437.7 ± 24.7^{efgh}	S
13.	VRBTG-23-1	125.7 ± 3.78^{ed}	5.0^{a}	78.3 ± 4.38^{b}	658.7 ± 28.0^{abc}	HS
14.	VRBG-37-1	207.3 ± 4.06^{b}	5.0^{a}	105 ± 11.4^{ab}	738 ± 37.3^{a}	HS
15.	VRBTG- 5	181.3 ± 5.67^{c}	5.0^{a}	81.3 ± 5.7^{b}	590.7 ± 12.1^{bcd}	HS
16.	VRBTG-12	104.0 ± 4.79^{e}	4.67^{ab}	41.6 ± 4.5^{cd}	494 ± 21.1^{defg}	HS
17.	VRBTG-4	205.0 ± 4.72^{b}	5.0^{a}	107.6 ± 6.4^{ab}	725.7 ± 13.9^{ab}	HS
18.	VRBTG-27	270.7 ± 3.54^{a}	5.0^{a}	119.6 ± 7.1^{a}	745 ± 50.7^{a}	HS
19.	VRBTG-47-1	110.0 ± 4.71^{e}	4.67^{ab}	36.7 ± 5.4^{cde}	513.7 ± 11.2^{def}	HS
20.	Kalyanpur Baramasi	142.0 ± 4.33^{d}	5.0^{a}	44.7 ± 5.6^{c}	575.3 ± 14.7^{ede}	HS
	df	19, 40	19, 40	19, 40	19, 40	
	F value	257.47	35.75	60.01	42.57	
	P Value	<0.0001	<0.0001	<0.0001	<0.0001	

Data represented in Mean ± SE. Means with different letters indicate significant differences between bitter gourd genotypes at *P*<0.05 using Tukey's HSD test. R: Resistant, MR: Moderately resistant, S: Susceptible, HS: Highly Susceptible.

Table 2: Reconfirmation of promising bitter gourd genotypes with *Meloidogyne incognita* resistance

S. No.	*Genotype*	*Number of galls per root system*	*Root gall index (1-5 scale)*	*Egg mass per root system*	*Final nematode population in soil*	*Resistant reaction*
1.	IC-44428	03.3 ± 0.55^{c}	2.0^{c}	1.0 ± 0.5^{d}	212.7 ± 9.2^{c}	R
2.	IC-44438	05.7 ± 0.73^{c}	2.0^{c}	1.3 ± 0.3^{d}	227 ± 11.3^{c}	R
3.	IC-212504	16.0 ± 2.16^{bc}	3.0^{b}	11.3 ± 1.2^{c}	316.0 ± 7.5^{b}	MR
4.	VRBTG-10	13.3 ± 1.66^{bc}	3.0^{b}	9.0 ± 0.9^{cd}	287.7 ± 4.5^{b}	MR
5.	VRBTG-11-1	21.7 ± 4.46^{b}	3.0^{b}	14.7 ± 2.0^{c}	330.3 ± 7.6^{b}	MR
6.	VRBTG-47-1	103.7 ± 3.82^{a}	4.67^{a}	59.7 ± 2.6^{b}	521.3 ± 13.7^{a}	HS
7.	Kalyanpur Baramasi	107.0 ± 3.86^{a}	4.67^{a}	77.3 ± 2.6^{a}	572.7 ± 11.9^{a}	HS
	df	6, 14	6, 14	6, 14	6, 14	
	F value	119.80	38.33	143.56	119.72	
	P Value	<0.0001	<0.0001	<0.0001	<0.0001	

Data represented in Mean ± SE. Means with different letters indicate significant differences between bitter gourd genotypes at *P*<0.05 using Tukey's HSD test. R: Resistant, MR: Moderately resistant, S: Susceptible, HS: Highly Susceptible.

Table 3: Morphological traits of the bitter gourd genotype

S. No.	*Genotype*	*50% Flowering (days)*	*1st Harvest (days)*	*Fruit color*	*Fruit tubercles (present/ absent)*	*Fruit length (cm)*	*Fruit circum. (cm)*	*Number of fruits per plant*	*Fruit Wt. (g)*	*Yield per plant (kg)*
1.	VRBTG-5-1	32 ± 2.35^{a}	45 ± 1.41^{a}	LG	Present	18.57 ± 0.94^{bc}	8.5 ± 0.94^{a}	34.33 ± 0.94^{c}	45.00 ± 2.35^{fg}	1.45 ± 0.04^{efg}
2.	VRBTG-11-1	35 ± 1.89^{a}	52 ± 2.82^{a}	DG	Present	12.9 ± 1.89^{c}	11.17 ± 1.89^{a}	33.00 ± 1.89^{c}	56.67 ± 1.89^{ef}	1.77 ± 0.04^{def}
3.	VRBTG-47-2	33 ± 1.41^{a}	47 ± 2.82^{a}	DG	Present	16.67 ± 1.34^{bc}	13.47 ± 1.41^{a}	34.16 ± 1.41^{c}	81.67 ± 1.41^{b}	2.57 ± 0.09^{bcd}
4.	VRBTG 29-1	35 ± 2.35^{a}	49 ± 2.35^{a}	DG	Present	18.77 ± 0.90^{bc}	14.67 ± 0.47^{a}	11.67 ± 0.94^{h}	86.67 ± 2.82^{b}	1.01 ± 0.18^{fgh}
5.	IC-44428	39 ± 1.89^{a}	50 ± 1.89^{a}	DG	Present	14.67 ± 1.89^{c}	12.09 ± 0.47^{a}	18.67 ± 1.89^{efgh}	73.33 ± 2.82^{bcd}	1.32 ± 0.14^{efgh}
6.	BBGS-09-1	41 ± 1.41^{a}	55 ± 2.35^{a}	LG	Present	10.33 ± 1.41^{c}	12.67 ± 0.94^{a}	32.25 ± 1.41^{c}	60.00 ± 1.41^{de}	1.83 ± 0.09^{cde}
7.	IC-44438	39 ± 2.82^{a}	51 ± 1.89^{a}	DG	Present	15.33 ± 0.47^{bc}	12.33 ± 1.88^{a}	20.67 ± 0.47^{efg}	65.00 ± 2.35^{cde}	1.25 ± 0.04^{efgh}
8.	VRBTG-43	41 ± 2.82^{a}	55 ± 1.41^{a}	DG	Present	12.57 ± 0.47^{c}	10.47 ± 1.88^{a}	12.66 ± 0.47^{gh}	55.00 ± 1.88^{ef}	0.70 ± 0.04^{gh}
9.	IC-212504	36 ± 2.35^{a}	49 ± 2.35^{a}	LG	Present	12.60 ± 0.94^{c}	13.83 ± 1.41^{a}	14.67 ± 0.94^{efgh}	83.33 ± 1.41^{b}	1.22 ± 0.18^{efgh}
10.	VRBTG-10	32 ± 1.88^{a}	46 ± 1.88^{a}	DG	Absent	29.53 ± 1.89^{a}	9.7 ± 0.94^{a}	37.33 ± 1.89^{c}	105.0 ± 2.82^{a}	3.91 ± 0.14^{a}
11.	VRBTG-15	35 ± 1.41^{a}	51 ± 1.41^{a}	LG	Present	11.46 ± 1.89^{c}	10.77 ± 1.89^{a}	22.33 ± 0.94^{de}	36.67 ± 2.82^{gh}	0.80 ± 0.09^{gh}
12.	VRBTG-1-1	39 ± 2.82^{a}	55 ± 2.82^{a}	LG	Absent	14.67 ± 1.41^{c}	13.57 ± 1.41^{a}	13.30 ± 1.89^{fgh}	75.00 ± 2.35^{bc}	1.05 ± 0.09^{efgh}
13.	VRBTG-23-1	41 ± 2.82^{a}	55 ± 2.82^{a}	W	Present	10.57 ± 0.94^{c}	10.67 ± 0.47^{a}	17.33 ± 1.41^{efgh}	56.67 ± 2.35^{ef}	1.13 ± 0.18^{efgh}
14.	VRBG-37-1	41 ± 2.35^{a}	57 ± 2.35^{a}	W	Present	17.67 ± 1.97^{bc}	17.03 ± 0.47^{a}	13.33 ± 0.47^{fgh}	101.7 ± 1.88^{a}	1.36 ± 0.14^{efgh}
15.	VRBTG- 5	33 ± 1.89^{a}	45 ± 1.88^{a}	LG	Present	23.97 ± 1.25^{ab}	11.30 ± 0.94^{a}	37.00 ± 0.47^{c}	83.33 ± 1.41^{b}	3.08 ± 0.09^{b}
16.	VRBTG-12	38 ± 2.35^{a}	48 ± 1.41^{a}	DG	Present	10.66 ± 0.94^{c}	11.67 ± 1.41^{a}	30.00 ± 0.94^{cd}	20.33 ± 2.35^{i}	0.61 ± 0.04^{h}
17.	VRBTG-4	39 ± 1.89^{a}	49 ± 2.35^{a}	DG	Absent	12.13 ± 1.89^{c}	11.23 ± 0.47^{a}	21.33 ± 1.89^{ef}	51.67 ± 1.89^{ef}	1.10 ± 0.04^{efgh}
18.	VRBTG-27	40 ± 1.41^{a}	51 ± 1.89^{a}	LG	Absent	13.33 ± 1.41^{c}	12.50 ± 0.47^{a}	13.60 ± 1.41^{fgh}	60.00 ± 1.41^{de}	0.58 ± 0.09^{h}
19.	VRBTG-47-1	34 ± 2.35^{a}	47 ± 1.41^{a}	DG	Present	15.63 ± 0.47^{bc}	13.43 ± 0.94^{a}	80.00 ± 0.47^{b}	32.33 ± 2.82^{ghi}	2.58 ± 0.18b^{c}
20.	Kalyanpur Baramasi	37 ± 1.89^{a}	48 ± 2.82^{a}	LG	Absent	28.67 ± 0.47^{a}	12.33 ± 1.89^{a}	95.67 ± 0.47^{a}	23.67 ± 2.82^{hi}	2.26 ± 0.14^{cd}
	df	19, 38	19, 38			19, 38	19, 38	19, 38	19, 38	19, 38
	F value	1.39	1.77			8.53	1.38	100.31	65.66	26.35
	P<0.0001	0.18	0.06			<0.0001	0.19	<0.0001	<0.0001	<0.0001

*LG-Light green; DG-Dark green; W-White. Data represented in Mean ± SE. Means with different letters indicate significant differences between bitter gourd genotypes at *P*<0.05 using Tukey's HSD test.

moderate resistance to *M. incognita* by producing a mean egg mass number per root system of 3.3, 9.6 and 12.6, mean root gall number per root system of 12.0, 23.7 and 23.0, mean final J_2 population per 100 cc soil of 229.3, 297.7 and 354.6, and mean root gall indices of 2.67, 3.0 and 3.0, respectively. The remaining genotypes and susceptible check 'Kalyanpur Baramasi' were susceptible to highly susceptible to *M. incognita* (Table 1), with gall indices ranging from 3.67 to 5.0 and final nematode populations ranging from 406 to 745 J_2/100 cc soil.

Further, a pot experiment was again conducted to reconfirm the resistance of promising bitter gourd genotypes against *M. incognita* under screen house condition during 2018 reveals that, two resistant genotypes i.e., IC-44428 and IC-44438 showed resistant reaction by reducing number egg mass per root system (1.0, 1.3), final nematode population in soil (212.7 and 227/ 100 cc soil) with lowest root gall index (2.0, 2.0) respectively, compared to highly susceptible checks 'Kalyanpur Baramasi' and VRBTG-47-1 (Table 2) which confirms the previous screen house pot study results. While, three genotypes such as VRBTG-10, IC-212504, and VRBTG-11-1 were also confirmed the previous screen house study results by recording moderately resistance reaction against *M. incognita* (Table 2.) Analysis of variance (ANOVA) showed a significant difference (*P* <0.05) between resistant bitter gourd genotypes and susceptible checks which are evaluated against *M. incognita* under screen house conditions with respect to production of number of root galls per root system, number of egg mass per root system and final nematode population in soil (Table 1; Table 2). Similar to our study, Joseph (2005) was reported a source of nematode resistance from different *Momordica* species viz., *M. dioica* and *M. sahyadrica* against *M. incognita*. Chandra et al. (2010) reported moderate resistance in *M. charantia* lines against root-knot nematode. Tamil Selvi et al. (2013) reported moderate level of resistance in *mithipakal (M. charantia* var. *muricata*) genotype against root-knot nematode. Similarly, a source of root knot nematode resistance was identified from Jhaarkarela (*M. balsamina*) lines (Kaur & Pathak, 2011; Pofu & Mashela, 2013; Sharma et al., 2019). Besides, the following morphological characteristics of bitter gourd genotypes were assessed under field conditions: fruit color, 50% flowering (days), fruit tubercles (present/absent), fruit length (cm), fruit circumference (cm), number of fruits/plants, fruit wt. (g) and yield/plant (kg) (Table 3).

Conclusion

Generally, the development of nematode resistant variety/ hybrids requires a source of nematode resistance from the genotypes of established cultivars or in related wild species genotypes. In fact, screening of popular lines of bitter gourd is important to realise the resistance potential in the present scenario. Thus, the identified resistant genotypes of *M. charantia* i.e. IC-44438 and IC-44428 from the present study can serve as useful genetic material to plant breeders for developing root-knot nematode resistant bitter gourd varieties or hybrids to combat *M. incognita* menace in prone areas.

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सारांश

करेला में पोशकीय एवं औषधीय गुण सबसे ज्यादा पाया जाता है और भारतवर्ष में इसकी खेती विस्तृत स्तर पर ग्रीष्म एवं खरीफ मौसम में की जाती है लेकिन यह फसल अनेकों जैविक एवं अजैविक प्रतिबलों के प्रति संवेदन शील है। जैविक प्रतिबलों में जड़ गांठ सूत्रकृमि (मेलायडोगायन स्पीशीज) सबसे अधिक नुकसानदायक है जिससे प्रतिवर्ष 13.5 प्रतिशत उपज में कमी होती है और 252.82 मिलियन रूपये की आर्थिक क्षति होती है। प्रतिरोधी स्रोतों के उपयोग एव ंनवीनतम किस्मों का विकास, इस फसल में लगने वाले सूत्रकृमि से बचाव का पर्यावरणहितैषी दृष्टिकोण है। इस प्रयास में करेले के आकारकीय रूपसे विविध 20 प्रभेदोंका जड़ गांठ सूत्रकृमि के प्रकोप के प्रति छंटनी के हेतु चुनौती, प्रवेशन 2000 जे-2 प्रति किलोग्राम मृदा में छंटनी घर में किया गया। परिणाम से स्पष्ट हुआ कि 20 प्रभेदों में दो प्रभेदों आईसी44438 एवं आईसी44428 को प्रतिरोधी, तीन प्रभेदों आईसी212504, वी.आर.बी.टी.जी.-10 एवं वी.आर.बी.टी.जी.-11-1, मध्यम प्रतिरोधी तथा शेष प्रभेदो ंको मेलायडोगायन स्पीशीज के प्रति अधिक संवेदनशील पाया गया। करेले के जड़ गांठ सूत्रकृमि प्रतिरोधी किस्मों को पुनः संवेदनशील किस्म ”कल्याणपुर बारहमासी” के साथ तुलना की गयी। वर्तमान अध्ययन में करेले की प्रतिरोधी प्रभेदों जैसे-आईसी44438 एवं आईसी44428, शोध प्रजननकर्ता को जड़ गांठ सूत्रकृमि के प्रति उपयोग योग्य अनुवांशिक संसाधन है जिससे जड़ गांठ सूत्रकृमि प्रतिरोधी उत्तम किस्मों व संकरों का विकास किया जा सकता है एवं संवेदनशील क्षेत्रों हेतु उगाने के लिये संस्तुत किया जा सकता है।