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Management of root knot nematode opting garlic crop in vegetable based cropping systems

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ABSTRACT

Root knot nematode is an economically important nematode infesting vegetable crops. Incidentally the three commonly followed rotations by farmers in Punjab *viz*., Brinjal-Tomato; Okra-Tomato and Cucumber-Tomato are supporting soil nematode population buildup leading to increased yield losses. In view of this, present trials were conducted to explore the potential of garlic as replacement crop in these rotations. Observations revealed that the inoculum load of root knot nematode and carry over population to the next crop in rotation decreased significantly by opting garlic as an alternative crop in place of tomato in the sequence followed. The yields of indicator crops, okra, tomato and cucumber were significantly increased in garlic rotated plots. The suppressive effect of garlic was more pronounced after continuous rotation with the crop for three years. The current study revealed that garlic can be successfully exploited as an alternative economical crop for management of root knot nematode in organic cultivation of vegetable crops in infested soils.

Key words: *Allium sativum*, *Meloidogyne icognita*, allelopathy, crop rotation, eel worm.

INTRODUCTION

Vegetable crops in fields are affected by number of biotic and abiotic stresses. Both soil and air borne pathogens are the cause of biotic stresses on plants. Multiple cropping and continuous growing of same crop on the same piece of land increases the problem of soil borne pest and diseases including plant parasitic nematodes. Root knot nematode (RKN) is emerging as an economically important pathogen and limiting the production of vegetable crops in open as well as in protected cultivation. These nematodes being soil borne, crop rotation has been reported to give good control especially for host specific nematodes as in cyst nematode (Chen *et al.,* 6). Root knot nematodes are polyphagous in nature and has wide acceptability of hosts hence its management becomes more challenging through crop rotations. Besides host status, the producer preference also plays an important role in selection of crop for the rotation.

Garlic (*Allium sativum* L.), a species of *Allium* genus, is one of the major vegetable and medicinal plant being used around the world. It is widely cultivated and consumed in India and has several desirable properties including insecticidal, antiviral, anticancer and antimicrobial that have attracted the wide attention. Allelopathic effects of garlic on other plants has been observed by different workers. Garlic root exudates have shown to produce noticeable effects on soil quality by altering soil pH, electrical conductivity, nutrient dynamics, and enzyme activity (Ahmad *et al.,* 2). With the need for an alternative option for management of root knot nematode in vegetable cropping systems in organic way, the present studies were planned to explore the potential of garlic as a crop in rotation for its suppressive effect on root knot nematode population along with its practical and economic feasibility under field conditions in the Punjab state.

MATERIALS AND METHODS

The planning of the experiment was based on the surveys conducted in vegetable areas of Punjab which revealed root knot nematode as a major constraint in production of crops in vegetable growing areas especially in three commonly followed crop rotations *viz*. Brinjal - Tomato; Okra -Tomato and Cucumber - Tomato. Continuous growing of these crops in the same field had led to nematode population build-up to the damaging levels. A green house experiment was conducted on nematode population buildup in different crops in order to identify an alternative crop in the sequence with ability to suppress the root knot nematode population. Based on these investigations, garlic was opted as the alternative crop for substitution in three rotations practiced by farmers taking into account its suitability in sequence, its economic value and its allelopathic effects. The present studies were conducted for three and a half year in the root knot nematode infested field with designated plots for each rotation so as

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to observe the suppressive effect of the crops on nematode infection.

For identification of crop, six vegetable crops *viz*., brinjal (cv. Punjab Sadabahar), cucumber (cv. Punjab Naveen), capsicum (cv. Indra), garlic (cv. PG-17), onion (cv. PRO-6) and tomato (cv. Punjab Ratta) were screened against RKN for population build-up at different intervals of 30, 60, 90 and 120 days in pot house. At the termination of trial after 120 days, observations were recorded on soil nematodes population (Cobb, 7) and root gall index as per 0-10 scale described by Bridge and Page (5).

The experiment was conducted for three consecutive years (2012–2016) in a root knot nematode infested field maintained at Department of Plant Pathology, Punjab Agricultural University, Ludhiana. On the basis of preliminary trials conducted in green house; garlic was selected as a substitution crop in three vegetable rotations as it did not support build-up of root knot nematode population in soil. The six cropping sequences taken in field were; CS-I - Brinjal (April-September) -Tomato (October–April); CS-II - Brinjal (April-September) – Garlic (October-March); CS-III - Okra (May-June)-Tomato (October-April); CSIV- Okra (May –September) - Garlic (October-March); CSV- Cucumber (April-September)-Tomato (October-April and CSVI- Cucumber (April-September)-Garlic (October-March). Garlic was taken as the second crop in rotation in place of tomato in three vegetable rotations (CS-II, CS-IV and CS-VI) in order to evaluate its suppressive effect on nematode population under field conditions. Brinjal, okra and cucumber were taken as the three susceptible indicator crops. Each sequence was replicated thrice in randomized block design in the designated infested plots of size 7x4m continuously for three and a half years. The crops were raised as per recommendations. Soil samples from each plot were taken from ten sites and mixed thoroughly. A core sample of 250 cc was washed by method as given above for extraction of nematodes. Root galling index was also taken at the end of each crop as per (0-10) scale (Bridge and Page, 5) and the results were statistically analyzed using analysis of variance for randomized block design.

RESULTS AND DISCUSSION

As per the studies conducted in green house for identification of crop with suppressive effect against root knot nematode, it was observed that the root knot nematode population increased in soil when brinjal, cucumber, capsicum and tomato were taken as crop (Rf>1) while, its population decreased in soil where garlic and onion crops were taken as crops (Rf<1) (Table 1). Observations recorded at the end of the crop showed that the root knot nematode population increased in soil by 47-61 percent where brinjal, cucumber, capsicum and tomato were taken while, it decreased by 69-73 per cent in onion and garlic grown soil. Sampling of soil at different ages of crop i.e. at 30, 60, 90 and 120 days recorded rise in nematode population on brinjal, capsicum and tomato

Table 1. Build-up of soil root knot nematode population in different crops under pot conditions.

Crop	Nematode population/250cc soil sample at different days				Reproduction factor (Rf)*	Percent reduction in population over control	Root Galling Index (RGI) 0-10 scale
	30	60	90	120			
Brinjal cv. Punjab Sadabahar	290.07 (17.05)	326.73 (18.08)	464.40 (21.57)	586.63 (24.24)	2.28	56.24 (+)	6.60
Cucumber cv. Punjab Naveen	299.96 (17.34)	407.73 (20.21)	584.40 (24.18)	663.26 (25.77)	2.58	61.30 (+)	6.96
Capsicum cv. Indra	262.16 (16.21)	276.73 (16.65)	436.63 (20.91)	486.63 (22.08)	1.89	47.25 (+)	6.50
Tomato cv.Punjab Ratta	307.73 (17.55)	331.63 (18.17)	522.66 (22.66)	599.96 (24.51)	2.33	57.22 (+)	6.73
Garlic cv. PG-17	179.96 (13.42)	133.30 (11.57)	91.06 (9.59)	68.83 (8.32)	0.26	73.18 (-)	0.30
Onion cv. PRO-6	166.66 (12.94)	132.16 (11.53)	92.30 (9.62)	78.83 (8.91)	0.31	69.28 (-)	0.60
CD (p = 0.05)	1.10	1.60	0.95	0.93			

Initial nematode population = 266.6nem/250cc soil;

*Rf = reproduction factor (Pf/PiX100) where Pf – final nematode population; Pi = initial nematode population; (+) = Percent increase in population; (-) = Percent decrease in population.

with increase in age of crop indicating multiplication of the nematode on these crops. In contrast, a gradual decline in soil nematode population in rhizosphere of garlic and onion crop was observed with increase of age of these crops. Similarly, nematode infestation in the roots as assessed by root galling index was observed to be higher in brinjal, cucumber, capsicum and tomato (RGI >6) while, negligible galls were observed on garlic (RGI = 0.3) and onion (RGI = 0.6) indicating their non-host/allelopathic nature. Based on the preliminary trials; garlic was selected as the substitution crop in sequences followed in the field.

The effect of substitution with garlic as the second crop in rotation was studied in root knot nematode infested field on three indicator crops *viz.*, brinjal, okra and cucumber in six different cropping sequences. These indicator crops were followed by tomato as the second crop in three different rotations (CS-I, III and V) and garlic as the second crop in other three rotations (CS-II, IV and VI). All the rotations were taken in the designated plots continuously for three and half years.

During first year trials; observations on soil nematode population from six different rotations showed a significant increase in the initial soil nematode population (266.6 nem/250cc soil) when the three indicator crops brinjal, okra and cucumber were taken as crop. The nematode population in soil increased by growing brinjal in first and second rotation (CS-I and CS-II) by 1.67 to 1.79 times (478.3nem./250cc soil) (Table 2). In CS-III and CS-IV rotations (Table 3), the nematode population in soil at the end of okra crop also showed an increase by 1.98 times (527.33 nem./250cc soil). The rising trends in population were also observed in CS-V and CS-VI rotations (Table 4) where, cucumber was taken as the first crop (Rf =2.35-2.39). Thus, in the first year growing of these crops increased inoculum levels of the root knot nematode in all the six crop rotations. Root galling index was observed to be >5.0 in all the indicator crops which showed greater multiplication of the pathogen on these crops.

A perusal of the data at the end of the second crop taken in rotation in the first year (2012-13) revealed that soil nematode population declined significantly in plots where garlic was taken as the following crop in rotation (CS-II, IV and VI). The root knot nematode populations at the end of garlic crop had decreased to 199.6 nem./250cc soil from 266.6 nem./250cc soil sample which was initial population in soil at the start of the trial. Negligible galling was observed in the garlic roots uprooted from the field (RGI < 1.0) at the harvest of crop, inferring its non-host nature. While in plots where tomato was taken as second crop (CS- I, III and V), there was further increase in nematode populations in soil leading to higher levels of initial inoculums for the next vegetable crop (568.33 to 699.66 nem./250cc soil). Tomato roots uprooted at the end of crop were found to be highly galled (RGI >6.0) thus, showing susceptible nature and helping in population build-up of root knot nematode.

The listed cropping sequences were followed in the same designated plots for another two and

Table 2. Soil and root population of root knot nematode in cropping sequences (CS-I) and (CS-II) during different years.

Cropping Year	Brinjal-Tomato : CS-I						Brinjal-Garlic : CS-II					
	Brinjal			Tomato			Brinjal			Garlic		
	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale
2012-13	446.66 (21.15)	1.67	5.9	568.33 (23.83)	2.13	6.1	478.33 (21.83)	1.79	5.8	175.55 (13.26)	0.65	1.2
2013-14	635.33 (25.21)	2.38	6.8	705 (26.54)	2.65	6.8	386.66 (19.67)	1.45	5.3	135.00 (11.65)	0.50	1.0
2014-15	770.66 (27.77)	2.89	7.1	682.00 (26.13)	2.56	7.0	299.66 (17.32)	1.12	4.4	78.63 (8.87)	0.29	1.0
2015-16	618.33 (24.49)	2.32	7.0	738.43 (27.18)	2.77	6.9	186.33 (13.68)	0.70	3.0	78.06 (8.87)	0.29	1.0
CD (p=0.05)	NS	-	0.60	1.96	-	0.6	2.12	-	1.05	1.40	-	NS

Initial population at the start of experiment = 266.6nem./250cc soil;
*Rf = reproduction factor (Pf/PiX100) where Pf – final nematode population; Pi = initial nematode population; **RGI= root galling index.

Table 3. Soil and root population of root knot nematode in cropping sequences (CS-III) and (CS-IV) during different years.

Cropping Year	Okra-Tomato: CS-III						Okra-Garlic: CS-IV					
	Okra			Tomato			Okra			Garlic		
	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale
2012-13	527.33 (22.97)	1.98	5.8	609.66 (24.70)	2.29	6.4	524.00 (22.89)	1.96	5.9	181.66 (13.50)	0.68	1.2
2013-14	801.66 (28.22)	3.01	6.5	795.66 (28.21)	2.99	6.7	399.66 (19.99)	1.50	5.5	144.00 (12.03)	0.54	1.0
2014-15	788.33 (28.07)	2.96	6.9	789.66 (28.11)	2.96	7.1	291.66 (17.89)	1.09	5.1	99.66 (10.00)	0.37	1.1
2015-16	824.33 (28.72)	3.09	7.2	747.73 (27.33)	2.81	7.2	207.33 (14.41)	0.77	3.8	92.16 (9.62)	0.34	1.0
CD (p=0.05)	3.25		0.74	1.97		NS	3.29		1.02	1.38		NS

Initial population at the start of experiment = 266.6nem./250cc soil;
*Rf = reproduction factor (Pf/PiX100) where Pf – final nematode population ; Pi = initial nematode population; **RGI= root galling index.

Table 4. Soil and root population of root knot nematode in cropping sequences (CS-V) and (CS-VI) during different years.

Cropping Year	Cucumber – Tomato: CS-V						Cucumber-Garlic: CS-VI					
	Cucumber			Tomato			Cucumber			Garlic		
	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale	Nematode population/ 250cc soil	Rf*	RGI** (0-10) scale
2012-13	637.33 (25.26)	2.39	6.0	699.66 (24.46)	2.63	6.6	627.33 (25.16)	2.35	6.0	199.66 (14.15)	0.75	1.4
2013-14	780.66 (27.95)	2.93	6.9	777.33 (27.89)	2.92	7.0	780.66 (27.95)	2.93	6.9	155.66 (12.48)	0.58	1.2
2014-15	804.00 (28.35)	3.02	7.2	794.00 (28.16)	2.98	7.2	804.00 (28.35)	3.02	7.2	159.33 (12.62)	0.59	1.0
2015-16	723.33 (26.81)	2.71	4.0	781.07 (27.94)	2.93	7.6	723.33 (26.81)	2.71	4.0	122.16 (11.05)	0.45	1.2
CD (p=0.05)	NS	-	0.71	NS	-	NS	NS	-	0.71	2.02	-	NS

Initial population at the start of experiment = 266.6nem./250cc soil;
*Rf = reproduction factor (Pf/PiX100) where Pf – final nematode population ; Pi = initial nematode population; **RGI= root galling index.

a half years to study the effect of substitution with garlic on nematode populations. Brinjal, okra and cucumber were taken as the first crop and tomato and garlic as the second crop. During second year also growing of indicator crops *viz*., brinjal, cucumber and okra resulted in an increase in root knot nematode populations in all the respective plots. However, when these crops were taken for second season in the designated plots, the buildup of nematode population in these indicator crops was comparatively less than the first year. In plots, where garlic was substituted as the second crop (CS-II, IV and VI), a gradual decrease in nematode population was observed, while nematode populations showed a consistent increase in plots where tomato was opted as second crop in sequence (CS-I, III and V) (Table 2-4).

During third and fourth year, the nematode population continued to prevail in high numbers in tomato rotated plots resulting in higher levels of inoculums load on indicator crops and the losses caused by them (Table 2- 4). The multiplication factors (Rf) were observed to increase by two times at the end of three year in rotation with tomato. Nematode population maintained its declining trend consistently in garlic rotated plots with higher decrease in the second and third season crop. Observations revealed that the nematode population reduction was observed during first and second year, however, after continuous rotation with garlic for three seasons, the pathogen population level in soil in the successive indicator susceptible crop became lower than the initial inoculum level or the threshold levels (Rf<1). Observations on soil nematode population in indicator crops grown for 4th year in the same plots revealed that the root knot nematode population in garlic rotated soils (CS-II, IV and VI) decreased to less than the initial population (266.6 nem./250cc soil sample). Soil nematode population in indicator crop brinjal was observed to be 186.33 nem./250cc in first cropping sequence CS-I (Brinjal -Garlic) as compared to high population of 618.33 nem./250cc in second cropping sequence CS-II (Brinjal -Tomato) (Table 2). The population in CS-I soil reached below than the threshold pathogenic levels of the nematode. Also similar results of decreased nematode population were observed in garlic rotated plots of other sequences viz., CS-IV :Okra - Garlic (Table 3) and CS-VI : Cucumber-Garlic (Table 4). The yield of indicator crops increased in garlic rotated plots in comparison to tomato rotated plots (Table 5).

Trials conducted in greenhouse for evaluating the potential of different crops revealed that the root knot nematode population decreased by growing of garlic and onion while, it multiplied and increased on brinjal, cucumber, okra and tomato. Root galling index was also observed to be negligible in garlic and onion crops indicating their suppressive nature. Disruption of nematode mobility, feeding and reproduction has also been reported by Fadzirayi *et al.* (9) which could be the reason for the low reproduction rate and low nematode numbers in garlic rotated plots. Use of essential oils of garlic or the use of garlic straw as amendment have also been reported to exhibit nematicidal effects in soils of tomato crop (Gong *et al.,* 10). The inhibitive action of garlic may be attributed to the presence of Allicin which has been observed to possess antimicrobial properties (Miron *et al.,* 14).

Based on the studies of green house, garlic was adopted as the selective second crop in cropping sequence after first susceptible indicator crop. Population of root knot nematode was observed to decrease where garlic was taken as crop, while there was severe increase in population where tomato was taken as second crop. Growing of garlic in root knot nematode infested sick fields did not support multiplication of root knot nematode and thus reduced inoculums levels to the successive susceptible crops i.e., brinjal, okra or cucumber and increased their yields. The suppressive nature of garlic was further ascertained when it was continuously taken in rotation for three years. Taking garlic crop continuously for three years was observed to be more effective as compared to one or two year rotation as the decline in populations was gradual over three years. Also due to the commercial value, cultivation of garlic could be beneficial economically to the farmers when taken as second crop in rotation. It also increased the yields of susceptible indicator crops by reducing the losses caused by nematode. Use of crop rotation with non-host plants to avoid soil-borne diseases has been discussed earlier where the strategy is to break the life cycle of the pathogen via increased plant species diversity and thus reduction in the inoculums levels of carry over populations in the absence of the host plant.

Non host crops have been reported to prevent pathogens buildup and diseases in number of crops. Use of *Avena strigosa* and the hybrid *Sorghum bicolor* × *Sorghum sudanense* in rotation with strawberries decreased nematodes as these plants are poor hosts for *Pratylenchus penetrans* (LaMondia *et al.,* 13). Besides the non-host nature of garlic against root knot nematode and other pathogens, it has also been reported for its microbial properties. Nigh (15) mentioned that garlic possesses biochemical substances and the allelopathic substances which are toxic to nematodes. The root knot nematode number

Table 5. Per cent increase in average yield of indicator crops in year (2015-16) in different cropping sequences.

Cropping sequence	Indicator Crop	Average yield of indicator crop (q/acre)	Per cent increase in yield
CS-I (Brinjal - Tomato)	Brinjal	102.3	-
CS-II (Brinjal - Garlic)	Brinjal	121.4	18.67
CS-III (Okra - Tomato)	Okra	41.2	-
CS-IV (Okra - Garlic)	Okra	49.5	20.14
CS-V (Cucumber -Tomato)	Cucumber	58.6	-
CS-VI (Cucumber-Garlic)	Cucumber	68.3	16.55

and the multiplication factors (Rf) were observed to continuously reduce with every increasing season of garlic indicating its suppressant action. It has been reported earlier that the many higher plant species contain chemicals with an allelopathic activity and the roots release an array of chemicals that are exuded into rhizosphere and bring about significant ecological effects (Bertin *et al.,* 4). Selection of suitable crop in rotation and management of crop residues play an important role in plant health management. Root mediated interactions, especially the allelopathic ones, are very common in the rhizosphere soil. Under certain circumstances, these allelochemicals are released into environment, either as exudates from living plants (Bais *et al.,* 3) or as decomposition of plant residues in sufficient amount in order to affect the neighboring or successional plants (Einhellig, 8). Garlic has been reported to possess biochemical substances and the allelopathic substances which are toxic to nematodes (Nigh, 15). The continuous reduction in nematode population in garlic rotated plots and its suppressive nature in the present studies may be attributed to its allelopathic properties and release of leachates in soil during its growth in field apart from its non host nature. The soil treatment with a commercial product containing the aqueous garlic extract reduced the nematode-root gall index and increased the activity of catalase, B-1, 3-glucanase of tomato leaves (Abd-Elgawad *et al.,*1). Infection of root knot nematode was also observed to be negligible in roots of garlic while tomato roots were observed to be severally galled after three years. The increase in yields of susceptible crops could be attributed to decrease of RKN infestation and inoculum levels in the field as well as improvement in soil health. Han *et al.,* (11) had also reported that decomposed garlic stalk had good impact on soil enzyme activity which helped in increase of crop production. Intercropping of pepper with garlic also enhanced sucrose, alkaline phosphatase, catalase, pH and electrical conductivity of the soil (Khan *et al.,* 12). Garlic being an economic crop along with its suitability in cropping sequence could be exploited for the management of root knot nematodes in the infested fields.

The present studies revealed that the garlic expressed a suppressive effect on root knot nematode population and its effectiveness increased with number of seasons. In addition, its suitability in vegetable cropping systems will be highly applicable for nematode infested soils under organic farming system as it will help in effective management of root knot nematode population. A three year cropping rotation of susceptible crop with garlic should be opted for decreasing nematode populations to below threshold levels. This rotation can help the farmers to take susceptible crops in the infested soils and manage root knot nematodes with an ecofriendly approach without wastage of land or growing season.

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