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Assessment of avoidable yield losses due to root-knot nematode, *Meloidogyne incognita* infesting Indian spinach (*Basella alba* L.) under West Bengal field conditions

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Abstract
The field experiment was conducted during April, 2016 & 2017 at Central research Farm (CRF) of Bidhan Chandra Krishi Viswavidyalaya, West Bengal to assess the avoidable yield losses due to root-knot nematode in Indian Spinach cv. Local (*Basella alba* L.) under field conditions with paired plot design with ten replications by soil application of Carbofuran granules @ 3 kg a.i./ha. Ten plots each of 6 m x 2 m size were treated and another ten plots were kept untreated control (without Carbofuran application).The results indicated that the loss in yield of Indian Spinach in an untreated ranged from 10.82 % to 12.44 %. However, average avoidable loss in the vegetative yield of the crops was recorded to be 9.76 % to 11.06 per cent, when the crop was treated with Carbofuran granules @ 3 kg a.i./ha.

Keywords: *Meloidogyne incognita,* Indian spinach, carbofuran 3 G, *Basella alba,* yield loss

Introduction
Indian Spinach (*Basella alba*) is an edible perennial vine in the family Basellaceae. It is found in tropical Asia and Africa where it is widely used as a leafy vegetable. These leafy vegetables are grown almost in all parts of India. In West Bengal it is commonly known as "Puinsaag" and cultivated as economically important leafy vegetables throughout the seasons. According to Premachandra *et al.*, (2015) [1], this vegetable is rich in calcium, magnesium, potassium and iron as well as several vitamins including vitamin A. The soil and climate of India and Bangladesh are very favourable for the cultivation of Spinach with high average yield was recorded by BARI (2015) [2].However, the yield of the vegetable is not satisfactory because of many constraints including the infection of several plant parasitic nematodes. Timmet. *et al*., (1960) [3] reported that around 15 genera of plant parasitic nematodes are reported to associate with commercial crops grown, where *Meloidogyne* spp. are found most abundant and widespread. Potter *et al*., (1993) [4] and Castillo *et al*., (2003) [5] have stated that among the nemic diseases, the root-knot caused by *Meloidogyne javanica* and *Meloidogyne incognita* are one of the most common and damaging nematodes on Indian spinach. Furthermore, Chester (1950) [6] reported that the root-knot disease causing by nematode predisposes the plants for further invasion by other micro-organisms. Indian Spinach is attacked by various insect and non-insect pests. In addition to insect pests and diseases, plant parasitic nematodes have also becoming a limiting factor in the successful cultivation of this crop. Many species of phytonematodes have been found associated with rhizosphere of this plant. Amongst these, root-knot nematode, *Meloidogyne incognita* is considered to be of great economic importance. And it has a host range of about 232 host genera recorded by Krishnappa (1985) [7]. Kanwar and Bhatti (1989) [8] recorded the stem galls on a cucurbitaceous host *Luffa acutangulla* caused by *M. javanica*. Krishnaveni and Subramanian (2002) [9] recorded 69.2 per cent yield losses in cucumber due to *M. incognita*. The genus *Meloidogyne* attacks nearly every crop and has been reported to cause an annual loss of Rs. 547.5 million INR in cucurbits by Chandra *et al*., (2010) [10] and Jain *et al*., (2007) [11]. Literature on study of infection by root knot nematode on Indian spinach are very limited. Therefore, in the present study, the assessment of yield losses due to *Meloidogyne incognita* on the crop was studied.

2. Materials and Methods

The experiment was carried out on nematode sick plots at Central Research Farm (CRF), Gayashpur of Bidhan Chandra Krishi Viswavidyalaya during the *Prekharif* of 2016 and 2017 to evaluate the yield losses due to root-knot nematode, *M. incognita* on Indian spinach. Paired plot technique given by Leclerg [12] was employed to conduct the experiment, *viz.*, (T_1) treated and (T_2) untreated and each treatment was replicated ten times in plot size measuring 6 m × 2 m each. After land preparation initial soil nematodes population was determined based on counting number of nematodes (2nd stage juveniles) by Cobb's sieving and decanting method from multiple samples and presented as number of INP/ 200 cm^3 soil. The requisite buffer area between the plots maintained was 1m X 1m. Recommended fertilizer doses and other agronomic practices were followed for management of the crops. Then seeds were sown at a spacing of 40 cm X 20 cm plant to plant and row to row respectively Ten plots were treated with Carbofuran granules @ 3 kg a.i./ha prior to seed sowing and the rest ten plots were kept as untreated. Plant stands observations were taken at 15 days after sowing and at the time of harvest of the crops. Plants from each plot were uprooted and washed carefully in the tap water to remove adhering soil particles. Number of root galls on roots per plant was recorded and gall indices 1 to 5 scales were worked out. Yield (kg/plots) was calculated from each plots and then converted to quintal/ha. For final nematode population soil sample comprising of several subsamples were collected from different sites of each plot and mixed thoroughly and 200 cc of soil was drawn and processed by Cobb's sieving and decanting method.

Statistical analysis

Per cent increase in yield and avoidable loss was calculated as per the formula given in the following example:

Calculation Sheet

Example: Method of computation of t-value

Yields from a field experiment conducted to compare treated and untreated plots and some of the computations necessary for a test of significance between the two treatments.

Calculation Sheet

Paired plots (No.)	Yield/plot (kg)		Difference (x_1-x_2)	Deviations from the mean of the difference (d)	Square of the deviations from the mean (d^2)
	Treated (x_1)	Untreated (x_2)			
1	14.6	6.2	8.4	- 0.1667	0.0278
2	12.6	3.3	9.3	0.7333	0.5377
3	15.0	6.8	8.2	- 0.3667	0.1345
4	15.6	6.6	9.0	0.4333	0.1877
5	12.7	4.2	8.5	- 0.0667	0.0044
6	12.0	4.0	8.0	- 0.5667	0.3211
Sum	82.5	31.1	51.4		1.2132
Mean	13.75	5.18	8.5667		

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

Difference, x_1-x_2 = 14.6 – 6.2 = 8.4

Deviation from the mean of the difference (d)

d = 8.4 - 8.5667 = 0.1667

Square of the deviation from the mean difference (d^2)

$d^2 = (-0.1667)^2 = 0.0278$

Similar procedure is followed to obtain the values for the remaining paired plot data.
In this example
n = number of paired plots = 6
(n-1) = degree of freedom i.e. 6-1 = 5
Mean difference = 51.4/6 = 8.5667
S = Standard deviation

$$= \sqrt{\frac{\text{sum of } d^2}{n-1}} = \sqrt{\frac{1.2132}{5}} = \sqrt{0.2426}$$

$$= 0.4925$$

$$\text{Standard error (Sd)} = \frac{\text{Standard deviation}}{\sqrt{n}}$$

sd = standard error of mean difference

$$\text{i.e.} \quad S = \frac{0.4925}{\sqrt{n}} = \frac{0.4925}{\sqrt{6}} = 0.201$$

Substituting in Equation (1), we obtain:

$$T = \frac{x_1 - x_2}{sd} = \frac{8.57}{0.201} = 42.64 = t$$

This calculated value of 't' needs to be compared with tabulated value to ascertain whether the observed value is statistically significant at 0.05 and 0.01 probability levels.
From the two mean tables in Table, one can compute the percentage reduction in actual yield per cent avoidable losses in yield.

$$100 \times \frac{13.75 - 5.18}{13.75} = 62.3\%$$

$$\text{Per cent avoidable loss in yield} = \frac{\text{Yield in treated plots - Yield in untreated plots}}{\text{Yield in treated plots}} \times 100$$

$$\text{Per cent increase in Yield} = \frac{\text{Yield in treated plots - Yield in untreated plots}}{\text{Yield in untreated plots}} \times 100$$

3. Results

The results obtained in the study on assessment of yield losses due to *Meloidogyne incognita* on Indian Spinach revealed that in the year 2016 application of carbofuran 3G @ 3 kg a.i. ha^{-1} significantly increased the yield of Pui by 12.44 % with significant reduction in *M. incognita* population by 55.49 % (Table-1). It is found that an infestation of root-knot nematodes on the crop inflicted an avoidable yield loss of 11.06 %. In next season the performance of the crop with reference to all growth attributes under study was significantly better in carbofuran 3G @ 3kg a.i. ha^{-1} compared to untreated check. Application of carbofuran 3G @ 3 kg a.i. ha^{-1} significantly increased the yield of Indian Spinach by 10.82% with significant reduction in *M. incognita* population by 39.78% (Table-2). It is found that an infestation of root-knot nematodes on the crop inflicted an avoidable yield loss of 9.76 %. The reduction in number of gall index in treated plots was 35.00% in the year 2016 and 41.89 per cent in 2017. The average initial population of larvae of root knot nematodes was 192 and 205per 200 cc of soil for two years (2016 & 2017) respectively. In untreated plot, the nematode population at the time of final crop harvest were increased upto 65.10% and 45.85% for two years respectively. Whereas the population were decreased in treated plots at 26.30% and 11.91% in the year 2016 and 2017. The avoidable yield losses was recorded 11.06% & 9.76% for the year 2016 and 2017 and yield increased percentage was 12.44% & 10.82% respectively. (Table – 1 and 2).

Table 1: Estimation of experimental yield loss due to *Meloidogyne incognita* in Indian Spinach during 2016

Crop	Mean yield in treated plot (q/ha)	Mean yield in untreated plot (q/ha)	% avoidable yield loss	% increase in yield
Indian Spinach (Pui)	198.08	176.17	11.06	12.44
Paired t-test value (P=0.05)	5.65			
Tabulated t	2.26			

Crop	Plant stand 15 days after sowing/plot		Plant stand at harvest/plot		RKI (1-5 scale)		Final nematode population ($200cm^3$ soil + root) *M. incognita*	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
Indian Spinach (Pui)	148.60	151.50	107.90	107.10	2.22	3.15	141.50	317.92
Paired t-test value (P=0.05)	0.80 (NS)		0.66 (NS)		(-) 2.38		(-) 5.23	
Tabulated t	2.26		2.26		2.26		2.26	
Nematode	% reduction of *M. incognita* population over untreated control							
M. incognita	55.49							

T_1=Treated, T_2=Untreated, INP = 192 /200 cm^3 soil

Table 2: Estimation of experimental yield loss due to *Meloidogyne incognita* in Indian Spinach during 2017

Crop	Mean yield in treated plot (q/ha)	Mean yield in untreated plot (q/ha)	% avoidable yield loss	% increase in yield
Indian Spinach (Pui)	200.58	181.00	9.76	10.82
Paired t-test value (P=0.05)	6.89			
Tabulated t	2.26			

Crop	Plant stand 15 days after sowing/plot		Plant stand at harvest/plot		RKI (1-5 scale)		Final nematode population ($200cm^3$ soil + root) *M. incognita*	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
Indian Spinach (Pui)	147.90	151.80	109.10	107.50	2.20	2.97	180.58	299.85
Paired t-test value (P=0.05)	(-)1.28 (NS)		1.38 (NS)		(-) 2.09		(-) 4.86	
Tabulated t	2.26		2.26		2.26		2.26	
Nematode	% reduction of *M. incognita* population over untreated control							
M. incognita	39.78							

T_1=Treated,T_2=Untreated, INP=205/200 cm^3 soil

4. Discussion

The statistical analysis of the data revealed that performance of Indian Spinach local variety with Carbofuran 3G at 3 kg a.i./ha was significantly better for two years as compared to the untreated control. The decreasing vegetative yield data recorded for the untreated Indian Spinach local variety was probably a result of the stunting action of root-knot nematode (*M. incognita*). The treated plants started profuse vegetative growth than the untreated. Early vegetative growth is very important because it affects the yield at the time of harvesting the plants. The yield of the crop was found to be higher with the application of nematicide-Carbofuran at 3kg a.i/ha. A significant reduction in the yield of the crop in untreated plots was mainly attributed to direct damage of the root system by the feeding activities of root knot nematode (*M. incognita*). The ovicidal effect of carbofuran is more effective in preventing penetration of nematodes into the root. This may suggest that carbofuran acts directly on the nematodes in the soil thereby affecting hatching of eggs and the movement of larvae into the root. This is in agreement with the work of Di-Sanzo (1973), Kinloch (1974, 1982), Adegbite and Agbaje (2007) and Adegbite and Adesiyan (2001). The two seasons data from yield losses on Indian Spinach (*Basella alba* L.) cv local indicated that the root knot nematode is responsible for an average yield loss to the extent of 10.41% and adoption of suitable management practices against the nematode can enhance average yield of the crop upto 11.63%. There is very little information available regarding avoidable yield loss assessment by root knot nematode in Indian spinach (*Basella alba* L.). Therefore the present findings are compared with some other vegetable crops. The results obtained under study are in conformity with those of Darekar and Mhase [13] who reported 36.72 per cent yield losses in bitter gourd (*M. charantia*) CV. Coimbatore White long due to *M. incognita* race 3 and Krishnaveni and Subramanian [12] and Khanna and Kumar (2003) [14] also recorded 69.2 per cent and 22.9 to 42.8

per cent losses in yield of cucumber and bitter gourd respectively due to *M. incognita*. Similar findings were also reported by Khan *et al*. (2014) [15] on bottle gourd, snake gourd, bitter gourd, cucumber and pumpkin due to the infestation of root-knot nematodes. Lack of awareness among the farmers increases the losses caused by these tiny creatures if proper management strategies are not adopted on the crops. Therefore, necessary steps should be taken in the field of awareness as well as management of these nematodes to minimise economical losses to the farmer.

5. Conclusion
It is concluded from the experiment of avoidable yield losses of Indian Spinach (Pui) under West Bengal field conditions that the avoidable losses of yield of the crop range upto 9.76 - 11.06 %. Application of Carbofuran 3G at 3 kg a.i./ha can increase the yield of Indian Spinach (Pui) by 10.82 to 12.44%. Therefore, management of root knot nematode (*M. incognita*) is necessary to get maximum yield of the crop.

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