Bangladesh J. Bot. **51**(3): 411-416, 2022 (September) DOI: https://doi.org/10.3329/bjb.v51i3.61985

GROWTH AND YIELD VARIABILITY IN RICE OWING TO ROOT KNOT NEMATODE (*MELOIDOGYNE GRAMINICOLA*) AT DIFFERENT PLANT AGE

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Keywords: Rice, *Meloidogyne graminicola*, Inoculation, Growth, Yield

Abstract

Meloidogyne graminicola (nematode) mostly attacks young roots of plants; hence, age of host becomes a predominant factor in infection and pathogenesis. A pot experiment was conducted in the net house condition during *kharif*, 2018 in complete randomized design to find out the changes in growth and yield parameters of rice cv. Naveen due to inoculation of *M. graminicola* at different plant age. The nematode infested rice plants showed chlorosis, stunting and characteristic terminal galls on the roots which ultimately resulted in severe reduction in growth, unfilled spikelets, reduction in tiller development and other growth attributes over control. Nematode inoculation at early crop stage retarded the plant growth and yield attributes by reducing the rice yield up to 57.4%. The maximum percentage of reduction in plant height (19.8%), tiller number (39.6%), dry weight of shoot (43.6%), dry weight of root (45.6%) and total biomass (49.6%) was observed in the plants inoculated at two weeks after sowing.

Introduction

In India, rice (*Oryza sativa* L.) is a staple food crop and a vital nutritional source for rural people. The quantum of total crop losses is much more than apparent and the repercussions can lead to food insecurity. Biotic stresses can cause a 37.4% loss of rice production (Oerke 2006) in which loss due to plant parasitic nematodes constitutes a key component. The ecological conditions suitable for the cultivation of rice crop are very well congenial for the multiplication of nematodes infecting rice (Jain *et al*. 2012). In rice growing areas, root knot nematode (*M. graminicola*) becomes a serious bottleneck in most of the cultivars of rice. It is a serious problem in the nurseries and upland rice but has been found to be widespread in the deep water and irrigated rice in many states of India (Jairajpuri and Baqri 1991). In Odisha, mainly in Cuttack and Kalahandi district, *M. graminicola* infestation become severe in *kharif* rice causing a significant reduction in grain yield in susceptible varieties. Damage caused by nematodes is determined by relating pre-plant nematode densities to growth and yield of annual crops. The minimal density that causes a measurable reduction in plant growth or yield varies with nematode species, host plant, cultivar and environment (Barker and Olthof 1976). It is generally assumed that young plants are more severely damaged by nematodes than older plants. In view of the above facts, an experiment was conducted to study the change in growth and yield of rice (*Oryza sativa* L.) cv. Naveen due to inoculation of rice root-knot nematode at different plant age.

Materials and Methods

The experiment was carried in the net house, Department of Plant Physiology, College of Agriculture, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar during *kharif*, 2018. Twenty five pots, each pot having depth 20 cm, diameter 50 cm, were filled with 3 kg of autoclaved sterilized field soils (sandy loam soil, pH 6.9 and E.C 1.164 dSm^{-1}) collected

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from Central Research Farm, OUAT. The seeds of rice cv. Naveen susceptible to *M. graminicola* (Subudhi *et al*. 2017) were sown on the pots laid out in completely randomized design having 5 treatments and replicated 5 times for data generation and statistical analysis. The normal recommended dose of fertilizer (80:40:40 NPK kg/ha) was applied. Root knot nematode was inoculated @ 1000 J_2s/kg soil rice plants at sowing, 2, 4 and 6 weeks after sowing. Out of twenty five pots the 1st set of five pots were kept as such for control without nematode inoculation. Freshly hatched J_2 of *M. graminicola* isolated from pure culture pot were surface sterilized by treating with aqueous solution of 0.5% Hibitane solution for 5 min and were inoculated @ 1000 / kg soil to the 2, 3, 4 and 5 set of pots at time of sowing, 2 weeks after sowing (WAS), 4 WAS and 6 WAS sequentially around the root zone. The above ground morphological parameters *i.e.* plant height (cm), number of leaves per plant, number of tillers per plant, leaf area (cm^2)**,** were recorded at 90 days of sowing. The observation on total biomass, shoot and root dry weight, percentage portioning of shoot and root, Harvest Index (HI), number of panicles per plant, panicle length, total grains, filled grains, unfilled grains and chaffy percentage per panicle of rice were recorded at the time of harvest. Observation on days to flowering was also recorded.

Partitioning % = [Dry wt. of particular plant part (g)/dry wt. of whole plant (g)] × 100

Harvest Index (HI) was calculated by the formula given by Nichiporovic (1960).

Harvest Index (HI) = (Economic yield/Biological yield) x 100

The data related to various morphological, physiological, biochemical and yield parameters collected in this experiment were arranged in appropriate tables according to the treatment and analyzed statistically in analysis of variance (ANOVA) technique in a completely randomized design (CRD) with the help of the "Statistical procedures for agricultural research" by Gomez and Gomez (1984). The comparison of means was done at 5% level of significance.

Results and Discussion

Results showed that the growth parameters of rice plant were significantly affected by *M. graminicola.* The height of plant is an important growth character directly linked with the reproductive potential of plant. The decrease in plant height was prominent in all the nematode inoculated pots than the control (Table 1). T_2 plants (inoculated 2 WAS) showed the highest reduction (19.8%) among all plants. However, the reduction rate decreased as the time of inoculation increased as the T4 plants (6 WAS) exhibited lowest reduction (5.7%) among all other inoculated plants. Naveen variety being susceptible to nematode (Subudhi *et al*. 2017) showed drastic reduction in plant height due to lack in supply water and nutrients as the highest number of galls formed in T_2 roots which impaired absorption and indirectly all the metabolisms needed for growth. Similar findings were also reported by Jaiswal *et al*. (2012) who found a relationship between growth of rice seedlings and time of infection with *M. graminicola.* Total number of leaves per plant in all the inoculated plants had significantly less number than the control (Table 1). Inoculation at 2 WAS resulted maximum decline (19.9%) in leaf number, whereas inoculation at 6 WAS exhibited minimum reduction (6.6%). The decrease in number of leaves might be due to ethylene accumulation in plant tissue which resulted in senescence and death of leaves (Vinod *et al*. 2014). Highest percentage (28.0%) of decline in leaf area was recorded in T_2 followed by T_1 plants (24.1%) but the lowest reduction was observed in T_4 plants (6.6 %). The significant decrease in leaf area might be due to reduction in photosynthetic rate which induced more enzymatic activities of catalase, peroxidase and lipid peroxidation as observed in the present study. These findings corroborated with the work of Bimpong *et al.* (2010).

The tabulated data indicated that nematode stress caused remarkable decrease in tiller number in all the inoculated plants as compared to the control (Table 1). T_2 plants exhibited highest

reduction (39.6%) in tiller number over the control and lowest reduction was observed in T_4 plants (18.7%). This might be due to root anoxia causing accumulation of ethylene and toxic effect of glycosides produced by host nematode interaction as well as less supply of water. Also nutrients might inhibit the tiller number and growth of inoculated plants. The finding is in agreement with the findings of Soomro and Hague (1993) and Jain *et al.* (2012).

Table 1. Effect of different inoculation time of root knot nematode on plant growth parameters of rice cv. Naveen.

Treatments (Inoculation time)	Plant height (cm)	Leaves/ Plant (number)	Tillers/ Plant (number)	Leaf area (cm^2)
T_0	102.0	33.2	10.6	23.4
T_1	84.6	29.4	7.4	17.8
	(-17.1)*	(-11.4)	(-30.6)	(-24.1)
T_2	81.8	26.6	6.4	16.9
	(-19.8)	(-19.9)	(-39.6)	(-28.0)
T_3	90.6	30.2	7.9	20.7
	(-11.2)	(-9.0)	(-25.5)	(-11.7)
T_4	96.2	31.0	8.6	21.9
	(-5.7)	(-6.6)	(-18.7)	(-6.6)
SE(m)±	3.655	1.643	0.536	1.064
CD 5%	10.781	4.847	1.582	3.137
CV %	8.98	12.21	14.67	11.81

*Figure in parentheses indicates % decrease over control. T0: Control, T1: 1st inoculation of 1000 J2s / kg soil at time of sowing, T2: 2nd inoculation of 1000 J2s / kg soil at 2 weeks after sowing, T3: 3rd inoculation of 1000 J2s / kg soil at 4 weeks after sowing and T4: 4th inoculation of 1000 J2s / kg soil at 6 weeks after sowing.

Flowering delayed in all the inoculated plants as compared to the control plants (Table 2). The maximum days delay in flowering (up to 7 days) was observed in T_2 plants followed by T_1 plants showing delay of 4 days than the control plants. However, T4 plants showed minimum delay in flowering (1 day) than the control. The delay in days to flowering was found statistically significant among the treatments. The flowering delayed more in highly infected plants inoculated at early stage of growth. This might be due to more production of stress molecules thus inhibiting the production of flowering hormone and also uptake of nutrients from soil. The finding is in line with the work of Israel *et al.* (1963).

Results presented in Table 2. Shoot dry weight, root dry weight and total biomass indicated that nematode infestation impact was negative on all the above parameters. Lowest shoot dry weight (8.0g) was recorded in the T_2 plants followed by the T_1 plants (8.8g) at a tune of 43.6 and 37.5% decrease, respectively. Similar trend was also recorded in root dry weight with a decreasing tune of 45.6 and 38.9% in T_2 and T_1 plants, respectively. However, the total biomass also decreased at a maximum rate of 49.6% in the T_2 plants followed by T_1 plants (40.6%) whereas minimum decrease (11.7%) was observed in T_4 plants. Shoot and root dry weight and total biomass were found statistically significant among the treatments. This reduction in dry weight of plant parts might be due to more diversion of food, nutrients for the feeding of nematode thus

causing remarkable reduction in growth and development of all plant parts. The similar finding was also reported by Khan *et al.* (2012) and Win *et al*. (2013).

Table 2. Effect of different inoculation time of root knot nematode on flowering, biomass, shoot and root dry weight, percentage portioning of shoot and root of rice cv. Naveen.

Treatments (Inoculation time)	Days to flowering	Total biomass (g)	Shoot dry weight (g)	Root dry weight (g)	Partitioning percentage of shoot (%)	Partitioning percentage of root (%)
T_0	67	54.9	14.1	13.2	25.9	24.1
T_1	71	32.6 (-40.6)*	8.8 (-37.5)	8.1 (-38.9)	27.2	24.8
T_2	74	27.6 (-49.6)	8.0 (-43.6)	7.2 (-45.6)	29.2	26.2
T_3	69	41.9 (-23.7)	10.9 (-23.2)	10.2 (-22.6)	26.1	24.5
T_4	68	48.5 (-11.7)	12.5 (-11.5)	11.8 (-10.5)	25.9	24.4
SE(m)±	0.970	0.776	0.695	0.653	1.604	1.101
CD 5%	2.860	2.289	2.051	1.926	4.731	3.248
CV %	9.34	11.34	14.33	14.46	15.46	10.61

*Figure in parentheses indicates % decrease over control. T0: Control, T1: 1st inoculation of 1000 J2s/kg soil at time of sowing, T2: 2nd inoculation of 1000 J2s/kg soil at 2 weeks after sowing, T3: 3rd inoculation of 1000 J2s/kg soil at 4 weeks after sowing and T4: 4th inoculation of 1000 J2s/kg soil at 6 weeks after sowing.

Table 3. Effect of different inoculation time of root-knot nematode on different parameters of panicle, weight and grain yield of rice cv. Naveen.

Treatments (Inocula-tion time)	Panicles/ plant (No.)	Panicle length (cm)	Total No. of grains/ panicle	Filled grains/ panicle (No.)	Unfilled grains/ panicle (No.)	Chaffy % per panicle	1000-grain wt. (g)	Grain yield per plant (g)	HI (%)
T_0	10.4	24.3	123.2	113.8	9.4	7.7	17.9	20.7	49.8
T_1	7.9 (-24.0)*	19.8 (-18.6)	100.6 (-18.3)	87.4 (-23.2)	13.2 (+40.1)	14.0	14.8 (-17.3)	11.4 (-44.8)	46.6
T_2	6.8 (-34.6)	17.8 (-26.8)	89.2 (-27.6)	74.2 (-34.8)	15.0 (+59.2)	16.9	13.5 (-24.6)	8.8 (-57.4)	43.2
T_3	8.6 (-17.3)	21.4 (-12.0)	109.8 (-10.9)	99.4 (-12.6)	10.4 (+10.4)	9.4	16.4 (-8.4)	15.4 (-25.9)	48.6
T_4	9.4 (-9.6)	23.2 (-4.6)	116.2 (-5.7)	106.2 (-6.7)	10.0 (+6.2)	8.6	17.3 (-3.4)	18.0 (-13.0)	49.2
SE(m)±	0.586	0.892	5.387	5.493	0.727	1.267	0.707	0.795	1.049
CD 5%	1.728	2.632	15.890	16.202	2.144	3.737	2.086	2.345	3.095
CV %	15.20	8.60	11.17	12.77	14.01	12.21	10.33	11.62	10.11

*Figure in parentheses indicates % decrease over control. T0: Control, T1:- 1st inoculation of 1000 J2s/kg soil at time of sowing, T2:- 2nd inoculation of 1000 J2s/kg soil at 2 weeks after sowing, T3:- 3rd inoculation of 1000 J2s/kg soil at 4 weeks after sowing, T4:- 4th inoculation of 1000 J2s / kg soil at 6 weeks after sowing.

The percentage of partitioning of shoot and root presented in Table 2 showed that there was not so much difference between inoculated and uninoculated plants. Percentage partitioning of shoot and root was found to be the highest in T_2 plant (29.2 and 26.2%) and lowest in the control (25.9 and 24.1%), respectively. The percentage were statistically significant among the treatments. Root knot nematodes reaction in host plants in which nutrient flow to the root system increased to support nematode development and elicit profound changes in root morphology. Giant cell formation and hypertrophy and hyperplasia of surrounding cortical root tissues are symptoms of an altered host metabolism (Bergeson 1966, McClure 1977).

A significant reduction in grain yield and yield attributing characters like panicle number, panicle length, total number of grains per panicle**,** 1000-grain wt., number of filled grains per panicle etc. were observed in all the inoculated plants than the control (Table 3). The plants inoculated at early tillering stage (T_2) gave the lowest yield of 8.8 g/plant with highest number of chaffy grains due to increase in nematode population that caused severe infestation among all other plants. The number of unfilled grains per panicle was also found to increase due to nematode infestation in a trend $T_0 < T_4 < T_3 < T_1 < T_2$ with a maximum increase of 59.2% in T_2 plants. Harvest index reduced significantly in all the inoculated plants than the control. The plants inoculated at 2 weeks after sowing showed the lowest HI (43.2%) and it was in descending trend i.e. $T_0 > T_4 > T_3 > T_1 > T_2$. The reduction in yield attributing characters might be due to the formation of root galls that blocked the supply of water, essential elements which in turn induced the accumulation of ET, ABA. These growth retarding hormones degrade the chlorophyll, causing flower and grain abscission and reduction in photosynthetic activity under biotic stress condition. In spite of that the food produced might be diverted more to fulfil the food requirement of nematodes. Thus nematode stress caused less diversion of energy towards the economic part causing more chaffy grains and significant reduction in grain yield as wells as test weight of the plant. Similar findings were also reported by many other workers (Padgham *et al.* 2004, Bridge *et al.* 2005, Jain *et al.* 2007, Gaur and Pankaj 2010, Patil and Guar 2014).

It may be concluded that the rice root-knot nematode (*M. graminicola*) had a very detrimental effect on growth, and development of rice cv. Naveen at an early growth stage than other stages of rice plant as soft tender roots facilitate high invasion of nematode causing more root galls. Therefore, the inoculation at two weeks after sowing showed the highest reduction in plant height, leaf area, numbers of leaves, tiller and also hampered the flowering. *M. graminicola* has the potential to severely impair the growth of rice at early growth stage but delay exposure of rice to nematodes can significantly abate yield losses.

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(Manuscript received on 24 June, 2021; revised on 2 July, 2022)