IMPACT OF WHEAT ON *MELOIDOGYNE GRAMINICOLA* POPULATIONS IN THE RICE-WHEAT SYSTEM OF BANGLADESH

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ABSTRACT

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A soil bioassay, using rice as an indicator plant, and a host susceptibility experiment were conducted to investigate the impact of wheat on population densities of *Meloidogyne graminicola* in a rice-wheat rotation area of Bangladesh. The bioassay revealed widespread infestations of *M. graminicola* following wheat harvest. Root-galling severity ratings on a 1 to 9 scale for all 18 fields tested ranged from 1.5 to 7.0 with a mean of 4.8. Root-galling severity in rice nursery seedbeds ranged from 1.0 to 4.4 with a mean of 3.3. In the host susceptibility experiment, all wheat varieties commonly cultivated in rice-wheat rotation areas of Bangladesh were determined to be excellent hosts to *M. graminicola.* The reproduction on wheat roots was 26.4 to 57.9 times the initial nematode population density. The results of these two experiments indicate that wheat is contributing to high population densities of *M. graminicola* in soil which can negatively impact rice, and possibly wheat, productivity in a rice-wheat rotation.

Key words: Bangladesh, *Oryza sativa*, rice root-knot nematode, *Triticum aestivum.*

RESUMEN

Padgham, J. L., G. S. Abawi, J. M. Duxbury, and M. A. Mazid. 2004. Impacto del trigo sobre poblaciones de *Meloidogyne graminicola* en un sistema de arroz-trigo en Bangladesh. Nematropica 34:183-190.

Un bioensayo de campo suelo, usando el arroz como una planta indicadora y un experimento de compatibilidad del hospedero fue conducido para investigar el impacto del trigo sobre la densidad demográfica de *Meloidogyne graminicola* en un área de rotación arroz-trigo en Bangladesh. El bioensayo reveló que las infestaciones de *M. graminicola* se extendieron después de la cosecha del trigo. La severidad del daño en las raíces por la formación de las agallas fue determinada en una escala de 1 a 9. En los 18 campos evaluados el daño estuvo en un rango de 1.5 a 7.0 con un promedio de 4.8. La severidad del daño en las plantas de arroz en los semilleros por la formación de agallas vario entre 1.0 a 4.4, con un promedio de 3.3 en la misma escala. En el experimento para determinar el mejor hospedero, se usaron todas las variedades de trigo comúnmente cultivadas en Bangladesh en sistema de rotación arroz-trigo. La reproducción de los nematodos sobre las raíces de trigo era 26.4 a 57.9 veces mayor a la población inicial. Los resultados de ambos experimentos indican que el trigo contribuye a la alta densidad demográfica de *M. graminicola* en el suelo, el cual puede afectar negativamente de productividad del cultivo del arroz, y posiblemente el trigo, en sistemas de rotación arroz-trigo.

Palabras claves: Bangladesh, *Oryza sativa,* nematodo formador del nódulo de las raíces de arroz, *Triticum aestivum.*

INTRODUCTION

A rotation of rice and wheat in a cropping system is commonly practiced on 12 million ha in South Asia's Indo-Gangetic Plains. Recent long-term yield trials on rice and wheat demonstrated that productivity of these two important cereal crops has stagnated or, in some cases, declined across the region (Hobbs and Morris, 1996). While the contribution of declining soil fertility (Abrol, 1998; Gill, 1994; Hobbs and Morris, 1996; Roy, 1996) and foliar pest pressure (Cohen *et al.*, 1998; Gill, 1994; Thresh, 1989) to poor rice yields has been well documented, the role of soilborne pathogens in rice-wheat production has not been widely studied.

Recent reports of rice root-knot nematode (*Meloidogyne graminicola* Golden and Birchfield) infestations in rice-wheat rotation areas of India (Gaur *et al.*, 1993; 1996), Nepal (Sharma *et al.*, 2001), and Pakistan (Munir and Bridge, 2003) suggest that nematode damage may be a contributing factor to poor productivity in this system. The impact of *M. graminicola* on rice yield has been well established, with reported yield losses of 20 to 90% (Arayarungsarit, 1987; Bridge and Page, 1982; Netscher and Erlan, 1993; Plowright and Bridge, 1990; Prot and Matias, 1995; Tandingan *et al.*, 1996). However, less is known about the role of wheat in maintaining high population densities of *M. graminicola* between rice seasons and on the tolerance of wheat to damage from this nematode.

The rice-wheat rotation occurs on approximately 0.5 million ha in Bangladesh, with 85% of the area planted to wheat located on land where monsoon rice is grown (Hobbs and Morris, 1996). In a recent study on rice-wheat production fields in Bangladesh, Padgham *et al.* (2004) measured a 16 to 20% rice yield increase where nematicide was applied to *M. graminicola*-infested field plots compared with rice yields in nontreated plots. This finding suggests that *M. graminicola* is significantly impacting rice productivity in this rotation system. A soil bioassay of rice-wheat production fields and a host susceptibility experiment were conducted in 2001 and 2002, respectively, to investigate the impact of wheat on sustaining infestation levels of *M. graminicola* in a rice-wheat rotation, and to assess the susceptibility of commonly planted wheat varieties in Bangladesh to *M. graminicola.*

MATERIALS AND METHODS

Bioassay

In 2001, soil from an area in northwestern Bangladesh (24.3°N latitude and 38.6°E longitude) dominated by a rotation of monsoon rice with irrigated wheat were bioassayed for *M. graminicola* infestation. Soil was sampled from 18 fields (16 farmer fields and two agricultural research station fields) and seven rice seedbeds in the period after wheat harvest and before transplanting of monsoon rice. There were no other soilborne diseases reported in the surveyed area.

The soils located in a high Gangetic floodplain area were calcareous, with a soil pH between 8.0 and 8.6. The soil texture was predominately silty loam. Soil organic matter ranged from 1.7 to 3.1%, and the soils were deficient in P, S, Zn, and total N. The field size ranged from 0.5 to 1.5 ha. In all fields, composite soil samples were collected in a 'W' pattern in 15 to 25 m^2 plots. The number of sampling plots within a field varied between two and six depending on the size of the field. Within each plot, approximately 4 liters of soil were collected to a depth of 8 to 10 cm using a trowel. Seedbeds were sampled similarly, except that composite samples were collected from a 5 m^2 area.

Soils were bioassayed on rice at the Bangladesh Rice Research Institute Regional Station, Rajshahi, Bangladesh. Composite soil samples from each plot were thoroughly mixed and two subsamples removed and each placed in a clay pot of 800 cm^3 in volume. Granular fertilizers consisting of triplesuperphosphate, muriate of potash, and gypsum at rates of 60, 40, and 20 kg ha^{-1} of P_2O_5, K_2O, and S, respectively, were incorporated 3 to 4 cm below the soil surface prior to seeding with ten rice, var. BR11, seeds per pot. Soluble urea was added at a rate of 30 kg N ha^{-1} on top of the soil at sowing and at 15 days after sowing. The pots were maintained outside under ambient conditions for 30 days and were watered twice daily. The emerged rice seedlings were grown under aerobic soil conditions for the duration of the test. At the end of the experiment, rice roots were washed and rated for root-galling severity on a 1 to 9 scale. A rating of 1 indicated no visible galling; ratings of 2 to 9 indicated 1-3%, 4-10%, 11-25%, 26-35%, 36-50%, 51-65%, 66-80%, and >80% of the root system was galled, respectively (Viaene and Abawi, 1996). Root-knot galling severity per plot was determined as the mean of the two subsamples.

Analysis of variance was performed on the bioassay data to test for differences in root-galling severity between two sets of fields, those previously planted in wheat compared with those that were either in short-term fallow or were previously planted in a crop other than wheat.

Host Susceptibility Experiment

Nematode eggs, recovered from *M. graminicola*-infected rice roots of one of the bioassay samples, were inoculated on rice grown in steam-pasteurized soil (60°C for 40 minutes) in a greenhouse at Cornell University. The eggs were extracted using a modified NaOCl extraction method (Hussey and Barker, 1973). Washed roots were pulse-blended in 1% a.i. NaOCl at 20-second intervals for 3 minutes in a Waring blender, and the eggs were recovered on a 25 μm sieve, and washed for several minutes with tap water to remove excess bleach. The eggs were used to establish a population of the nematode for the host susceptibility experiment, and eight mature females from this population were later subjected to perineal pattern analysis to identify the nematode to species level.

In 2002, the susceptibility of four cultivars of wheat (var. Gourab, Kanchan, Satabdhi, and Sourab) to *M. graminicola* was assessed in a greenhouse experiment at Cornell University. The rice variety BR11 was included as a control. Rice seed was obtained from the Bangladesh Rice Research Institute and wheat seed was obtained from the Bangladesh Wheat Research Center. The varieties tested in the host suitability study were selected because of their importance in rice-wheat areas of Bangladesh. The soil used in this experiment was a sandy loam with a pH of 7.1. It was obtained from the New York State Agricultural Experiment Station in Geneva, New York. The soil was steam-pasteurized, as described above, after mixing four parts of soil with one part of sand.

An 8-ml suspension containing 10,500 *M. graminicola* eggs was pipetted on the surface of soil contained in a 1.5-liter pot. After adding the inoculum to the soil surface, an additional 2 cm of soil was added to each pot to bring the soil level even with the top of the pot. The soil was watered to field capacity. One day after nematode infestation, 7 seeds, pre-germinated for 3 days, were planted in each pot at <1 cm depth. The seedlings were maintained for 48 days in a greenhouse at a mean ambient temperature of 24°C. The plants received 15 hours artificial light per day. The pots were watered twice daily and fertilized weekly with a liquid solution of Excel 15-5-15 Cal-Mag (Scotts Co., Marysville, Ohio, USA). The treatments were arranged in a randomized complete block design with six replications.

At the end of the experiment, roots were washed, weighed, and evaluated for root-galling severity on a scale of 1 to 9 as described above. *M. graminicola* eggs were extracted from a 10-g subsample of roots from each pot using the modified NaOCl extraction method. The total number of eggs per root system was considered to be the final population (Pf), and was calculated by multiplying the number of *M. graminicola* eggs recovered from the 10-g subsample by the ratio of the total root mass to the subsample mass. Host susceptibility was determined by the reproduction factor (Pf/Pi), and was described according to categories developed by Ferris *et al.* (1993). For $R > 10$, $10 > R > 1$, $R \approx 1$, $R < 1$, and $R = 0$, host susceptibility was designated as excellent, good, maintenance, poor, and nonhost, respectively. Differences in mean nematode reproduction and root-galling severity between the wheat varieties and rice were assessed with a Tukey's test.

RESULTS

The hook shape of the root galls observed in all of the bioassayed rice was consistent with the morphology of root-knot gall formation on rice caused by *M. graminicola* (Bridge, 1990). A perineal pattern analysis performed on eight females obtained from infected rice roots also positively identified this nematode as *M. graminicola.*

All of the fields and six of the seven seedbeds tested were infested with *M. graminicola.* Root-galling severity ratings of rice roots ranged from 1.5 to 7.0 with a mean of 4.8 in the field soil bioassays (Table 1), and was between 1.0 and 4.3 with a mean of 3.3 for the rice seedbed soil bioassay. Fields that were previously planted in wheat had significantly greater *M. graminicola* densities in soil, as measured by the bioassay, compared with those not previously planted in wheat ($p < 0.05$).

Rice (var. BR11) and wheat (var. Gourab, Kanchan, Satabdhi, and Sourab) were all excellent hosts of *M. graminicola* (Table 2). The mean root-galling severity ratings of these hosts ranged from 6.3 to 7.7. Rice supported higher levels of *M. graminicola* reproduction than wheat ($p < 0.05$).

DISCUSSION

Results from the bioassays demonstrated that *M. graminicola* infestation was widespread in this rice-wheat production area, but that the level of soil infestation varied substantially among the fields sampled. The high severity of root-galling on plants from fields previously planted in wheat indicates that this crop can maintain high population densities of *M. graminicola* between rice seasons. This is the first report of severe infestations by *M. graminicola* on rice-wheat production fields in Bangladesh. Previous studies from Bangladesh have reported *M. graminicola* infestations in predominately deepwater (Bridge and Page, 1982) and pre-monsoon (Miah *et al.*, 1985) rice production areas. However, the discovery of *M. graminicola* infestations in this predominately rice-wheat area of Bangladesh is consistent with reports from other rice-wheat areas of the IndoGangetic Plains region (Gaur *et al.*, 1993; 1996; Munir and Bridge, 2003; Sharma *et al.*, 2001).

The high reproduction rate of *M. graminicola* on rice and on the four varieties of wheat tested in the host susceptibility study illustrates that a rice-wheat rotation can lead to a build-up of population densities of *M. graminicola.* Moreover, the short intervals between these crops—2 to 4 weeks between rice harvest and wheat seeding, and 2 to 3 months between wheat harvest and rice transplanting—would ensure high densities of *M. graminicola* in soil at the time of initial root establishment of rice or wheat.

Other studies on *M. graminicola* have demonstrated variable host susceptibility

Table 1. Severity of root-knot galling from *Meloidogyne graminicola* in rice bioassay of soil from fields and rice nursery seedbeds in a predominately rice-wheat production area of Bangladesh, 2001.

Field	No. replications[w]	Mean RGS[x]	RGS range	Preceding crop
1	6	1.5	1-2	fallow[y]
2	3	2.3	2-4	onion
3	3	2.5	2-5	onion
4	4	2.7	1-4	fallow
5	4	4.3	3-7	wheat
6	3	4.3	3-6	wheat
7	4	4.6	1-6	lentil
8	2	4.8	4-6	wheat
9	2	5.0	5-5	wheat
10	4	5.3	4-6	sugarcane
11	4	5.3	3-7	wheat
12	6	5.6	4-6	wheat
13	2	5.8	3-9	wheat
14	4	6.0	4-8	wheat
15	4	6.5	6-7	sugarcane
16	3	6.7	4-8	wheat
17	4	7.0	6-8	wheat
18	4	7.0	6-8	wheat
Field mean		4.8		
Seedbed	No. replications[w]	Mean RGS	RGS range	
1	2	1.0	1-1	
2	3	2.8	1-5	
3	4	3.5	3-5	
4	3	3.7	2-6	
5	4	3.8	2-6	
6	3	4.0	4-4	
7	4	4.0	3-6	
Seedbed mean		3.3		

[w]The number of replications was determined by the size of the field or seedbed. A field replication consisted of a composite sample of a 15 to 25 m^2 area. A seedbed replication consisted of a composite sample of a 5 m^2 area.
[x]Root-galling severity (RGS) was rated on a scale of 1 to 9. A rating of 1 indicates no visible galling; ratings of 2 to 9 indicate 1-3%, 4-10%, 11-25%, 26-35%, 36-50%, 51-65%, 66-80%, and >80% of the root system galled, respectively. Mean differences in root-galling severity ratings between fields previously planted in wheat or not previously planted in wheat were significant at $p < 0.05$.
[y]Fallow for less than one year.

Table 2. Host susceptibility to *Meloidogyne graminicola* of selected rice and wheat varieties from Bangladesh in a greenhouse experiment.

Botanical name	Common name	RGS[w]	SE[x]	Pf[y]	SE	R[z]
Triticum aestivum	wheat var. Gowrob	6.7 a	0.6	607,689 a	136,257	57.9
	wheat var. Satabdhi	7.0 a	0.4	597,086 a	203,572	56.9
	wheat var. Kanchan	6.3 a	0.3	277,256 a	19,266	26.4
	wheat var. Sourab	7.7 a	0.5	562,229 a	164,610	53.5
Oryza sativa (control)	rice var. BR11	7.0 a	0.4	1,216,551 b	203,957	115.9

[w]Mean of six replications. Root-galling severity (RGS) was rated on a scale of 1 to 9. A rating of 1 indicates no visible galling; ratings of 2 to 9 indicate 1-3%, 4-10%, 11-25%, 26-35%, 36-50%, 51-65%, 66-80%, and >80% of the root system galled, respectively.

[x]SE = standard error.

[y]Pf = population densities of *M. graminicola* 48 days after nematode inoculation.

[z]Reproductive factor (R) was calculated as Pf divided by a Pi of 10,500. Values followed by the same letter in a column are not significantly different at $p < 0.05$, as determined by a Tukey's test.

of wheat to this nematode. Wheat varieties tested in India were reported to support poor to excellent reproduction of *M. graminicola* (Roy, 1977), whereas a Brazilian population of *M. graminicola* reproduced moderately to poorly on both wheat and rice (Siciliano *et al.*, 1990). The similar severity of root-knot galling on both rice and wheat measured in this study was consistent with that reported by Soomro and Hague (1992), while Gaur and Sharma (1999) measured two- to three- times more root-knot galling on rice than on wheat for an *M. graminicola* population from India.

There have been no reports on yield loss of wheat caused by *M. graminicola*. However, root-galling severity ratings as high as 6, on a 1 to 9 scale, were measured on wheat seedlings tested in a soil bioassay of *M. graminicola*-infested farmer fields just prior to the 2001 wheat season in Bangladesh (Padgham *et al.*, 2004). Nematode infections of this severity could exacerbate the effect of high ambient temperatures and other stress factors associated with wheat production in Bangladesh. Other plant-parasitic nematodes associated with wheat in rice-wheat areas of South Asia include *Pratylenchus*, *Tylenchorhynchus*, and *Hoplolaimus* (Sharma and Rahaman, 1997), and *M. incognita* has been reported to be associated with wheat in Bangladesh (Banu, 1997).

Crop rotations that include resistant varieties, poor-hosts, or non-hosts can be utilized as an effective strategy for reducing population densities of plant-parasitic nematodes. However, managing nematodes through crop rotation practices requires the removal of the susceptible crop from the rotation for at least 2 to 4 years (Bridge, 1998; Hirunsalee *et al.*, 1995; Rodriguez-Kabana and Canullo, 1992). Given the economic importance of rice and wheat to Bangladesh, a nematode management strategy relying on crop rotation would not be feasible for control of polyphagus species such as *M. graminicola*. Yet, substituting wheat with crops that support less reproduction of *M. graminicola*, if combined with other nematode management strategies, could reduce root-knot nematode population densities in soil and lessen its potential damage to rice.

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