POPULATION DYNAMICS OF RICE NEMATODES UNDER A SYSTEM OF RICE INTENSIFICATION

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Summary. Field experiments were conducted for two consecutive growth seasons to study the dynamics of the populations of the rice root nematode, *Hirschmanniella oryzae*, and the rice root-knot nematode, *Meloidogyne graminicola*, infecting rice under a System of Rice Intensification (SRI) in comparison with a conventional lowland irrigated cultivation system. Population densities of *H. oryzae* and *M. graminicola* were markedly influenced by the two different rice cultivation systems. In the soil, the populations of *H. oryzae* increased significantly by harvest of the second season in the conventional lowland cultivation system, but remained at low levels under SRI, while the populations of *M. graminicola* increased greatly under SRI and were low in the conventional system. In the roots, *H. oryzae* populations increased greatly in both seasons and peaked at harvest, while *M. graminicola* remained at rather low levels throughout the two seasons. The grain yield was significantly larger in SRI plots than in conventional irrigated rice plots in both seasons, by 33.3% in the first season but only 18.5% in the second season.

Keywords: *Hirschmanniella oryzae, Meloidogyne graminicola, Oryza sativa*.

Rice (*Oryza sativa* L.) is the staple food of more than two billion people, predominantly in Asia, where more than 90% of the world's rice is grown and consumed. Of the total irrigation water available in Asia, more than 90% is used to produce rice (Bhuiyan, 1992), and it is now becoming increasingly scarce. The per capita availability of water resources, which declined by 40-60% in many Asian countries between 1955 and 1990 (Gleick, 1993), is expected to decline further in future. In this context, any approach that would reduce the amount of irrigation water used without reducing the yield of rice would certainly be a welcome strategy. Recently, a rice cultivation system called 'System of Rice Intensification' (SRI) was developed by Fr. Henri de Laulanie in Madagascar, and is now being promoted in rice growing countries to reduce water usage and increase the yield potential of rice. This system is gaining popularity, especially among rice growers in Asia (Uphoff, 1999, 2003). SRI is a different way of cultivating rice, though the fundamentals remain more or less the same as in the conventional irrigated cultivation method (Uphoff, 2002). Some of the special practices followed in SRI, which permit great root growth and better tillering, consist of transplanting single 12 to 14-day-old seedlings per hill at a wider spacing in a square arrangement, use of a mechanical weeder, alternate wetting and drying in the irrigation schedule, and need-based nutrient applications (Uphoff, 2001; Gujja *et al*., 2008). SRI has dramatic effects on yield, generally raising it by 50-100% and sometimes even more (Rajendran *et al*., 2003; Uphoff, 2007).

However, any change in cultivation system has a concomitant effect on the rice ecosystem and associated biological communities. Plant parasitic nematodes are an important component of the microfauna associated with the rhizosphere of rice plants, which needs to be studied under the SRI cultivation system. More than 35 genera and 130 species of plant parasitic nematodes have been found associated with rice (Gerber *et al*., 1987; Bridge *et al*., 2005). Among them, the root-knot nematode, *Meloidogyne graminicola* Golden *et* Birchfield and the rice root nematode, *Hirschmanniella oryzae* Van Breda de Haan are the major species affecting rice production in India (Prasad *et al*., 1987; Prasad and Gubbaiah, 2006). Hence, an investigation was undertaken at the Agricultural College and Research Institute (Tamil Nadu Agricultural University), Killikulam during 2006-2007 to monitor the population dynamics of *H. oryzae* and *M. graminicola* under SRI in comparison with a conventional lowland irrigated rice cultivation system.

MATERIALS AND METHODS

Two identical paired field trials were conducted at the same locations over two consecutive growth seasons, the Kharif season 2006 (June 2006-September 2006) and the Rabi season 2006 (November 2006-February 2007), using an irrigated transplanted rice production system with two treatments: SRI cultivation and conventional lowland irrigated rice cultivation. The field was naturally infested with *H. oryzae* and *M. graminicola*. Soil texture was clay loam (44% clay, 37% silt, 19% sand, pH-8.5, CEC-11.2 c mol (p+)/kg, organic carbon 3.2 g/kg, electrical conductivity 0.52 dS/m, low in avail-

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able N (215 kg/ha), medium in P (16.5 kg/ha), high in K (275 kg/ha), available Ca 7.6 c mol/kg, Mg 0.92 c mol/kg, Zn 0.56 ppm, Fe 1.01 ppm, Mn 0.70 ppm and Cu 0.20 ppm).

Seeds of the rice cultivar, ADT 43, used in the experiments were obtained from the Central Farm Unit, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Killikulam, India. The seeds were surface disinfested by dipping in 1% $Ca(OCl)_2$ for 15 minutes and sown in the rice nurseries laid out at sites free from nematodes. Rice seedlings were transplanted into plots measuring 4 m × 5 m and each plot was separated by raised bunds, leaving 0.5 m spaces between each plot. There were ten replicated plots per treatment, according to Student's *t*-test design.

Agronomic practices followed for the two treatments were as follows:

In the SRI cultivation system, a modified mat nursery according to Thiyagarajan (2003), was used to raise seedlings. Fourteen-day-old seedlings were transplanted; one seedling per hill was planted fairly shallowly (1-2 cm deep) at 20 cm × 20 cm spacing. The recommended dose of fertilizer (120:38:38 kg of NPK/ha) was applied to the field. The entire recommended dose of P_2O_5 (super phosphate) and 50% of K_2O (potash) were applied as a basal fertilization at the time of the last puddling before transplanting. The N fertilizer was applied based on crop needs as determined from a leaf colour chart (LCC). Ten days after transplanting (DAT), the LCC reading attained level 3. Hence, the N fertilizer, as urea at 40 kg N/ha, was applied. The second dose of N fertilizer at 30 kg N/ha as urea was combined with the remaining 50% of K_2O (potash) and applied at 30 DAT. The same quantity of N was applied as a third top dressing at 50 DAT, based on the LCC. Weeding was done with a hand-operated rotary weeder four times at 10-day intervals, starting 15 DAT. During the early stages of crop growth, irrigation water was let in to a depth of 2 cm and the next wetting was given to the same level only when hairline cracks had appeared in the field. At the later stages (from panicle initiation), 2 cm deep water was maintained at all times.

In the conventional lowland irrigated rice cultivation system, a conventional nursery as per farmers' practice was used to raise seedlings. Twenty-five-day-old seedlings were transplanted, with multiple seedlings per hill at a 20 cm × 10 cm spacing. The recommended dose of fertilizer (120:38:38 kg of NPK/ha) was applied to the field. The entire recommended dose of P_2O_5 (super phosphate), 50% of K_2O (potash) and 25% of N (urea) were applied as a basal fertilization at the time of the last puddling before transplanting; the remaining 75% of the recommended dose of nitrogen was applied as three equally split doses of urea at tillering, panicle initiation and flowering stages. The remaining 50% of K_2O was applied along with the urea at panicle initiation stage. Weed management involved three rounds of hand weeding at 15-day intervals starting 30 DAT. A normal flood irrigation regime of 5 cm deep water was followed up to the grain maturity stage.

The nematodes in 100 cm^3 sub-samples of soil, taken from larger samples collected from each plot, were identified and counted at planting (Pi), tillering, panicle initiation, flowering and harvesting (Pf) stages. Each sample was a composite of ten cores collected to a depth of 15-20 cm from random positions in the rhizosphere of the plants from each plot. These cores were pooled into a composite sample and a 100 cm^3 sub-sample was collected by quartering. Samples were processed for extraction of nematodes by Cobb's sieving and decanting technique, followed by a modified Baermann's funnel technique (Southey, 1986). The nematodes extracted were fixed in 4% formalin and mixed life stage populations of *H. oryzae* and second stage juveniles of *M. graminicola* were counted in a counting dish under a stereo-microscope.

At planting, tillering, panicle initiation, flowering and harvesting stages of the crops, roots from five randomly selected plants of each plot were taken and combined as a composite sample, washed free of adhering soil and a one-gram sub-sample used to estimate the root populations of both nematodes. For this, the roots were stained in boiling acid fuchsin-lactophenol for two minutes, washed in tap water and kept in plain lactophenol for 48 h at room temperature (28 ± 5 °C). Then numbers of mixed life stages of *H. oryzae* (II, III, IV and adult) and of *M. graminicola* (III, IV and adults) were counted. Also, the root gall indices of the five plants randomly selected at harvest were assessed according to a 0-5 scale, where 0 = 0% galled roots; 1 = <10%, 2 = 10-25%, 3 = 25-50%, 4 = 50-75% and 5 = >75% galled roots (Soriano *et al.*, 2000).

The crops were harvested 105 DAT and grain yield was recorded from all plots. Data from SRI and conventional rice systems were compared using Student's *t*-test following Panse and Sukhatme (1989).

RESULTS

The population densities of *H. oryzae* and *M. graminicola* were markedly influenced by the two different rice cultivation systems. *Hirschmanniella oryzae* developed better in the conventional lowland irrigated rice cultivation system but remained at low levels in SRI plots (Figs 1 and 2). SRI was more favourable to *M. graminicola* than to *H. oryzae*. During the Kharif season (first season), the population density of *H. oryzae* in the soil did not significantly change from the planting to the panicle initiation stage under either system of rice cultivation (Fig. 1). But at flowering and harvesting, the population of *H. oryzae* increased significantly in the conventional rice cultivation system. The population of *M. graminicola* was significantly larger in SRI at tillering, panicle initiation, flowering and harvesting stages than in the conventional rice cultivation system. During the Rabi sea-

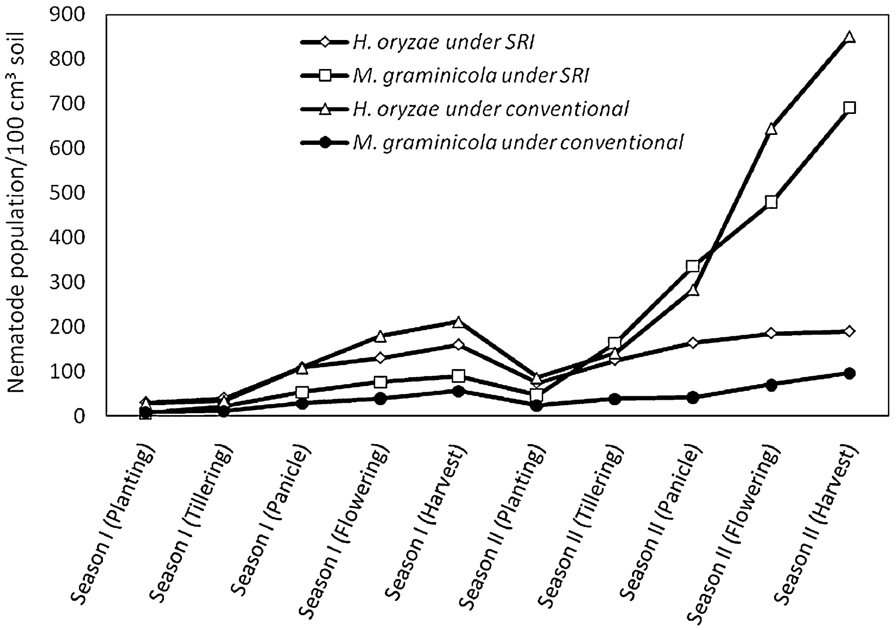

Fig. 1. Population dynamics of rice nematodes in soils under SRI and conventional rice cultivation systems.

son (second season), up to the tillering stage, the populations of *H. oryzae* did not change, but from panicle initiation to harvest they increased significantly in the conventional system. However, the populations of *M. graminicola* were significantly larger than those of *H. oryzae* in SRI throughout the second season. Similar trends were observed for the nematode population densities in rice roots (Fig. 2). Root population densities of *H. oryzae* increased markedly during both seasons and reached levels of 323.0 and 488.3 specimens/g roots by harvest of the first and second seasons, respectively, under the conventional irrigated cultivation system, while they remained at low levels under SRI. The population density of *M. graminicola* in rice roots increased steadily in both seasons, reaching 117.7 specimens/g roots under the SRI cultivation system but only 25.5 specimens/g roots under the conventional irrigated cultivation system.

The root gall indices were 2.1 and 4.3 in SRI and only 1.3 and 1.8 in conventional rice cultivation, at harvest of the first and second seasons respectively.

The grain yield ranged from 5,750 to 6,800 kg/ha in

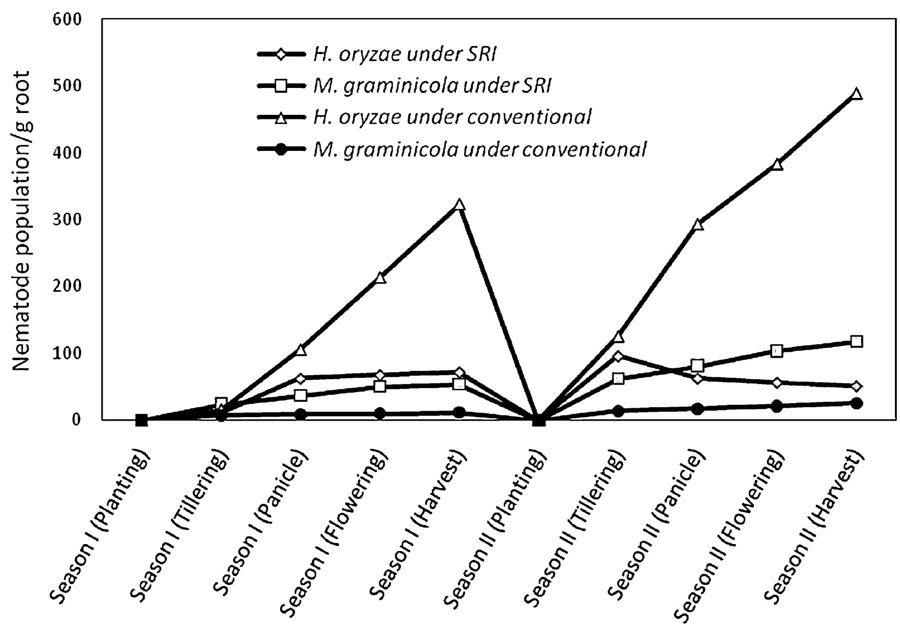

Fig. 2. Population dynamics of rice nematodes in rice roots under SRI and conventional rice cultivation systems.

SRI and from 4,850 to 5,100 kg/ha in conventional rice cultivation; it was significantly greater in SRI than in conventional rice cultivation in both seasons, with increases in SRI over conventional rice cultivation of 33.3% in the first season but only 18.5% in the second season.

DISCUSSION

Hirschmanniella oryzae and *M. graminicola* are common plant parasitic nematodes associated with irrigated rice systems, but *Hirschmanniella* spp., which are specialized to thrive under anaerobic ecosystems, are commonly predominant. Both nematodes occur in irrigated rice and they also multiplied under SRI. However, the population levels varied significantly between the two nematodes and cropping systems. The greater increase of *M. graminicola* in SRI plots than in conventional irrigated rice plots indicates that SRI is more favourable to this nematode. Previous studies in India have reported that *M. graminicola* infestations are common in upland aerobic rice (Sharma, 2001), semi-deep water rice (Jairajpuri and Baqri, 1991) and semi-irrigated rice (Prasad *et al.*, 2006) production areas. This is the first report of predominance of *M. graminicola* under SRI and it is consistent with reports of Prasad *et al.* (2008), who hypothesized that switching to SRI might result in a gradual decline in populations of rice root nematode species, which prefer irrigated systems, and an increase in populations of more pathogenic species such as root-knot and lesion nematodes, which prefer upland and aerobic environments. Our results support this hypothesis. Fortuner and Merny (1979) reported that *M. graminicola* is found in irrigated paddy fields, but this relationship is doubtful as this nematode is known to be very susceptible to flooding, and is most probably associated with plants growing when the field is free of water as in upland rice. The alternate wetting and drying and weeding by a hand-operated rotary weeder that is followed under SRI results in alternating periods of aerobic and anaerobic soil conditions, and this might have permitted the multiplication of *M. graminicola*. In clay loamy soils, as in our field experiments, the penetration of *M. graminicola* into rice roots is best when soil moisture content is 32% on a dry weight basis and its further development is favoured by soil moisture contents of 20 to 30% followed by alternating periods of soil dryness (Rao and Israel, 1971).

This study showed that SRI has the potential to increase grain yield of rice, thus confirming previous findings (Oprety, 2006; Thiyagarajan, 2006; Vijayakuymar *et al.*, 2006). *Meloidogyne graminicola* is relatively more pathogenic and causes more severe yield loss than *H. oryzae* in rice (Fortuner and Merny, 1979). Therefore, the greater increase of *M. graminicola* in the soil in the second season might have contributed to the reduced yield under SRI in the second crop. Hence, any transition from a traditional irrigated system to SRI may be threatened by increased populations of this nematode. Sustaining the higher yield of SRI will require attention to be paid to management strategies for *M. graminicola*; this method of cultivating rice would therefore be more appropriate where *M. graminicola* is not present. However, further research to elucidate the role *of M. graminicola* in reducing the yield potential of rice under SRI cultivation system would be helpful.

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