

EFFECT OF ZERO TILLAGE ON THE NEMATODE FAUNA IN A RICE-WHEAT CROPPING SYSTEM¹

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Summary. Field observations and field experiments were conducted in Meerut, Baghpat and Saharanpur districts of western Uttar Pradesh, India, in 2003-2006, to investigate the effects of tillage and no tillage, in a rice-wheat cropping system, on soil nematode population densities, yield of wheat and numbers of weeds at harvest time of the wheat. In the fields used for the observations, at both sowing (November) and after harvest of the wheat crop (March/April), zero-tillage fields had population densities of plant parasitic nematodes (*Tylenchorhynchus brevilineatus* and *Pratylenchus* spp.) larger than those of conventionally tilled fields. In the field experiments, ploughing decreased nematode population densities significantly, irrespective of fertilizer application. The plots kept fallow (no ploughing + no fertilizer + no crop) had the lowest final population densities of *T. brevilineatus* (205/200 cm³ soil). When wheat was grown without disturbing the soil and without fertilizer application, the nematode soil population density was greatest (779/200 cm³ soil). The multiplication rate of the nematode was highest ($\times 3.6$) in the no ploughing + no fertilizer + wheat crop treatment, followed by the ploughing + fertilizer + wheat crop treatment. There were more plants of the weed *Phalaris minor* in the conventionally grown than in the zero-tilled crop.

Key words: Nematode management, *Oryza sativa*, *Pratylenchus* spp., *Triticum aestivum*, *Tylenchorhynchus brevilineatus*.

Different cropping systems, involving different yearly sequences of specific crops or fallow in a given area, create conditions of varying favourability for microbes, plant parasitic and free living nematodes and weeds, and thus affect the fauna and flora both qualitatively and quantitatively (Taylor, 1971; House and Parmelee, 1985; Minton, 1986). A rice-wheat cropping system is practised by farmers of the Indo-Gangetic plains, over an area of about 2.7 million ha. Zero- or no-tillage systems allow early and timely sowing of wheat (Tomar *et al.*, 2006) and reduce the cost of production through less use of fossil fuels and herbicides, etc. In zero tillage, wheat crops are planted with minimum disturbance of the soil by placing the seeds in a narrow slit (3-4 cm wide and 4-7 cm deep) without any land preparation. The introduction of no-till and other resource conservation technologies into the rice phase of the rice-wheat system has the potential to further increase long-term profitability of Indian farms.

The nematode community structure varies in time and space, both in zero/minimum tillage and in conventionally tilled soil (Anonymous, 2000; Dabur, 2001). Puddling of soil prior to planting paddy rice significantly reduces

the population densities of root-knot nematode, *Meloidogyne graminicola* Golden *et* Birchfield, *M. tritico-ryzae* Gaur, Saha *et* Khan, stunt nematode, *Tylenchorhynchus mashoodi* Siddiqi *et* Basir (Gaur and Singh, 1993). The impact of tillage practices, in contrast to a no tillage/conservation system, on nematode populations has been inconsistent on various crops, perhaps due to the larger effects of weeds, soil structure, nutrition and other factors on crop growth (Barker and Koenning, 1998). Other factors too, such as soil type, temperature, moisture, nematode species etc., may also determine the effect of tillage on nematode populations. The long term effects of zero tillage technology on biotic (insect pests, pathogens and nematodes) factors needs thorough investigation. Therefore, the present study was undertaken to observe the effect of zero tillage on the wheat crop and plant parasitic nematode populations under a rice-wheat cropping system in western Uttar Pradesh.

MATERIALS AND METHODS

The farmer fields selected for the experiments were infested with the plant parasitic nematodes *Pratylenchus* spp. and *Tylenchorhynchus brevilineatus* Williams, along with various species of free living nematodes. The weed *Phalaris minor* Retz was also present.

Field observations were made during the period 2003-2006 in farmers' fields in the rice-wheat growing areas of western Uttar Pradesh. The aims were to assess the effects of two cropping systems on nematode popu-

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lation densities, yield of wheat and weed densities. Soil samples (5 cores) of 1000 cm³ were taken in three different villages in November (before sowing) and April (at harvest time of the wheat crop), for three consecutive years, from five fields of both conventionally grown and zero-tilled crops in Meerut, Baghpat and Saharanpur districts of western Uttar Pradesh. The selected fields were permanent sites of zero tillage in wheat, maintained by the Project Directorate for Cropping System Research, Modipuram, Meerut. A total of 30 samples per year (15 each from conventionally grown and zero-tilled fields) were collected. Each sample was mixed in a 24-inch plastic bowl and a sub-sample of 200 cm³ was processed by Cobb's sieving and decanting method (Cobb, 1918). The nematodes in the water suspension were examined in three 1-ml aliquots under a stereo-microscope and the predominant plant parasitic nematodes identified to species and genus level and counted. Nematodes other than plant parasitic nematodes, categorized as free living nematodes, were also counted. The average populations of these nematodes, for the three years of observations, were then calculated.

The population density of the weed *P. minor* was recorded on the 30th day after sowing wheat in a one square metre area from five positions (at the four corners and in the centre of each field) in the conventionally grown and zero-tilled fields in the three districts and the average value for the three years determined.

Wheat was harvested by hand during April of each year from 2004 to 2006 from all of the selected fields (size ranging from 0.5 to 2 ha) and grain yield was recorded and the three year average expressed as q (quintals)/ha.

The data collected from these fields were statistically analyzed and compared using the "t" test at 5% probability.

Field experiments were conducted in two farmers' fields in a village in Meerut district in the 2005-2006 season. The aim was to ascertain the effects of combinations of the tillage systems with fertilizers and fallow on the nematode soil population densities. The following treatments (Table I) were arranged in a randomized block design and replicated seven times: Ploughing + Fertilizer (NPK: 120 kg N; 60 kg P₂O₅; 40 kg K₂O kg/ha) (recommended dose) + no crop; Ploughing + Fertilizer + Wheat Crop; Ploughing + No Fertilizer + Wheat Crop; No Ploughing + No Fertilizer + Wheat Crop and No Ploughing + No Fertilizer + No Crop (control). The no ploughing treatment was the zero-tillage system, wherein wheat (*Triticum aestivum* L., cv. HD 2285) was sown directly into the rice (*Oryza sativa* L.) stubble using a zero-till seed drill set at a row spacing of 20 cm without prior land preparation. In the plots of the other treatments, wheat was sown after ploughing and appropriate land preparation. Wheat was sown at the rate of 100 kg/ha using a seed-cum-fertilizer drill at a row spacing of 20 cm. This gave 29 rows in the 6 x 4 m plots, which were managed by the farm-

ers once the treatments had been applied. Soil samples (1000 cm³), made up of five cores per plot, were collected randomly to a depth of 30 cm after removing the upper soil crust or the debris, in November (initial population) and March-April (final population, after harvest of the wheat crop). Each sample was mixed thoroughly and a sub-sample of 200 cm³ was processed and counted as described above. Multiplication rates [Final population (Pf)/Initial Population (Pi)] were calculated for the predominant *T. brevilineatus*.

Data collected from different plots (pooled from the two farmers' fields) were statistically analyzed and subjected to analysis of variance (ANOVA) using MSTAT-C software (Michigan State University Version 2.1).

RESULTS AND DISCUSSION

In the observations from the fields during 2003 to 2006, at sowing (November) and after harvest (March/April) of wheat, the zero-tillage fields had population densities of the plant parasitic nematodes *T. brevilineatus* and *Pratylenchus* spp. significantly greater than those of conventionally tilled fields (Fig. 1). This could be attributed to the fact that in the conventionally tilled fields the nematodes are exposed to adverse environmental conditions. Also, the presence of more root biomass during the later stages of crop growth (Tomar *et al.*, 2003) may have increased the reproduction rate of the nematodes. Conservation tillage, and particularly zero tillage, reduces disturbance of the soil, increases organic matter content, improves soil structure and buffers soil temperatures. Farmers who utilize these methods only disturb their soil once or twice a year, when it is necessary (i.e. at seeding). When the soil is disturbed more frequently in conventional tillage, it may affect the reproduction of the soil flora and fauna and their population densities. House and Parmelee (1985) found that soil cultivation affects soil fauna in both quality and quantity.

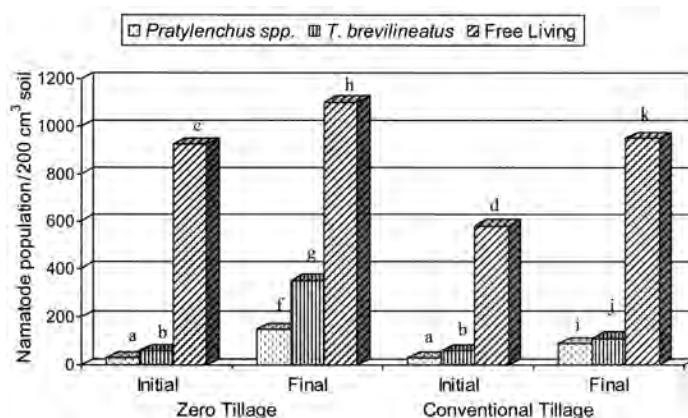


Fig. 1. Effect of zero tillage and conventional tillage on nematode populations in wheat crops in rice-wheat cropping systems. Bars with the same letter are not significantly different ($P \geq 0.05$). (Averages of three years of field observations).

Our results conform with those of Minton (1986) and Ornat *et al.* (1999) in intensive vegetable-based cropping sequences. However, Cabanillas *et al.* (1999) observed that the free living nematode population decreased while the population of *Rotylenchulus reniformis* Linford *et* Oliveira increased in a no-till environment.

The percentage increase of the nematode population in our experiment was greater in the wheat crop with no-tillage followed by the wheat crop with ploughing. These results conform with findings of other workers (Stinner and Crossley, 1982). An increase of nematode populations, though small, was also observed in plots with no wheat crop, which could be due to the presence of weeds that might have acted as nematode hosts. Species of nematodes other than plant parasites are also found abundantly in agricultural soils, including fungal feeders, bacterial feeders, algal feeders, omnivores and carnivores. No definite trend was observed in these investigations of the population densities of free living nematode species in relation to the treatments. Similar results under zero tillage conditions were reported by Dabur (2001).

With early planting, seeds of wheat germinate and the crop covers the soil before the germination of *P. minor*, a weed that has developed resistance to the common herbicide isoproturon in the northwest of India (Walia *et al.*, 1997). The occurrence of root-knot nematodes on monocotyledonous weeds has been reported in rice-wheat cropping systems (Gaur *et al.*, 1993). These weeds are good hosts for the nematodes and thus increase their multiplication and the damage they may cause to the next crop. The weed *P. minor* germinates only when temperatures drop below a critical level after mid-November. Also, as soil disturbance is very little in zero tillage compared to conventional tillage, fewer weeds germinate and the weed seed stock remains buried in the plough layer (Fig. 2). Thus, an effective weed management strategy is provided for wheat production in the rice-wheat cropping system. Furthermore, there was no significant difference in the yield of wheat (q/ha) between zero-tillage and conventional tillage fields. This may be due to less weed competition and negligible or no loss of yield due to the presence of nematodes in these fields.

In the field experiments, there were no significant differences in the initial population densities of *T. brevilineatus* after harvest of the rice crop (i.e. before sowing the wheat) (Table I). The nematode population density increased irrespective of whether the wheat was grown with or without fertilizers or in ploughed or non-ploughed plots. Fertilizers improve wheat growth and root biomass, which in turn increases the nematode population. The nematode populations in the ploughed plots that grew a wheat crop were significantly less than those in unploughed plots that grew wheat, irrespective of whether fertilizer was applied to the ploughed plots. Defrancq (1993) reported that tillage reduced the nematode population as it disturbs soil ecology and especially

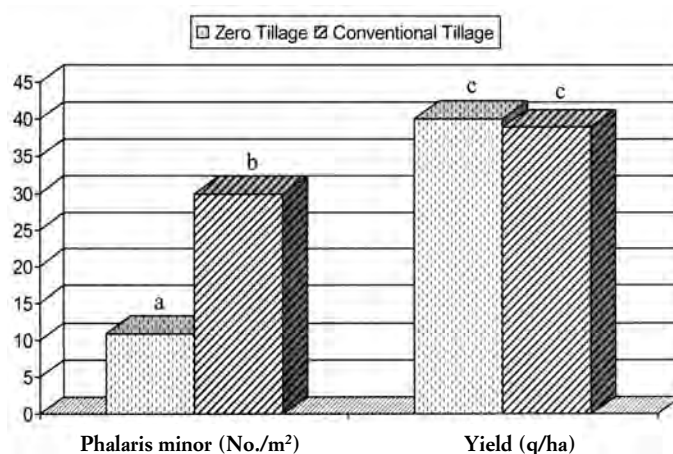


Fig. 2. Effect of zero tillage and conventional tillage on the number of plants of *Phalaris minor* and yield of wheat (q/ha), under farmers' field conditions. Bars with the same letter are not significantly different ($P \geq 0.05$). (Averages of three years of field observations).

soil moisture. Plots that were kept fallow (no ploughing + no fertilizer + no crop) had the lowest final population density of *T. brevilineatus* (205/200 cm³ soil). When wheat was grown without disturbing the soil, and without fertilizer application, the population density of this nematode was greatest (779/200 cm³ soil). The multiplication rate of *T. brevilineatus* was greatest ($Pf/Pi = 3.61$) in plots with the no ploughing + no fertilizer + wheat crop treatment, followed by plots with ploughing + fertilizer + wheat crop, i.e. the tillage regime normally used by the farmer.

Fallow with tillage reduced the population density of *Meloidogyne arenaria* (Neal) Chitw. and *Pratylenchus neglectus* (Rensch) Filipjev *et* Schuurmans Stekhoven in a vegetable-based cropping system (Ornat *et al.*, 1999). However, these decreases were not correlated with the length of the fallow period. Further, untilled soil had a greater population of *P. neglectus* infected by *Pasteuria penetrans* (Thorne) Sayre *et* Starr in comparison to tilled soil. Thus, untilled soil may also protect obligate parasites such as *Pasteuria penetrans*, whereas a density dependent relationship between *Pratylenchus penetrans* and its host plant has been reported. Singh *et al.* (2002) found that the population density of soil fungi was greater in conventional tillage than in no-till fields in Haryana (India) at the crown root initiation (CRI) and dough stage of wheat, while no consistent trend was observed in paddy rice.

In general, farmers plough the soil six and nine times for wheat sowing. By using zero tillage (ZT), 2000-2500 Indian Rupees (Rs.)/ha (= \$ 42.5 – 53.2/ha) may be saved due to the reduced cost for land preparation in ZT and there is also an increase in yield when ZT is used. Considering all of the above, a net return greater by Rs. 2500-3000/ha (\$ 53 – 63.8/ha) may be obtained with the use of ZT in comparison to conventional tillage. Moreover, the seed rate per ha is also marginally

Table I. Effects of tillage and other inputs on the population of *Tylenchorhynchus brevilineatus* under wheat (Pooled data of two fields).

Treatment	Initial population (Pi)/200 cm ³ soil	Final population (Pf)/200 cm ³ soil	Pf/Pi
Ploughing + Fertilizer + No crop	180 (13.41)	212 (14.56)	1.17
Ploughing + Fertilizer + Wheat Crop	160 (12.65)	450 (21.21)	1.81
Ploughing + No Fertilizer + Wheat Crop	178 (13.34)	302 (17.38)	1.69
No Ploughing + No Fertilizer + Wheat Crop	169 (13.00)	779 (27.91)	3.61
No Ploughing + No Fertilizer + No Crop	188 (13.71)	205 (14.31)	1.09
CD (P = 0.05)	NS	(3.9)	

Figures in parentheses are square-root transformed values.

less in zero tillage (average: 90-110 kg/ha) than in conventional tillage (average: 100-115 kg/ha), with no difference in wheat yield between the two (Fig. 2).

Although the net returns were higher in zero-tilled fields, the nematode population density was also rather higher (but with negligible or no yield loss), and populations would probably increase further in wheat if zero tillage were widely adopted by farmers in the future. However, the nematodes mentioned are not of major concern in wheat grown in western Uttar Pradesh region of India, and are used here simply as model species to illustrate the potential for tillage systems to affect the nematode fauna in agricultural soils.

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