LONG-TERM RESPONSE OF ZERO-TILLAGE SOIL FUNGI, NEMATODES & DISEASES OF RICE-WHEAT SYSTEM

Ram Singh, Kali Ram Dabur and R. K. Malik

Regional Research Station, Kaul
Department of Nematology
and
Directorate of Extension Education
CCS Haryana Agricultural University, Hisar-125 004, India

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Cover Page :-
Left : Rice panicles infested with false smut.
Right : Rice roots infested with root-knot nematode.

Authors :
Ram Singh, Regional Research Station, CCS Haryana Agricultural University, Kaul.
Kali Ram Dabur, Department of Nematology, CCS Haryana Agricultural University, Hisar.
R. K. Malik, Director of Extension Education, CCS Haryana Agricultural University, Hisar.

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INTRODUCTION

Zero tillage technology for planting wheat after rice is presently gaining popularity amongst the farmers in the Indo-Gangetic Plains of India, Pakistan, Nepal and Bangladesh due to its apparent advantage of timely planting of wheat within short turn–around time and reduction in cost of production. The conservation tillage had been a common practice in Arkansas, USA by rice growers primarily for economic and soil conservation reasons. It has also been widely adopted over the past 20 years in Australia and several other countries. Conservation tillage has been found to influence the population of soil fungi and nematodes occurring in rice-wheat system. Many plant pathogens increase to damaging level under zero tillage conditions and become major constraints to efficient profitable farming while others are reduced to a considerable extent or not affected at all. Leaving plant debris on the surface or partially buried in the soil may allow a number of pathogens to overwinter or survive until next crop is planted but conditions favourable for biological control of plant pathogens may also be increased (Sumner *et al*., 1981).

Of various diseases and nematodes known to attack rice and wheat crops in rice-wheat sequence in Haryana, the important ones are as under.

A. RICE DISEASES

I. Bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*)

The disease appears in two phases i.e. wilt or kresek and leaf blight. The earlier and more damaging phase is kresek, which occurs in seedlings to early tillering stage. The leaves turn yellow or grey, roll, droop and the tillers dry up completely. It resembles the stem borer damage ‘dead heart’ but differs from it by presence of yellowish bacterial ooze, which can be observed by cutting off lower part of the plant and squeezing it in between the fingers. Leaf blight phase generally occurs from maximum tillering onwards as water soaked linear stripes with wavy margins on the leaves. The stripes start from the tip on one or both margins, occasionally from centre of the leaf, extend downward and turn yellow to straw coloured. Later the leaves dry and blighting may extend to leaf sheath in susceptible varieties. In early morning/humid weather small yellow droplets of bacterial ooze can be seen on the affected leaves, which dry up to form small yellowish beads.

II. Blast (*Pyricularia grisea*, teleomorph: *Magnaporthe grisea*)

The disease appears on leaves, nodes, neck of the panicles and grains. Small bluish flecks, 1-3 mm in size are produced on the leaves, which enlarge into spindle shaped spots with dull greyish green centre and dark brown margin. They may grow several centimeters in length and up to 1 cm in width (leaf blast). Brown to black spots are produced on the nodes and in severe cases culm may break at this region (node blast). Similar spots are produced on the neck region of the panicle resulting in the production of dirty white panicles with shriveled or chaffy grains (neck blast). Brown coloured spots are also produced on panicle branches and grains. The fungus also infects the collar of leaf and leaf sheath and kills the entire leaf blade.

Leaf blast

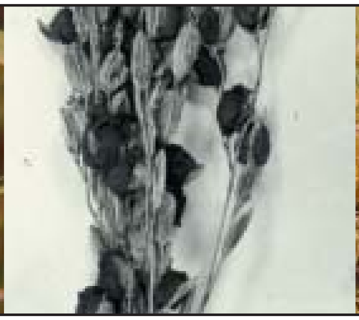
Node blast

Neck blast

III. False smut (*Ustilaginoidea virens*, teleomorph : *Claviceps oryzae sativae*)

The disease appears after the emergence of the panicles. Ovaries of few florets in a panicle are transformed into large velvety spore balls. The spore balls are initially small, flattened, smooth, light yellow and remain confined between the glumes. Later the smut balls increase in size up to 1 cm or more and the colour changes from orange to yellowish green, green, olive green and finally to greenish black. The centre of the spore ball is off white. The grains adjacent to smut balls usually remain chaffy.

Yellow spore balls



Black spore balls

Field view

IV. Foot rot & bakanae (*Fusarium moniliforme*, teleomorph: *Gibberella fujikuroi*)

The most conspicuous and common symptoms are the bakanae symptoms *i.e.* abnormal elongation of the plant, which may be observed both in nursery as well as in field. The affected plants become pale, lanky and taller than healthy plants. Such plants usually die before maturity and if survive may bear panicles with chaffy grains. Production of adventitious roots on lower internodes and presence of white to pinkish fungal growth on dying plants are other diagnostic features of the disease.

Pale lanky plant

Field view

White fungal mycelium

V. Stem rot (*Sclerotium oryzae*, teleomorph: *Magnaporthe salvinii* = *Leptosphaeria salvinii*, anamorph: *Helminthosporium sigmoideum*)

The disease appears as small, blackish irregular lesions on the outer leaf sheath near the water level at maximum tillering stage. As the disease advances, infection reaches to culm of the plants causing rotting of the stem which leads to premature lodging of the crop and production of partially filled or chaffy grains. On split opening the infected culm, white grey mycelium and numerous small, round, black sclerotia of the fungus are observed in lower 2-3 internodes.

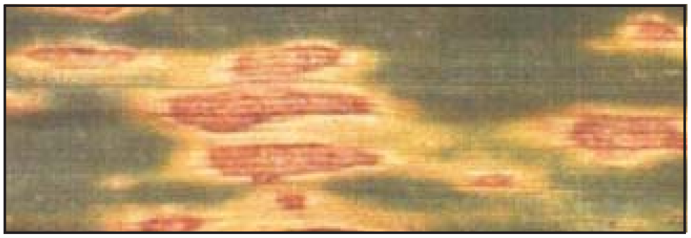
Black lesions on leaf sheath

Lesions on culms & fungal scleroeia

B. WHEAT DISEASES

I. Leaf blight (*Alternaria triticina, Bipolaris sorokiniana* (=*Drechslera sorokiniana*, teleomorph: *Cochiliobolus sativus*)

Small oval, chlorotic lesions are found irregularly scattered on leaf blade. Later the spots increase in size, assume irregular shapes, turn brown to grey and may have yellow margin. The lesions progressively develop from lower to upper leaves and blighting may extend to ear heads and leaf sheaths. In some cases the leaves start drying from the tip. Under humid weather black powdery conidia of the fungus are visible on the lesions. The disease is more severe in areas where humidity and soil moisture are high.



II. Brown rust or leaf rust (*Puccinia recondita*)

Small oval, orange-brown uredopustules are produced on all aerial plant parts, being more frequent on leaves. The pustules are found scattered on upper surface of leaves. These are bigger than those in yellow rust (1 x 1-2 mm in diameter) and burst early exposing the spore mass. When leaves become senescent, a green island develops around individual pustule. Towards the end of crop season, dark telia may or may not develop on lower surface of leaves.

III. Karnal bunt or partial bunt (*Tilletia indica* Syn. *Neovossia indica*)

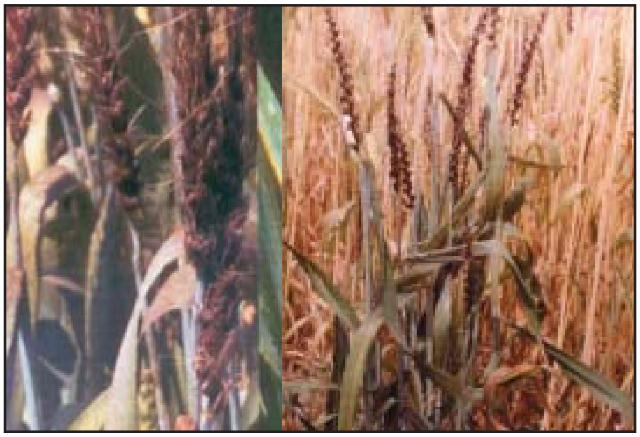
The disease becomes evident after grain formation. Due to infection at flowering stage few grains in an ear are partially converted into black fungal spore mass. Generally the infection spreads along the groove of the grain covering 1/4th, 2/4th, 3/4th of the endosperm or some times entire endosperm with only pericarp being intact. As the grains mature, infected grains spread out glumes. At harvesting and threshing pericarp ruptures removing spore mass resulting in boat shaped partially affected grains. In case of severe infection the embryo is also damaged. The infected grains give fishy odour due to production of trimethylamine.

IV. Powdery mildew (*Erysiphe graminis* f. sp. *tritici*)

The symptoms appear on leaves, stem, sheath and the ear as superficial grayish white powdery mass consisting of fungal mycelium and conidia. The white powdery mass on leaves later turns brownish studded with black dot-like fruiting structures (cleistothecia) resulting in their premature drying. Chlorotic patches normally appear on the leaf surface directly opposite mildew colonies. Infected plants lose vigour and their growth, heading and grain filling is impaired. The rate of transpiration and respiration is increased while photosynthesis is decreased.

V. Loose smut (*Ustilago segetum* var. *tritici*)

The most conspicuous symptoms of loose smut appear after heading. However, in few cultivars particularly Sonalika, characteristic yellowing and chlorotic streaks have been observed on flag leaves before emergence of smutted panicles. Normally all ear heads in an infected plant are converted into a dry, olive black teliospore mass. However, occasionally some tillers escape infection and produce normal ears. The smutted spikes generally emerge earlier than healthy ones. Initially the spore mass is covered by a delicate translucent membrane which ruptures exposing powdery spore mass that is blown off by wind leaving behind a bare rachis.



C. NEMATODES

I. Rice root-knot nematode (*Meloidogyne* species)

M. graminicola species of root-knot nematode is a pest of rice-wheat cropping system. It is prevalent in upland, lowland and deepwater rice. Wheat is also host of this nematode, though not a very good host. The nematode causes swellings and galls throughout the root system. Infected root tips become swollen and hooked. Its high population in the field can cause severe growth reduction, chlorosis, wilting, reduced tillering, unfilled spikelets and poor yield.

Nematode infected hooked root

Field view

II. Rice root nematode (*Hirschmanniella* species)

There are no easily identifiable above-ground symptoms of nematode damage in the field. Retardation of growth in early stage, occasional yellowing, delayed flowering, turning of roots brown and rotting are some of the important symptoms. It is present in approximately 60% of the rice fields causing about 25% yield losses.

III. Wheat Seedgall Nematode (*Anguina tritici*)

The disease caused by this nematode is known as '*ear-cockle', 'Gegla', 'Sehun'* or *'Mumni'* in wheat. Infected seedlings show basal swellings of the stem, crinkling and curling of leaves. Earhead formation may be preponed. The affected earheads are shorter and broader. The glumes may be loosely arranged. If the infestation of cockles in the wheat seeds is more than 5%, there is significant loss in quality of flour.

IV. Cereal cyst nematode (*Heterodera avenae*)

This nematode causes *'Molya'* disease of wheat and barley. Patches of stunted plant growth and chlorosis appear when the crop is about 1-2 month old. Tillering is greatly reduced. The affected plants may flower prematurely and earheads bear fewer grains. In severe infestation, there may not be any grain formation.

Factors affecting population of soil fungi, nematodes and plant diseases

Tillage practices directly influence the physical and chemical properties of the soil, root growth, nutrient uptake and population of other soil microorganisms, which ultimately affect the viability and activity of the plant pathogens and susceptibility or resistance of the host. Changes in soil temperature, moisture, aeration, compaction, porosity, plant nutrients, pH and organic matter brought about by the tillage practices greatly influence the incidence and severity of plant diseases. Increased soil moisture can reduce the diseases through reducing the plant water stress or compaction can predispose the host to infection and disease development. High soil moisture can also increase the disease through increasing mobility of the pathogens or diffusion of the host exudates. Pore size may limit the activity or movement of the pathogens.

Effect on soil fungi and diseases

A. Work done abroad

The population of soil fungi in rice and wheat rhizosphere and diseases caused by them vary due to changes in their cultivation practices by the growers. Reduced tillage can favour the pathogens by lowering of soil temperature, increasing soil moisture, changes in root growth, nutrient uptake, population of vectors of plant pathogens and leaving soil undisturbed. Subsequent plant residue decomposition may result in phytotoxin release and the stimulation of toxin producing microorganisms, thereby predisposing the plants to pathogens (Sturz *et al*., 1997). Relatively high soil microbial activity can lead to competition effect that may ameliorate pathogen activity and survival. Microbial antagonism in root zone can lead to the formation of disease suppressive soil.

The incidence and severity of several foliar and root pathogens *viz*., *Septoria tritici* (speckled leaf blotch or Septoria blotch), *Septoria nodorum* (leaf and glume blotch), *Rhizoctonia solani* (Rhizoctonia bare patch or root rot), *Pythium* species (seed and root rot), *Erysiphe graminis* (powdery mildew), *Fusarium* species causing crown rot of wheat has been reported to be more in conservation tillage. In contrast, *Bipolaris sorokiniana* (foliar blight), *F. culmorum* and *F. avenaceum*- incitant of common root rot of wheat were partially or completely controlled by reduced tillage due to increase in soil moisture, disruption of spore movement from straw to crop by large amount of straw and production of dry conditions due to less dense crop canopy that occurs from reduced tillage (Sumner *et al*., 1981; Sturz *et al*., 1997; Bockus and Shroyer, 1998). There are many conflicting reports about *Cephalosporium gramineum* (stripe), *Pyrenophora tritici-repentis* (tan spot), *Fusarium graminearum* (head blight or head scab), *Cochliobolus sativus* (common root rot), *Gaeumannomyces graminis tritici* (take-all) and *Pseudocercosporella herpotrichoides* (foot rot/eye spot) of wheat (Brooks and Dawson, 1968; Hosford, 1976; Watkins *et al*., 1978; Cook *et al*., 1978; Sumner *et al*., 1981; Rothrock, 1992; Sturz *et al*., 1997; Bockus and Shroyer, 1998; Asefa Taa *et al*., 2002).

Cook *et al*., 1978 observed that take-all is significantly more severe but eyespot less severe in no-till than conventional tillage systems in the winter rainfall wheat area of the Northwestern United States. However, diseases such as take-all of wheat have declined where reduced tillage practice has been adopted (Brooks and Dawson, 1968). Tillage distributed the inoculum of *Gaeumannomyces graminis tritici* throughout the cultivated layer and influenced the location of take-all symptoms on wheat roots. The inoculum of the fungus spread only 10 cm in undisturbed soil compared to an average of 0.9 m and as much as 2.5 m following cultivation (Rothrock, 1992). He further mentioned that the incidence and severity of take-all disease of wheat has increased under no-tillage in the Pacific Northwest of the United States and southern Australia. In contrast, the disease has decreased in severity or not affected under no-tillage in England, the southeastern United States and Western Australia. Severity of tan spot of wheat in the mid western US is a direct consequence of adoption of reduced tillage practices (Hosford, 1976; Watkins *et al*., 1978). Hood, 1965 observed that zero tillage did not influence the incidence of eye spot caused by *Pseudocercosporella herpotrichoides*, sharp eye spot (*Rhizoctonia solani*) and brown foot rot caused by *Fusarium* species. Wiese and Ravenscroft, 1975 found that ploughing under wheat residue reduced the sporulation of *Cephalosporium gramineum* in the top 7.6 cm of soil. In Nepal, the total fungal counts were highly variable according to location and crop. The total population of fungi was higher in conventional tillage in Belwa and Benauli village during rice crop season. However, there were no differences in wheat crop except in village Santapur. The severity of root necrosis and foliar blight of wheat was not affected under different tillage practice (Anonymous, 2002). Most of the fungi detected in Pakistan were known saprophytes and included beneficial organisms such as *Trichoderma* species. Pathogenic fungi included *Fusarium graminearum*, *F. solani*, *Rhizoctonia solani*, *R. oryzae*, *Sclerotium oryzae*, *Nigrospora oryzae*, *Macrophomina phaseolina* and *Bipolaris sorokiniana*. No clear differences were observed between fields under different type of tillage practice (Anonymous, 2002).

In a long term field experiment on conservation tillage and sheath blight in Arkansas, USA, a lower level of *Rhizoctonia solani* have been observed in conventional seedbed plots regardless of rice cultivar in the rotation. On the basis of mean of 5 years data of two sites, the number of viable sclerotia of *R. solani* were found to be 3.4 & 5.0 per kg dry soil in conventional seed-bed plots compared to 4.9 & 11.3 in stale seeded and 5.8 & 8.2 in no-till treatments for rice cultivar Katy and Lacassine, respectively. The mean sheath blight incidence was 4.3, 10.6 & 4.7% with a disease severity of 5.6, 6.6 & 5.6 on 0-9 scale for cultivar Lacassine and 1.4, 2.4 & 1.1% with a disease severity of 3.0, 3.0 & 3.0 for cultivar Katy on conventional, stale-seeded and no-till treatments, respectively (Cartwright *et al.*, 1997-Table 1). In California, evidences on stem rot suggested that reduced tillage practices in continuous rice culture may not result in increased disease severity depending on in-season rice management and the build up of beneficial fungi (Cartwright, 1992).

Table 1. Effect of tillage practice on sheath blight of rice

Cultivar	Tillage	Viable sclerotia/kg dry soil[a]	Disease incidence/Severity[a]		Yield bu/ac[a]
			Infected tillers (%)	Disease score (0-9)	
Katy	Conventional	3.4	1.4	3.0	136.6
	Stale seeded	4.9	2.4	3.0	137.6
	No Till	5.8	1.1	3.0	101.4
Lacassine	Conventional	5.0	4.3	5.6	170.3
	Stale seeded	11.3	16.6	6.6	171.5
	No Till	8.2	4.7	5.6	131.5

[a]: Mean values of 1993 to 1997 of two sites

B. Work done in India

Analysis of soil samples collected during November 1999 to March 2002 from the fields of selected farmers adopting zero and conventional tillage for wheat sowing for the last 4-5 years in Kaithal and Karnal districts of Haryana revealed that the population of soil fungi varied significantly with growth stage, tillage practice, farmers' fields and crop season in rice-wheat sequence. On the basis of mean of three years data, the fungal counts were more in conventional (19.7 x 10^3 and 3.8 x 10^3/g dry soil) than zero tillage fields (10.4 x 10^3 and 3.2 x 10^3/g dry soil) at CRI and dough stage of wheat, respectively (Table 2). In rice also, the fungal population was more in conventional tillage (3.0 x 10^3/g dry soil) compared to 1.6 x 10^3/g dry soil in zero tillage at tillering stage. However, the trend was reverse at flowering stage (Fig. 1). *Fusarium* species viz., *F. moniliforme*, *F. pallidoroseum* and *F. oxysporum*, *Drechslera* species namely, *D. rostrata, D. oryzae* and *Penicillium* species were predominant in rhizosphere of wheat sown by either tillage method followed by *Alternaria triticina*, *Bipolaris sorokiniana*, *Cladosporium cladosporioides*, *Curvularia tetramera* and *Mucor* species. Besides, *Rhizopus oryzae*, *Aspergillus* species namely, *A. nidulans* var. *dentatus*, *A. ochraceus* and *A. terreus*, *Epicoccum purpurascens*, *Chaetomium globosum* and a few sterile species were also isolated.

Like wheat, *Fusarium* species were the main fungi isolated from rice rhizosphere followed by *Penicillium* species, *Mucor* species, *Curvularia tetramera* and *D. rostrata*. Other fungi namely, *Rhizopus oryzae, Aspergillus flavus, A. nidulans* var. *dentatus* and a few sterile species were also encountered to the extent of 17.2-48.7% of the total fungal population depending on crop growth stage. Among the fungi isolated from rhizosphere of rice and wheat, *F. moniliforme* has been reported to cause foot rot and bakanae, withering of shoots & sheath rot in rice and head scab of wheat. *F. moniliforme*, *D. rostrata*, *A. flavus* and *Penicillium* species have been found associated with wheat grains in field and storage. *C. cladosporioides*, *E. purpurascens* are the common black or sooty molds. *D. oryzae* and *A. triticina* & *B. sorokiniana* are well known pathogens causing brown spot of rice and foliar blight of wheat. In our studies, *F. moniliforme* and *F. pallidoroseum* caused bakanae and seedling mortality, respectively. *D. oryzae* caused brown spot while *D. rostrata* produced small oval spots with grey centre and dark border on lower most leaf sheath of rice. *A. triticina* & *B. sorokiniana* induced foliar blight of wheat. *F. moniliforme* increased the height of rice seedling to 149.7 mm as against 76.5 mm in uninoculated check besides seedling mortality while *F. pallidoroseum* caused only seedling mortality.

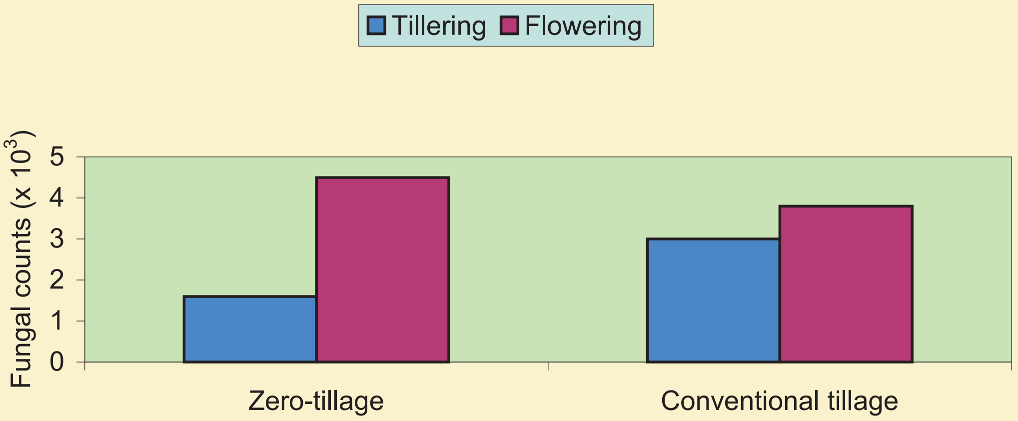


Fig. 1. Population of soil fungi in rice rhizosphere at different growth stages

Table 2. Counts of soil fungi at CRI and dough stage of wheat during 1999-00 to 2001-02

Farmer	Fungal counts (x 10^3/g dry soil)							
	Zero				Conventional			
	99-00	00-01	01-02	Mean	99-00	00-01	01-02	Mean
Nakli Ram	2.7 (5.1)*	22.3 (2.7)	6.0 (3.3)	10.3 (3.7)	18.8 (5.4)	98.3 (1.3)	6.3 (3.0)	41.1 (2.9)
Naresh	15.2 (3.0)	13.7 (2.3)	7.3 (2.7)	12.1 (2.7)	6.0 (0.8)	14.3 (5.0)	3.7 (5.0)	8.0 (3.6)
Dharamvir	3.8 (3.0)	18.0 (3.3)	5.0 (3.7)	8.9 (3.3)	14.0 (6.3)	8.3 (3.3)	7.7 (4.0)	10.0 (4.5)
Mean	7.2 (3.7)	18.0 (2.8)	6.1 (3.2)	10.4 (3.2)	12.9 (4.2)	40.3 (3.2)	5.9 (4.0)	19.7 (3.8)

*: Fungal counts at dough stage of wheat

On mean basis, the population of *F. moniliforme* was significantly higher in conventional (1.6 x 10^2 and 1.8 x 10^2/g dry soil) than zero till plots (0.6 x 10^2 and 0.5 x 10^2/g dry soil) in wheat rhizosphere at CRI and dough stage while it was more in zero drill sown fields in rice rhizosphere (0.4 x 10^2/g dry soil) relative to conventionally till plots (0.2 x 10^2/g dry soil) at tillering stage. However, the fungus could not be recovered at flowering stage on selective medium in either type of tillage practice

(Table 3). In contrast *F. moniliforme*, the population of *F. pallidoroseum*, a potential bioherbicide for management of congress grass-*Parthenium* sp. (Jeyalakshmi *et al.*, 2001) and water hyacinth-*Eichhornia crassipes* (Praveena and Naseema, 2004), was more in conventionally sown fields in both the crops. The fungal population in conventional plots was 2.1 x 10^2 and 4.9 x 10^2/g dry soil at CRI and dough stages in wheat relative to 1.4 x 10^2 and 4.6 x 10^2/g dry soil in zero tillage plots while in rice it was 12.2 x 10^2 and 2.2 x 10^2/g dry soil in conventional and zero till plots at tillering stage. However, the fungus could not be detected at flowering stage.

Table 3. Counts of *Fusarium moniliforme* at CRI & dough stages of wheat during 1999-00 and tillering & flowering stages in rice during 2000

Farmer	Fungal counts (x 10^2/g dry soil)			
	Wheat		Rice	
	Zero	Conventional	Zero	Conventional
Nakli Ram	0.5 (0.6)*	4.7 (2.3)	0.0 (0.0)*	0.3 (0.0)
Naresh	0.2 (1.0)	0.5 (1.3)	0.6 (0.0)	0.3 (0.0)
Dharamvir	1.1 (0.0)	0.9 (0.0)	0.6 (0.0)	0.0 (0.0)
Mean	0.6 (0.5)	1.6 (1.8)	0.4 (0.0)	0.2 (0.0)

* Dough stage in wheat and flowering in rice, respectively.

Observations recorded at selected fields of 10 farmers each adopting zero and conventional tillage in Uttar Pradesh, India also revealed that there was no significant difference in the incidence and severity of foliar blight of wheat. The fungal population was found to be higher in zero than conventional tillage fields at maturity stage on all three media in wheat. In rice, zero till fields had a higher percentage of foliar diseases incidence and severity as against conventional tillage fields (Anonymous, 2000, 2001). Kapoor, 2001 also recorded a significantly higher population of fungi and bacteria in zero till plots while the population of actinomycetes was found to be more under conventional tillage. In our studies, there was no significant difference in the incidence and severity of foliar blight and powdery mildew of wheat; neck blast, false smut, sheath rot, stem rot, brown spot and narrow brown leaf spot of rice (Table 4, 5 & Fig. 2). However, mean incidence of foot rot and bakanae and grain discolouration of rice was more in zero tillage plots (6.5% and 14.6%) as against 2.0 and 9.8% in conventionally sown plots. Typical withering of plants due to foot rot & bakanae was also evident at maturity in zero tillage plots (Singh *et al.*, 2002, 2004).

Table 4. Effect of tillage on diseases of non-scented rice

Disease	Incidence/Severity*									
	Zero					Conventional				
	2000	2001	2002	2003	Mean	2000	2001	2002	2003	Mean
False smut (% tillers)	2.3	-	-	Tr	2.3	0.7	1.0	-	Tr	0.8
Sheath rot (%)	22.1	27.8	2.3	26.7	19.7	20.9	24.0	1.2	23.7	17.5
Stem rot (%)	29.1	-	18.5	-	23.8	38.3	-	11.2	-	24.8
Brown spot (0-9)	3.0	-	7.0	-	5.0	2.3	-	5.0	-	3.6
Grain discolouration (%)	8.2	22.2	7.8	5.6	14.6	5.8	13.9	5.6	4.0	9.8

- No disease; Tr: Traces

Table 5. Effect of tillage on foliar blight of wheat

Farmer	Leaf area affected (%)									
	Zero					Conventional				
	2000	2001	2002	2003	Mean	2000	2001	2002	2003	Mean
Naresh	6.5	2.5	3.8	4.9	4.4	5.9	1.8	4.0	5.7	4.4
Dharamvir	9.5	5.8	4.0	4.3	5.9	8.7	4.0	5.7	6.7	6.3
Nakli	–	–	4.8	–	4.8	–	–	2.9	–	2.9
Mean	8.0	4.2	4.2	4.6	–	7.3	2.9	4.2	6.2	–

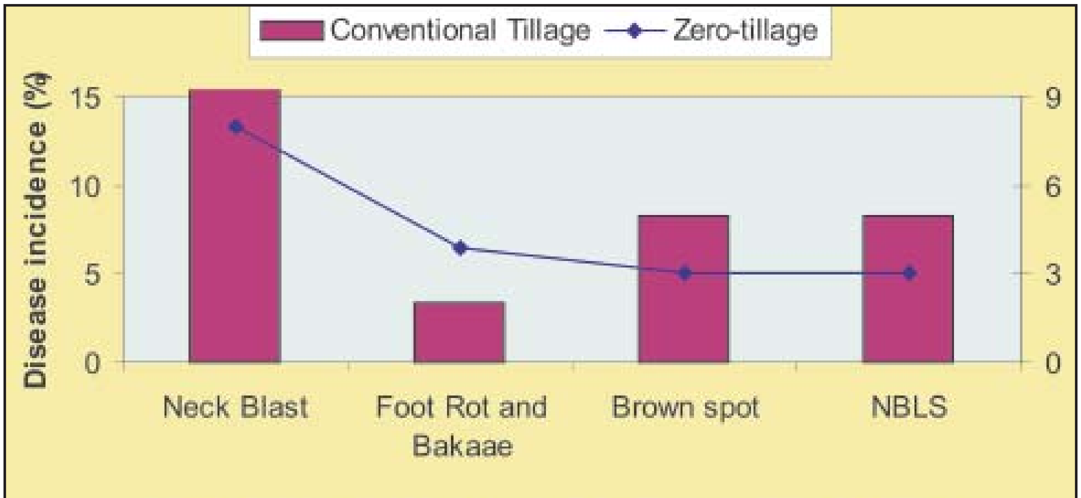


Fig. 2. Effect of tillage practice on diseases of rice cv Taraori Basmati

Effect on nematodes

The soil and root samples collected from earlier described sites were analysed for plant parasitic and saprophytic nematodes following Cobb's Sieveing and Decanting Method (Cobb, 1918) and modified Baerman Funnel Technique and Waring and Blanding Technique.

Data on rice-root nematodes revealed that minimum population level of *Hirschmannella oryzae* was recorded in the month of November (21.7 nematodes/200 cc soil) and maximum (156.3/200 cc soil) in September. Except for the month of July all other observation periods had less population in the fields having no tillage during winter (wheat) season. Maximum cumulative decrease in the nematodes population (147.6%) in zero-tilled fields was observed in the month of September. Mean population of rice-root nematode was 78.7 nematodes/200 cc soil in no-tilled fields as compared to 135.8 nematodes/200cc soil in conventionally tilled fields. Cumulative decrease in zero tillage field population as compared to that of conventional fields was more than 72% within a span of approximately four years (Table 6). Data on stylet/stunt nematode (*Tylenchorhynchus* spp.) in Table 7 showed that population of the nematode had a declining trend during November and July samplings while the samplings during March and September depicted a steep decrease in its population. Stylet nematode is an ectoparasite of the cropping system meaning thereby it is a parasite of rice as well as wheat crops. September and March are two respective growth peaks of rice and wheat crops, respectively providing ample avenues for feeding and in turn its multiplication. Ambient and soil temperature during both the cropping seasons are also congenial for any organism's (nematode) growth and development.

Data in Table 7 revealed that at all the sampling timings nematode populations in zero tillage fields decreased ranging from 2.2 % to 69.0%. The minimum mean difference (2.2%) was recorded during November sampling. Mean population per 200 cc soil was 205.5 in zero tillage fields as compared to 294.9 in conventional fields. Overall decrease during the period of four years was 43.5%. Maximum population was recorded in conventional fields in the month of March owing to wheat crop, a preferred host of this nematode as compared to rice (Table 7).

When data on plant parasitic nematodes were clubbed together it was observed that zero tillage fields had less population (142.1/200 cc soil) relative to conventional (215.3/200 cc soil). Based on mean of four years data, a drastic reduction (51.5%) in population of plant parasitic nematodes was observed in zero tillage plots (Table 8).

Table 6. Cumulative effect of zero-tillage on rice-root nematode population (200 cc soil)*

Month of observation	**Tillage Practice**		**% increase or decrease**
	Zero	Conventional	
Nov. 2003	21.7	47.0	-116.6
March 2004	50.3	78.6	- 64.4
July 2004	86.7	30.7	+ 64.6
Sept.2004	156.3	387.1	-147.6
Mean	78.7	135.8	- 72.5

* Nov. 1999-March 2004

Table 7.Cumulative effect of zero-tillage on stunt nematode population (200 cc soil)

Month of observation	**Tillage Practice**		**% increase or decrease**
	Zero	Conventional	
Nov. 2003	137	140	-2.2
March 2004	269	454.7	-69.0
July 2004	139	168.3	-21.1
Sept.2003	277.3	416.7	-50.5
Mean	205.5	294.9	-43.5

* Nov. 1999-March 2004

Table 8. Cumulative effect of zero tillage on plant parasitic nematodes (200 cc soil)

Nematode group	**Tillage Practice**		**% increase or decrease**
	Zero	Conventional	
Tylenchorhynchus spp.	205.5	294.9	-43.5
Hirschmanniella spp.	78.7	135.8	-72.5
Mean	142.1	215.3	-51.5

Cumulative population data of saprozoic nematodes are presented in table 9 which showed that zero tilled fields had 314.7 nematodes/200 cc soil in comparison to 221.5 nematodes in conventionally tilled fields at the termination of the experiment which indicated that zero tillage fields had more than 29% higher nematodes at the end of the experiment (Table 9).

Table 9. Cumulative effect of zero-tillage on saprozoic nematodes (200 cc soil)

Nematode group	**Tillage Practice**		**% increase or**
	Zero	Conventional	**decrease**
Cephalobid	162.9	113.8	30.1
Rhabditids	263.6	112.0	54.9
Dorylaimid	671.6	435.6	35.1
Araeolaimid	160.9	224.7	-39.7
Mean	314.7	221.5	29.6

Rice root nematode decreased during November, March and September samplings while the same increased when observations were taken during the month of July, while stunt nematodes decreased at all the sampling timings (Fig. 3). There was a significant change in the population levels of free living nematodes over the years. Dorylaimid group decreased maximum during March, Cephalobid during November and Araeolaimid during July (Fig. 4).

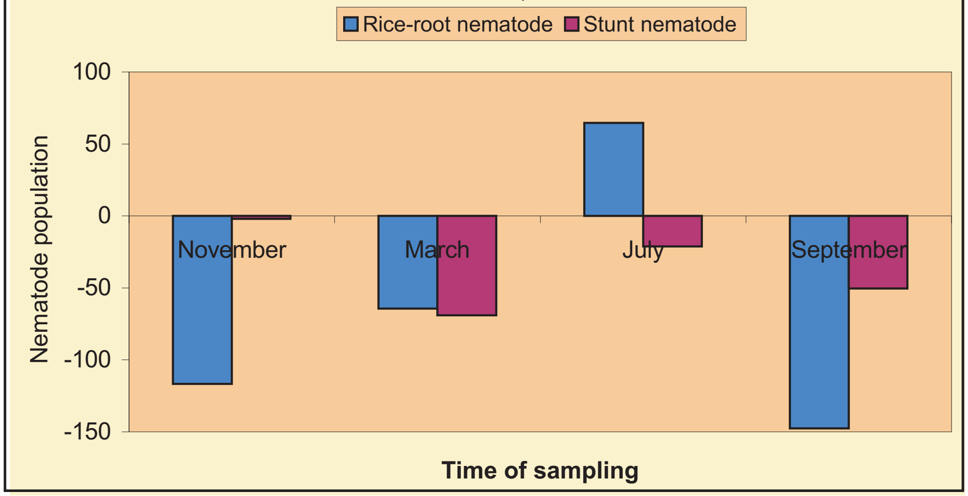


Fig. 3. Percent increase/decrease in population of plant parasitic nematodes as affected by zero-tillage in R-W crop rotation (Novemeber, 1999 - March, 2004)

Dabur (2001) reported that there were no conclusive trends in term of nematodes decrease/ increase when data for two year study were clubbed, either due to difference in initial nematode level or difference in transplanting date of that of zero tillage vis-à-vis conventional fields. However, in the present studies some of the nematode groups indicated some definite trends of increase/ decrease e.g. rice-root nematode population was significantly less in zero tillage fields at November, March and September samplings than in conventional fields. Also the stunt nematode’s population decreased ranging from 2.2% to 69.0% at all the sampling timings. The possible explanation for the same could be that during no-till practice the soil was left undisturbed and nematodes could not flourish much due to want of aeration of the soil by ploughing and turning activities. Sturz *et al.*

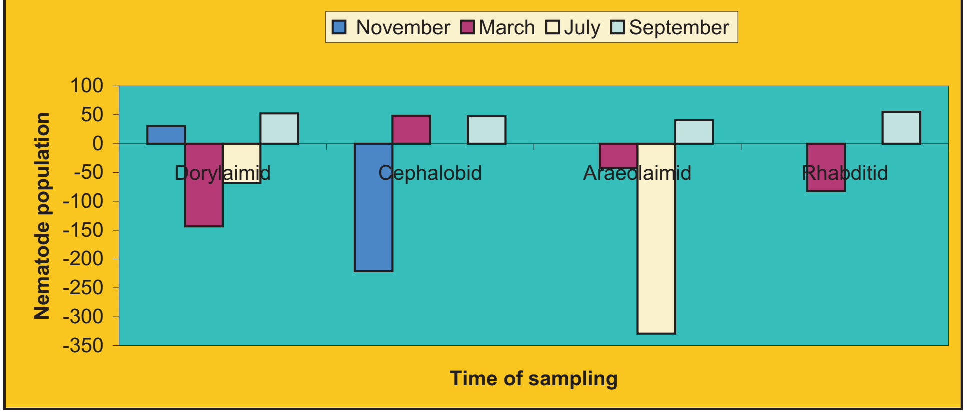


Fig. 4. Percent increase/decrease in the population of saprozoic groups of nematodes as affected by zero-tiilage in R-W crop rotation (November, 1999 - March, 2004)

(1997) said that reduced tillage can favour the pathogens by lowering the soil temperature, increasing the soil moisture, change in root growth, nutrient uptake etc. However the present results do not corroborate the hypothesis because zero tillage in winter season will increase the soil temperature and that will decrease the nematode population as happened with the stylet nematode during the course of present study. On the other hand some saprozoic groups were more in number in zero tillage fields and also vice-versa. This could be due to plenty of food material available for saprozoic nematodes during the cropping system.

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