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Nitrogen and weed management effect on soil microbial properties in rice-based cropping system under conservation agriculture

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ABSTRACT

A study was carried out to evaluate the influence of tillage-residue management, N-levels and weed management on the population of bacteria, fungi and actinobacteria in soil under rice-wheat-greengram system during 2014-15 to 2015-16 at Jabalpur, India. Results showed that tillage-residue management had significant influence on microbial properties of soil. Zero tillage with preceding crop residue retention followed in all three crops in a system markedly improved soil microorganism communities by stimulating the growth of bacteria, fungi and actinobacteria. After two years of the study, conservation agriculture based practice, *i.e.* zero tillage with preceding crop residue retention increased population of bacteria by 65-83%, fungi by 28-32% and actinobacteria by 22-37% compared with conventional tillage with or without preceding crop residue. No significant differences in the population of bacteria and fungi were found between N-levels in 2014-15, while significant improvement was observed in 100% recommended dose of N in 2015-16. Improvement in bacterial and fungal population due to 100% recommended dose of N was 4 and 7% over 125% recommended dose of N, respectively. There was no significant change in microbial activities due to different weed management practices. These results suggest that zero tillage with preceding crop residue retention, recommended dose of N was the best practice for improving soil biological properties under rice-wheat-greengram system.

Key words: Actinobacteria, Bacteria, Fungi, N-levels, Residue management, Tillage, Weed management

Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L. emend Fiori and Paol.) cropping system is the major system in India, which is fundamental to national food security. During summer season, inclusion of greengram (*Vigna radiate* L. R. Wilczek) in rice-wheat system is a remunerative option to sustain the productivity. Soil microorganisms play a vital role in biogeochemical cycling, which underpin the mechanisms of utilizing soil organic matter (Bowles *et al.* 2014). Tillage is a major factor which influences microbial activity and community structure in soil. Several studies confirmed that intensive conventional tillage practices reduce microbial biomass by decreasing or reversing C accumulation and breaking down soil structure (Lupwayi *et al.* 2012). In contrast, conservation agriculture, *i.e.* zero-till with preceding crop residue retention and crop rotation has been shown to increase microbial biomass and activity (Singh *et al.* 2015). Conservation tillage caused accumulation of soil microbial biomass in surface soil compared with conventional tillage. However, in other studies, tillage did not alter the soil microbial community structure (Helgason *et al.* 2009). Nitrogen fertilization induces alteration in soil microbial composition (Zeng *et al.* 2016). Improvements in productivity of crops can be achieved by combating weeds. Generally, herbicides are not harmful when applied at recommended rates (Selvamani and Sankaran 1993), but some herbicides may affect non-target organisms including microorganisms (Latha and Gopal 2010). Some herbicide may even stimulate the growth and activities of the microbial activities (Wardle and Parkinson 1990). Chemical or integrated methods of weed management should be tested in respect to microbial activities. Thus, the present investigation was undertaken to find out the effect of tillage-residue, N-levels and weed management on soil microflora of rice-wheat-greengram cropping system.

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MATERIALS AND METHODS

An experiment was initiated in 2013-14 at the ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh situated. Data presented in this article on rice (rainy season)-wheat (winter season)-greengram (summer season) were collected in the two subsequent years (2014-15 and 2015-16). The soil of the experimental site was classified as Typic

Chromusters (USDA classification). The treatments included four tillage-residue management practices, *viz.* zero tillage with preceding crop residue retention (ZT+RR), zero tillage with preceding crop residue burnt (ZT+RB), conventional tillage with preceding crop residue incorporation (CT+RI) and conventional tillage with preceding crop residue burnt (CT+RB); two N-levels, *viz.* 100% recommended dose of nitrogen (RDN) and 125% RDN, and three weed management options, *viz.* unweeded, herbicide and integrated for all crops in the system. Thus, 24 treatment combinations were laid out in a thrice replicated split-split plot design, keeping tillage-residue management in main plots, N-levels in sub-plots and weed management in sub sub-plots. Weed management practices included unweeded check, *i.e.* no weed management practices were applied; herbicide, *i.e.* pendimethalin 1000 g/ha as pre-emergence (PE) followed by (*fb*) bispyribac-Na 25 g/ha at 25 DAS in rice; mesosulfuron + iodosulfuron (12 + 2.4 g/ha) at 25 DAS in wheat; pendimethalin 1000 g/ha as PE *fb* imazethapyr 100 g/ha at 25 DAS in greengram; and integrated weed management (IWM), *i.e. Sesbania* co-culture + pendimethalin 1000 g/ha as PE *fb* 2,4-D at 25-30 DAS *fb* hand weeding (HW) at 45 DAS in rice; sulfosulfuron 25 g/ha at 25 DAS *fb* HW at 45 DAS in wheat; pendimethalin 1000 g/ha as PE *fb* HW at 25 DAS in greengram. Site-specific application of glyphosate was done at 1.0 kg/ha on the weeds in zero tillage plots and other weed management practices were applied as per treatments.

Enumeration of microorganisms

The soil samples were collected from 0-15 cm surface soil in all the plots at the time of harvest of rice, wheat and greengram. The soil samples were soaked into 90 ml deionized water at the rate of 10 g. Later this mixture was shaken for 10 min. and kept for 5 min. Thereafter, 1 ml of the supernatant was diluted twice and inoculated in the diluted water at the constant temperature (30 ºC). All samples were performed in triplicate, and were used for enumeration of microorganisms. The viable microbial counts were analyzed by the standard technique of serial dilution and dour plating. Enumeration of bacteria and fungi was carried out in soil extract agar medium (James 1958) and Rose Bengal agar medium (Parkinson *et al.* 1971). The Kenknight's agar medium (Wellingtonn and Toth 1963) was used for enumeration of actinomycetes. After allowing for development of discrete microbial colonies during incubations under suitable conditions, the colonies were counted and the number of viable bacteria, fungi and actinobacteria [expressed as colony forming units (cfu)] per gram dry weight of soil was estimated by taking into account the soil dilutions.

RESULTS AND DISCUSSION

Bacteria

Population dynamics of bacteria was markedly influenced by tillage-residue management and N-levels (Table 1). The highest population was recorded when zero-till with preceding crop residue retention was adopted in all the crops in the system. ZT+RB was comparable with ZT+RR in rice 2014, while CT+RI and ZT+RB did not significantly differ compared with ZT+RR in wheat 2014-15. ZT+RR led to significantly higher bacteria population in greengram 2015. In 2015-16, population of bacteria was higher in the rhizosphere of rice, wheat and greengram when ZT was done in the presence of preceding crop residue. Increasing bacterial population was due to continuous ZT with application of preceding crop residue which served as a continuous energy source for microorganisms. No significant difference was observed in bacterial population due to N-levels in rice 2015, however the population of bacteria was significantly improved under 100% RDN from wheat 2015-16. Additional N fertilizer can decrease soil pH, leading to leaching of magnesium and calcium and mobilization of aluminium, which may slow the growth of bacteria due to magnesium or calcium deficiency or aluminium toxicity. Liu *et al.* (2015) also found slow growth of bacterial biomass with increasing dose of N. Weed management practices did not influence the bacteria population significantly throughout both cropping cycles (Table 1).

Fungi

Population of fungi was influenced significantly due to tillage-residue management and N-levels while weed management had no significant influenced (Table 2). Maximum fungal population was recorded in ZT+RR, which was followed by ZT/CT with residue burnt in rice 2014. The population of fungi in rhizosphere was also significantly augmented in ZT+RR in wheat 2014-15 and greengram 2015. During rice 2015, the population of fungi was increased in ZT+RR, and the lowest population was noted in CT+RB. A similar trend was observed in wheat 2015-16 and greengram 2016. Sharma *et al.* (2012) reported that fungal population was increased with decrease the soil disturbance. Soil microbes typically are C-limited (Smith and Paul 1990) and the lower microbial biomass can be explained with low

Table 1. Effect of tillage-residue, N-levels and weed management practices on bacterial population

Treatment	Bacteria (10^6 cfu/g dry weight of soil)					
	Rice 2014	Wheat 2014-15	Greengram 2015	Rice 2015	Wheat 2015-16	Greengram 2016
Tillage-residue management						
ZT+RR	16.2	17.8	18.5	32.5	46.8	54.3
ZT+RB	15.3	17.2	17.9	29.5	40.4	45.9
CT+RI	14.7	16.8	17.3	25.3	26.8	27.7
CT+RB	14.4	16.1	16.6	24.3	24.3	22.4
LSD (P=0.05)	1.2	1.1	0.8	0.9	1.6	0.7
N-levels						
100% RDN	15.2	17.0	17.6	27.9	35.5	38.3
125% RDN	15.1	16.9	17.5	27.9	33.6	36.9
LSD (P=0.05)	NS	NS	NS	NS	0.6	0.6
Weed management						
Unweeded	15.3	17.1	17.8	28.0	35.3	37.9
Chemical	15.0	16.9	17.3	27.8	34.2	37.2
IWM	15.1	17.0	17.7	27.9	34.3	37.7
LSD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 2. Influence of tillage-residue, N-levels and weed management on fungal population

Treatment	Fungi (10^3 cfu/g dry weight of soil)					
	Rice 2014	Wheat 2014-15	Greengram 2015	Rice 2015	Wheat 2015-16	Greengram 2016
Tillage-residue management						
ZT+RR	14.4	14.8	15.1	25.1	30.1	32.0
ZT+RB	14.1	14.4	14.6	22.7	26.1	27.0
CT+RI	13.2	13.9	14.3	20.0	23.0	24.1
CT+RB	13.6	14.1	14.1	19.0	22.1	23.0
LSD (P=0.05)	0.9	0.6	0.7	1.9	1.8	2.2
N-levels						
100% RDN	14.1	14.3	14.7	22.5	26.5	27.5
125% RDN	13.6	14.3	14.3	20.9	24.1	25.5
LSD (P=0.05)	NS	NS	NS	1.63	0.7	0.8
Weed management						
Unweeded	14.0	14.4	14.8	21.8	25.4	26.8
Chemical	13.7	14.2	14.2	21.5	25.3	26.3
IWM	13.8	14.3	14.5	21.8	25.3	26.5
LSD (P=0.05)	NS	NS	NS	NS	NS	NS

organic C in the soil (Mathew 2012). In zero-till soils, the accumulation of preceding crop residues on the soil surface results in enrichment of soil organic matter in the surface layer, and as a consequence, increases the abundance of microorganisms. N-levels did not exert any change in the fungal population in 2014-15, however the effect of N-levels was significant in 2015-16. Recommended dose of N improved the population of fungi in 2015-16 over 125% RDN. N additions have shown suppressive effect on microbial growth in several field studies (Nohrstedt *et al.* 1989). A number of mechanisms have been proposed for the slow multiplication in fungal biomass under N enrichment. Osmotic potentials in soil solution could become toxic owing to the introduction of additional ions via additional dose of N fertilizer. In this way, N additions could directly influence microbial growth.

Actinobacteria

Population of actinobacteria varied among tillage-residue management practices (Table 3). Compared with conventional tillage, zero tillage increased the abundance of actinobacteria. During rice 2014 and wheat 2014-15, ZT with/without preceding crop residue retention had significantly higher actinobacterial population than CT with/ without preceding crop residue incorporation. However, actinobacterial population in ZT+RR was significantly higher in subsequent seasons after wheat 2014-15. ZT+RR led to actinobacterial population significantly higher over rest of tillage-residue management practices. Lowest population of actinobacteria was observed in CT+RB throughout cropping cycle in both years. Govindan and Chinnusamy (2014) also recorded higher actinobacterial population in rice based system under CA. The favourable effect of zero tillage and preceding crop residue retention on soil microbial populations are mainly due to increased soil aeration, optimum temperature and moisture fluctuations, and higher carbon content in surface soil. There was no significant change in actinobacterial population due to N-levels, and weed management practices.

Table 3. Actinobacterial population as influenced by tillage-residue, N-levels and weed management practices

Treatment	Actinobacteria (10^4 cfu/g dry weight of soil)					
	Rice 2014	Wheat 2014-15	Greengram 2015	Rice 2015	Wheat 2015-16	Greengram 2016
Tillage-residue management						
ZT+RR	14.8	16.0	17.1	20.4	25.0	29.1
ZT+RB	14.3	15.6	16.0	18.1	21.2	25.0
CT+RI	13.4	14.7	14.8	17.0	19.9	23.3
CT+RB	13.1	14.7	14.5	16.4	18.5	20.0
LSD (P=0.05)	1.0	0.7	0.9	1.3	1.6	0.8
N-levels						
100% RDN	14.1	15.3	15.7	18.2	21.4	24.4
125% RDN	13.7	15.2	15.5	17.8	20.9	24.3
LSD (P=0.05)	NS	NS	NS	NS	NS	NS
Weed management						
Unweeded	14.1	15.5	15.7	18.1	21.5	24.6
Chemical	13.8	14.8	15.5	17.8	20.7	24.0
IWM	13.8	15.4	15.6	18.1	21.3	24.4
LSD (P=0.05)	NS	NS	NS	NS	NS	NS

It was concluded that continuous practice of ZT with preceding crop residue retention improved soil microbial biomass. N fertilization made no change in soil microbial activities in the first cropping cycle but there was improvement in second cropping cycle when the 100% RDN was applied over 125% RDN. This study also showed that there was no influence of weed management practices on microbial activities. Direct seeding in rice-wheat-greengram system under zero-till in the presence of preceding crop residue along with recommended dose of N and application of recommended practice of weed management proved to be a promising technology for improving soil biological properties.

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