Indian Journal of Agricultural Sciences **88** (8): 1184–9, August 2018/Article

Effect of crop residue retention and phosphorus fertilization on P use efficiency of maize (*Zea mays*) and biological properties of soil under maize-wheat (*Triticum aestivum*) cropping system in an Inceptisol

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Received: 08 March 2018; Accepted: 04 May 2018

ABSTRACT

A field experiment was initiated in the year 2013 while current study was undertaken after two years of experimentation, i.e. in the year 2015-16 to study the effect of crop residue retention (CCR) and phosphorus fertilization in maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping system on yield and P use efficiency of maize at IARI Research Farm, New Delhi. Results indicated that crop residue retention significantly enhanced grain and straw yield of maize from 5.44 and 8.01 t/ha (No-CR) to 5.88 and 8.40 t/ha in 75% CR, respectively. Whereas, the treatment 50% RDP + PSB and AM significantly enhanced grain (6.22 t/ha), straw (9.07 t/ha) and biological (15.2 t/ha) yield of maize over 100% RDP, except grain yield. The combined use of 50% RDP + PSB and AM increased the grain yield by 1.46% over 100% RDP. The enhancement in total P uptake was 69% and 14% due to application of 50% RDP + PSB and AM and 75% CRR, respectively over control. The higher apparent recovery (ARP) of P, 18.1% and 28.2% were recorded under 75% CR and 50% RDP + PSB and AM treatment, respectively, whereas highest agronomic efficiency (AE) of P (34.7and 51.2 kg grain/kg P) were found under 25% CRR and 50% RDP + PSB and AM treatment, respectively. Soil biological properties, viz. DHA, MBC and MBP also significantly enhanced under 75% CRR and 50% RDP + PSB and AM treatments.

Key words: Apparent P recovery, Crop residue retention, Maize, Soil biological properties, Yield

Phosphorus (P) is an essential element for the growth and development of plants. It is a structural element of metabolically active compounds present in plants. As, its concentration and solubility in soils is low due to its reactive nature with different soil components, it has become a critical nutrient limiting plant growth (Kumar *et al*. 2014). Also, the efficiency of P fertilizers is quite low, which barely exceeds 15-20% in the year of its application. Rest of the applied P in soil either gets fixed with different soil component or sometimes gets lost through run-off. Crop residues retained on the soil surface has potential to enhance soil quality through improvement in soil organic carbon, and different physical and biological properties, which in turn may improve P availability in soil. Crop residue retention (CCR) also checks runoff and soil erosion, improve water infiltration, maintains soil temperature, reduce evapotranspiration losses of soil water, check weed growth, decrease the kinetic energy of impacting rain drops on the soil surface and thus, reduce soil compaction and aggregate breakdown (Ghosh *et al*. 2006). Improvement in soil microbial activity due to CCR may increase P availability in soil by solubilising fixed-P. No-tillage with residue retention increased soil microbial community (Govaerts *et al.* 2007, Kumar *et al*. 2014). In India, alluvial soils are extensively distributed in the Indo-Gangetic Plains and represent by far the most fertile and important group of soils for crop production. Many of these agriculturally important and productive soils suffer from P deficiency. Because of the low concentration and poor mobility of available P in soils, application of P fertilizers becomes inevitable to improve crop growth and yield (Shen *et al.* 2011). Maize-wheat cropping system is an important cropping system in India. Keeping this in view present investigation was undertaken to study the effect of crop residue retention and phosphorus fertilization on P use efficiency of maize and biological properties of soil under maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping system in semi-arid condition of India.

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MATERIALS AND METHODS

A field experiment was initiated in the year 2013 while current study was undertaken after two years of experimentation in maize in the year 2015 under maize-wheat cropping system at Experimental Research Farm, IARI, New Delhi with twenty treatments combinations, evaluated in a split-plot design. Treatments of main-plot were varying percentage of crop residue retention, i.e. T_1: Residue removal (No-residue), T_2: 25% crop residue, T_3: 50% crop residue, T_4: 75% crop residue and in sub-plot treatments were S_1**:** No-phosphours, S_2**:** 50% recommended dose of phosphorus (RDP), S_3**:** 100% RDP, S_4:150% RDP, S_5**:** 50% RDP + PSB and AM. Recommended dose of N-P-K were 150-80-60 kg/ha for maize. The dose of N and K were applied uniformly to all the plots through urea, muriate of potash, respectively. Whereas, P was applied as per treatments through diammonium phosphate (DAP). Entire amount of P and K was applied as basal dressing at the time of sowing. Fertilizer N was applied in three equal splits, i.e. at sowing, at four leaves vegetative stage and at eight leaves vegetative stage of maize. Previous wheat crop was harvested and above ground biomass/residues were retained as per treatments in the plots. Maize (cv. PHM 1) was sown in first week of July and harvested during end of October, 2015. Maize crop was raised under assured irrigated condition, and prescribed weed and pest control measures were adopted. Maize crop was harvested at maturity in the month of October and grain and straw yields were recorded. The collected plant samples (grain and straw) were digested with di-acid mixture (HNO_3: $HClO_4$ in 3: 1 ratio) and P content in the acid digest was estimated by vanado-molybdo yellow colour method (Jackson 1973). The uptake of phosphorus by grain and straw was obtained as product of P concentration in plant and yield. Apparent recovery of P (ARP) and agronomic efficiency (AE) were calculated as

$$\text{(i) ARP} = \frac{\text{P uptake T} - \text{P uptake T0}}{P_{appR}}$$

$$\text{(ii) AE} = \frac{(YT - Y_0) \times 100}{P_{appR}}$$

where, ARP = Apparent recovery of P, T = Treated plot, T_0= Control plot AE = Agronomic efficiency, YT = Grain yield (t/ha) of treated plot, Y_0 = Grain yield (t/ha) of control plot, P_{appR} = Rate of P application (kg/ha). The dehydrogenase enzyme activity in soil was measured colorimetrically following the procedure of Casida (1977). Microbial biomass carbon was estimated by fumigation extraction method (Jenkinson and Powlson 1976) and microbial biomass P was measured using a modified fumigation and $NaHCO_3$ extraction technique (Brookes *et al*. 1982).

RESULTS AND DISCUSSION

Yields

Grain yield of maize as affected by crop residues retention (CRR) and different rates of phosphorus fertilization are presented in Table 1. Different levels of crop residue retention significantly influenced the grain yield of maize from 5.42 t/ha (No-CR) to 5.88 t/ha (75% CR). The maximum grain yield of 5.88 t/ha was recorded with crop residue retention @ 75% CRR followed by 5.82 t/ha (@ 50% CRR. Whereas, mean grain yield of maize increased significantly with increasing rate of P fertilizer up to 100% RDP. The maximum grain yield (6.22 t/ha) was recorded with application of 50% RDP + PSB and AM followed by 100% RDP (6.13 t/ha) and 150% RDP (6.06 t/ha) which was 11.5 % higher over 50% RDP treatment. Application of 100% RDP was statistically at par with 50% RDP + PSB and AM treatments, but these treatments were significantly higher as compared to 50% RDP. Inoculants along with P fertilization gave 25-38% higher maize grain yield over control. Result indicates that application of microbial inoculants (combined use of PSB and AM) in maize can reduce 50% P fertilizer rate and increase the grain yield of

Table 1 Effect of crop residues and phosphorus fertilization on grain yield (t/ha) of maize

Crop residue retention (CRR)	Phosphorus rates (P)					
	No-P	50% RDP	100% RDP	150% RDP	50% RDP+ PSB & AM	Mean
No-CRR	4.33	5.40	5.76	5.73	5.87	5.42^D
25% CRR	4.44	5.52	6.14	6.09	6.21	5.68^C
50% CRR	4.62	5.63	6.28	6.19	6.37	5.82^B
75% CRR	4.69	5.75	6.34	6.22	6.41	5.88^A
Mean	4.52^D	5.58^C	6.13^{AB}	6.06^B	6.22^A	
	CR	P	P at same CR		CR at same P	
SEm (±)	0.02	0.03	0.07		0.06	
LSD (P≤0.05)	0.04	0.07	NS		NS	

Table 2 Effect of crop residues and phosphorus fertilization on straw yield (t/ha) of maize

Crop residue retention (CRR)	Phosphorus rates (P)					
	No-P	50% RDP	100% RDP	150% RDP	50% RDP+ PSB & AM	Mean
No-CRR	6.50	7.65	8.42	8.62	8.86	8.01^D
25% CRR	6.70	7.79	8.59	8.75	9.08	8.18^C
50% CRR	6.82	7.83	8.71	8.90	9.15	8.28^B
75% CRR	6.91	7.90	8.90	9.09	9.22	8.40^A
Mean	6.73^E	7.79^D	8.66^C	8.84^B	9.07^A	
	CR	P	P at same CR		CR at same P	
SEm (±)	0.02	0.02	0.05		0.05	
LSD (P≤ 0.05)	0.05	0.05	0.10		0.10	

maize. The maximum yield (6.41 t/ha) was obtained in 75% CR with 150% RDP combination, which is an increase of 48.0% over control. Integrated use of 50% CRR + 150% RDP and 75% CRR + 100% RDP resulted in similar grain yield of 6.37 t/ha and 6.34 t/ha, respectively.

Crop residue retention, increased the mean straw yield of maize from 8.01 t/ha to 8.40 t/ha. The maximum straw yield (8.40 t/ha) was recorded in 75% CRR followed by 50% CRR (8.28 t/ha). Phosphorus fertilization, significantly improved straw yield from 6.73 t/ha (No-P) to 9.07 t/ha (50% RDP + PSB and AM). The maximum straw yield (9.07 t/ha) was recorded in 50% RDP + PSB and AM followed by 150% RDP (8.84 t/ha) and 100% RDP (8.66 t/ha). Crop residues retention and phosphorus fertilization either alone or in combination enhanced the straw yield of maize over control (6.50 t/ha). The maximum straw yield (9.22 t/ha) was observed in 75% CRR with 50% RDP + PSB and AM combination, which was an increase by 41.8% over control (6.50 t/ha). Moreover, integrated use of 50% CRR with 50% RDP + PSB and AM and 75% CR with 150% RDP resulted in similar straw yield of 9.15 t/ha and 9.09 t/ha, respectively. This enhancement in yield of maize may be due to higher enzyme activities in rhizosphere and better uptake of nutrients. Therefore, use of PSB and AM would reduce P fertilizer dose, which ultimately reduces the high cost of phosphorus fertilizer. It also helps in solubilizing insoluble P and uptake by the plant.

Biological yield of maize increased with increasing CRR. The maximum biological yield 14.2 t/ha was recorded in crop residue retention @ 75% CRR followed by (14.1 t/ha) crop residue @ 50% CRR treatments. The biological yield of maize was also affected by P fertilization rates. The mean maximum biological yield (15.2 t/ha) was recorded with 50% RDP + PSB and AM followed by 150% RDP (14.9 t/ha) and 100 % RDP (14.7 t/ha). Both the treatments 100% RDP and 150% RDP were statistically at par with each other in increasing biological yield of maize. Integrated use of either 50% CRR + 50% RDP + PSB and AM or 75% CRR + 50% RDP + PSB and AM resulted in more or less same biological yield of 15.5 t/ha and 15.6 t/ha, respectively. The highest wheat grain yield was observed with 25-50% maize CRR (Alijani *et al.* 2012). Significant increase in dry matter yield and grain yield was observed due to seed inoculation with PSB. Similar increments in grain yield upon application of PSM were reported by other researchers (Patil *et al.* 2012, Dwivedi *et al.* 2017).

Table 3 Effect of crop residues and phosphorus fertilization on biological yield (t/ha) of maize in maize–wheat system

Crop residue retention (CRR)	Phosphorus rates (P)					
	No-P	50% RDP	100% RDP	150% RDP	50% RDP+ PSB & AM	Mean
No-CRR	10.8	13.0	14.1	14.3	14.7	13.4^{D}
25% CRR	11.1	13.3	14.7	14.8	15.2	13.8^{C}
50% CRR	11.4	13.4	14.9	15.1	15.5	14.1^{B}
75% CRR	11.6	13.6	15.2	15.3	15.6	14.2^{A}
Mean	11.2^{D}	13.3^{C}	14.7^{B}	14.9^{B}	15.2^{A}	
	CR	P	P at same CR		CR at same P	
SEm (±)	0.02	0.05	0.10		0.10	
LSD ($P \leq 0.05$)	0.06	0.11	NS		NS	

Phosphorus uptake

The results revealed that crop residue retention rates as well as P fertilization rates had significant positive impact on P uptake by maize grain over control. CRR significantly increased P uptake by the maize grain up to 50% crop residue retention treatment. After that, 50% CRR and 75% CRR treatments were statistically at par in maize grain P uptake. Crop residue retention as well as P fertilization rates differed in maize straw P uptake from 4.8 to 8.0 kg/ha. Crop residue retention increased in maize straw P uptake over control. The maximum straw P uptake (7.0 kg/ha) was recorded in crop residue retention @ 75% CRR followed by crop residue retention @ 50 CRR (6.8 kg/ha) and least P uptake in no crop residue retention (6.3 kg/ha).The treatment 50% crop residue retention was statistically at par with 25% CRR and 75% CRR in respect of straw P uptake. Among the various P fertilization rates, the mean maximum P uptake is (7.8 kg/ha) was recorded in 50% RDP + PSB and AM, followed by 100% RDP (7.2 kg/ha) and 150% RDP (7.0 kg/ha). Application of 100% RDP and 150% RDP were statistically at par in increasing P uptake by straw.

Total P uptake by maize was significantly and positively influenced by crop residue retention and different phosphorus fertilization rates**.** On an average, CRR increased total P uptake from 20.7 (control) to 23.7 kg/ha (75% CRR). The maximum total P uptake (23.7 kg/ha) was recorded with crop residue retention @ 75% CRR followed by crop residue retention @ 50% CRR (23.0 kg/ha) and least total P uptake (20.7 kg/ha) in control (No-CRR). Among various P fertilization treatments, the mean maximum total P uptake (26.6 kg/ha) was recorded in 50% RDP + PSB and AM, followed by 100% RDP (25.4 kg/ha) and 150% RDP (24.2 kg/ha) treatments. The increase in total P uptake could be attributed to higher yields as well as of P content in grain and straw (Suri and Choudhary 2012).

Apparent P recovery and agronomic efficiency

A significant improvement in apparent recovery of P (ARP) was observed under increasing levels of CRR and P fertilization (Table 2). CRR rates increased the ARP of maize from 17.2 (control) to 18.1% (75% CRR). Significantly higher apparent recovery of P (ARP) in maize was recorded (28.2%) in 50% RDP + PSB and AM, followed by 100% RDP (16.1%) and 50% RDP (14.3%) treatments which was 97% higher over 50% RDP. Result also indicated that ARP increased up to 100% RDP, after that, ARP in maize decreased significantly at 150% RDP. The study indicated that the application of microbial inoculants (combined use of PSB and AM) in maize can be reduce upto 50 per cent P fertilizer rate and increased the grain yield of maize.

Crop residue retention significantly increased agronomic efficiency of P in maize up to 50% CR over control. The maximum agronomic efficiency of P in maize (34.7 kg grain/kg P) was recorded in crop residue retention @ 25% CRR followed by crop residue retention @ 50% CRR (33.3 kg grain/kg P) and least agronomic efficiency (30.8 kg grain/kg P) in control (No-CRR). The 50% crop residue retention was statistically at par in respect of agronomic efficiency with 25% CRR and 75% CRR. Among various P fertilization rates, the maximum agronomic efficiency of P in maize (51.2 kg grain/kg P) was recorded with 50% RDP + PSB and AM, followed by 50% RDP (35.2 kg grain/kg P) and 100% RDP (26.8 kg grain/kg P) treatments. Significant decrease in agronomic efficiency of P in maize was recorded with increasing P fertilization rates.

Conservation tillage in most cases improved the availability of surface P by means of conversion of inorganic P to organic P (Meena *et al.* 2017). Maize crops, by virtue of its deep rooting pattern, can 'mine' the P from deep soil and deposit it on surface in terms of crop residue. In conventional tillage, remixing of surface P can be there, whereas, conservation tillage accumulates P at soil surface. Conservation agriculture improves labile pool of P in soil which supports in P nutrition to plants. CA restricts the intensive mixing of applied P with the soil constituents, thus preventing soil P fixation resulting in higher extractable P levels in zero tillage compared with tilled soil (Duiker and Beegle 2006). Retention of crop residue further enhances the benefit of CA manifold. Crop residue left at the surface is a great source of organic P, which can be mineralized over time and in synchrony with crop needs, improving P bio-availability. Addition of CRR decreased Al and Fe-bound, reductant soluble, Ca-bound P fraction, which constitutes the fixed from of P, in turn increasing the soluble and loosely bound P (Kumawat *et al.* 2016). These increase in organic bio-available pools of P due to CRR might be the main cause for an improvement in PUE under CRR plots.

Soil biological properties

Dehydrogenase activity (DHA): The dehydrogenase activity (DHA) in rhizospheric and non-rhizospheric (0-5 cm) soil as affected by different amounts of CRR and P fertilization rates is presented in Table 5. An increase of 6.1% and 4.4% in DHA activity in soil was recorded under CRR @ 75% in rhizospheric and non-rhizospheric (0-5 cm) soil, respectively over 50% crop residue retention treatment. However 75% CR (21.5 µg TPF/gm dry soil/h) recorded similar DHA to 25% CRR (21.3 µg TPF/gm dry soil/h) in non-rhizospheric (0-5 cm) soil. Moreover, the dehydrogenase activity (DHA) in rhizospheric soil was found higher as compared to non-rhizospheric soil (0-5 cm).This may be due to the higher carbon resources in the rhizosphere soil,which is considered as the driving force for microbial activity and density as reported by Yang *et al*. (2013).

Application of higher doses of inorganic P fertilizer significantly increased dehydrogenase activity (DHA) up to 100% RDP but decreased it at 150% RDP in rhizospheric and non-rhizospheric (0-5 cm) soil, whereas treatment 50% RDP + PSB and AM recorded significant highest DHA (27.9 µg TPF/gm dry soil/h) as compared to 100%

Table 4 Effect of crop residues retention and phosphorus fertilization on P uptake (kg/ha), apparent P recovery (%) and agronomic efficiency (kg grain/kg P) of maize

Treatment	P uptake grain	P uptake straw	Total P uptake	Apparent P recovery	Agronomic efficiency
Crop residue retention (CRR)					
No-CRR	14.3^{c}	6.3^{c}	20.7^{d}	17.2	30.8^{b}
25% CRR	15.5^{b}	6.6^{bc}	22.1^{c}	17.8	34.7^{a}
50% CRR	16.2^{a}	6.8^{ab}	23.0^{b}	17.6	33.3^{a}
75% CRR	16.7^{a}	7.0^{a}	23.7^{a}	18.1	33.2^{ab}
SEm (±)	0.16	0.09	0.17	0.65	1.01
LSD ($P \leq 0.05$)	0.39	0.22	0.41	NS	2.47
Phosphorus fertilization rates (P)					
No-P	10.5^{e}	5.2^{d}	15.7^{e}		
50% RDP	13.8^{d}	6.2^{c}	20.0^{d}	14.3^{c}	35.2^{b}
100% RDP	18.1^{b}	7.2^{b}	25.4^{b}	16.1^{b}	26.8^{c}
150% RDP	17.1^{c}	7.0^{b}	24.2^{c}	12.1^{d}	18.8^{d}
50% RDP + PSB and AM*	18.8^{a}	7.8^{a}	26.6^{a}	28.2^{a}	51.2^{a}
SEm (±)	0.15	0.11	0.20	0.55	1.15
LSD ($P \leq 0.05$)	0.30	0.22	0.41	1.14	2.38

*Phosphorus solubilizing bacteria and arbuscular mycorrhiza.

Table 5 Effect of crop residues retention and phosphorus fertilization soil biological properties of maize

Treatment	Dehydrogenase activity (DHA) (µg TPF/g dry soil/h)		Microbial biomass carbon (MBC) (mg/kg)		Microbial biomass phosphorus (MBP) (mg/kg)	
	Rhizospheric soil	0-5 cm	Rhizospheric soil	0-5 cm	Rhizospheric soil	0-5 cm
Crop residue retention (CRR)						
No-CRR	21.0[c]	19.9[c]	443[b]	353[c]	45.7[c]	37.7[c]
25% CRR	20.8[c]	21.3[ab]	448[b]	367[bc]	55.2[b]	40.6[bc]
50% CRR	22.9[b]	20.6[bc]	454[b]	374[ab]	56.8[b]	44.8[ab]
75% CRR	24.3[a]	21.5[a]	476[a]	388[a]	61.2[a]	48.1[a]
SEm (±)	0.35	0.34	5.98	7.77	3.84	2.10
LSD ($P \leq 0.05$)	0.86	0.83	14.64	19.01	4.89	6.68
Phosphorus fertilization rates (P)						
No-P	18.[8]d	18.6[d]	432[c]	356[c]	49.5[b]	39.8[bc]
50% RDP	20.2[c]	19.3[cd]	449[b]	362[c]	51.3[b]	38.1[c]
100% RDP	22.5[b]	21.8[b]	463[b]	365.5[bc]	59.7[a]	42.9[b]
150% RDP	21.9[b]	20.1[c]	453[b]	374.74[b]	53.6[ab]	40.7[bc]
50% RDP+ PSB and AM*	27.9[a]	24.4[a]	478[a]	395[a]	59.5[a]	52.4[a]
SEm (±)	0.42	0.53	6.85	5.83	3.08	1.93
LSD ($P \leq 0.05$)	0.85	1.07	13.95	11.87	6.52	4.09

*Phosphorus solubilizing bacteria and arbuscular mycorrhiza.

RDP (22.5 µg TPF/g dry soil/h). Across P fertilization rates, DHA registered 24 and 11.9 % increase under 50% RDP + PSB and AM over 100% RDP in rhizospheric and non-rhizospheric (0-5 cm) soil, respectively. Minimum DHA (18.6 µg TPF/g dry soil/h) was obtained under No-P (control) in non-rhizospheric (0-5 cm) soil. Treatments receiving 100% RDP and 150% RDP were statistically at par with each other in rhizospheric soil (Table 5).

Microbial biomass carbon (MBC) and Microbial biomass phosphorus (MBP)

The CRR rates enhanced the microbial biomass carbon over control. Maximum microbial biomass carbon (476 and 388 mg/kg) was found in 75% CRR followed by 50% CR (454 and 374 mg/kg), 25% CRR (448 and 367 mg/kg) and No-CRR (443 and 353 mg/kg) treatments in rhizospheric and non-rhizospheric (0-5 cm) soil, respectively. The 75% crop residue retention recorded significantly higher MBC as compared to rest of the treatments. The CRR @75% increased the MBC by 4.8 % in rhizospheric soil and by 3.7% non-rhizospheric (0-5 cm) soil over 50% CRR. Application of 50% RDP along with PSB and AM inoculation recorded significant highest MBC 478 and 395 mg/kg as compared to rest of other P fertilization rates in rhizospheric soil and non-rhizospheric (0-5 cm) soil respectively, which was increase by 32.4 and 8.0% over 100% RDP in rhizospheric and non-rhizospheric (0-5 cm) soil, respectively. Whereas 100% RDP and 150% RDP were statistically at par with each other in respect of microbial biomass carbon (MBC) and increasing rates of P enhanced MBC from 362 (50% RDP) to 374.7 mg/kg (150% RDP) in non-rhizospheric (0-5 cm) soil.

Microbial biomass phosphorus increased with increasing CRR rates and it ranged from 45.7 to 61.2 mg/kg in rhizospheric soil and 37.7 to 48.1 mg/kg in non-rhizospheric (0-5cm) soil (Table 5). Significant highest MBP was found (61.2 and 48.1 mg/kg) under 75% crop residue retention over other treatments in rhizospheric soil and non-rhizospheric (0-5 cm) soil, respectively. But 75% CRR treatment was statistically similar to 50% CR in respect of microbial biomass phosphorus in non-rhizospheric (0-5 cm) soil. In case of P fertilization rates, maximum MBP (59.77 mg/kg) was obtained in 100% RDP followed by fertilizer treatment 50% RDP + PSB and AM (59.50 mg/kg) which was statistically at par with each other and minimum in no-P (49.5 mg/kg) treatment in rhizospheric soil. The treatment receiving 150% RDP was found statistically at par with all other P fertilizer treatments in respect of MBP in rhizospheric soil. Significant highest MBP (52.4 mg/kg) was recorded in treatment receiving 50% RDP + PSB and AM as compared to other treatments in non-rhizospheric (0-5 cm) soil. All the treatments were statistically at par except 50% RDP + PSB and AM, which is significantly higher than rest of the treatments. The amount of carbon and P immobilized by the microbial biomass was the most important parameter in predicting the dynamics of carbon and P release from residues, and emphasized the importance of the microbial biomass as a pool of soil C and P as well as the driver of C and P mineralization and organic matter decomposition. Lundquist *et al.* (1999) observed higher microbial biomass carbon as an indicator of carbon availability in soil under organic practices. This might be due to the supply of additional mineralizable and readily hydrolysable carbon as a result of organic matter application resulting in higher microbial activity and in turn higher microbial biomass carbon. The increased microbial biomass in the surface soil of CR retained treatments has a direct effect on extractable P. The enhanced microbial biomass entraps P in SOM, which can be bio available in a short time period. The organic acids secreted by the PSB solubilized inorganic fixed P, thus increasing P bio-availability and PUE (Dwivedi *et al*. 2017).The CRR has beneficial effect on applied PSB along with inherent soil microbial biomass, which further reduces soil fixation of P and aggravates conversion of inorganic fixed P to organic P (Duiker and Beegle 2006).

Conclusions

Crop residue retention in cereal crops can enhance the crop productivity and soil fertility. The present study has also demonstrated higher microbial biomass, available soil P in CR retained plots. Overall, application of phosphorus solubilizing bacteria and AM fungi along with CRR can curtail P fertilization upto 50% besides improved crop yield, soil P availability, PUE vis-a-vis economic benefit to farmers.

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