



Crop residue and potassium management strategies to improve water use and soil microbial activities under zero till maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted with maize-wheat system during 2014-15 and 2015-16 at ICAR-IARI, New Delhi to study the soil microbial activities, crop growth, water use and its related parameters of maize and wheat as influenced by crop residue (CR) and potassium (K) management practices under zero till maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) system. The experiment was laid out in split-plot design with four CR levels (0, 2, 4 and 6 t/ha) and five K levels (0, 50%, 100%, 150% RDK [recommended dose of K] and 50% RDK + potassium solubilizing bacteria, KSB). The results revealed that significantly higher biomass production, water use efficiency (WUE), irrigation water productivity (IWP) and total water productivity (TWP) of maize and wheat were found with 4.0-6.0 t/ha CR as compared to no CR and 2.0 t/ha CR. This was in consonance with improvement in soil microbial activities. Among K management, 50% RDK+KSB, 100% RDK and 150% RDK were found significantly superior over no K and 50% RDK for soil microbial activities, biomass production, WUE, IWP and TWP of maize and wheat. Thus, a combination of 4.0-6.0 t/ha CR retention and 50% RDK along with seed inoculation of KSB microbial strain could be pre-eminent options to improve crop growth, water use efficiency and soil microbial activities in zero till maize-wheat system.

Key words: Conservation agriculture, Growth parameters, Indo-Gangetic Plains, KSB, Maize-wheat system, Microbial activity, Water productivity, Zero tillage

Crop residue burning, water table depletion and nutrient deficiencies are the serious concerns under the Indo-Gangetic Plains (IGP) for ease in sowing of succeeding wheat after rice (Raghavendra *et al.* 2017). Conservation agriculture (CA), with crop residue retention, zero tillage and crop rotation helps in improving the soil health, sustaining crop growth, productivity and enhancing input-use efficiency (Bhattacharyya *et al.* 2013). Crop residues (CR) are valuable assets in any agro-ecosystem and their returning into the soil serves as a useful technology for modifying soil hydrothermal regimes, storing water *in-situ* by minimizing evaporation and facilitating infiltration of water into the soil

profile for crop utilization which improve crop growth, yield besides soil microbial activities (Chakraborty *et al.* 2010). Potassium (K) is an essential plant macronutrient and plays an important role in many physiological processes, viz. water uptake, nutrient transport, growth and yield (Raghavendra *et al.* 2018). It is well known that the agricultural lands all over the world suffer from severe soil K deficiencies, especially in Asia (He *et al.* 2015). The reasons for this deficiency are that K fertilizer are applied seldom and also lacks attention by farmers who generally believe that K fertilizer does not effectively improve crop growth and yields compared to N and P fertilizers (Jiang *et al.* 2018), besides, K fertilizer cost has increased considerably over the past three years (Majumdar *et al.* 2012). Also, whole consumption of K fertilizers are imported which involves huge amount of foreign exchange. This necessitates the need to find an alternate K source that can meet the plants K needs and maintain K status in soils for sustaining crop production. K-solubilizing bacteria (KSB), ubiquitous, belong to *Bacillus* group and facilitate release of K into a plant-available form from K bearing minerals in soil (Meena *et al.* 2016). Therefore, present study was undertaken to identify the best crop residue and potassium management practice in zero till maize-wheat system to improve pertinent

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soil microbial activities and crop growth, water use efficiency of maize and wheat in IGP of India.

MATERIALS AND METHODS

The field experiment was conducted during 2014-15 and 2015-16 at the Research Farm, ICAR-Indian Agricultural Research Institute, New Delhi, located at 28° 37' - 28° 39' N latitude, 77° 9' - 77°11' E longitude and 228m above mean sea level (msl). Delhi falls under the agro-climatic zone 'Trans Indo-Gangetic Plains'. There was lot of variation in total rainfall received during cropping period in *kharif* 2014 and 2015 (395.4 and 633.10 mm) and *rabi* 2014-15 and 2015-16 (315.80 and 19.80 mm). The soil of experimental site was sandy loam in texture and having pH 8.33, EC 0.37 dS/m, soil organic carbon (SOC) 0.43%, KMnO_4 oxidizable N 143 kg/ha, NaHCO_3 extractable P 13.5 kg/ha, 1N ammonium acetate extractable K 245 kg/ha and bulk density 1.52 Mg m^{-3} at the initiation of the experiment. All these parameters of soil were analyzed by adopting standard procedures (Baruah and Barthakur 1999). The experiment was laid out in a split-plot design with 20 treatment combinations. Four levels of wheat crop residue [CR] (No CR, 2, 4 and 6 t/ha) sun dried retained on soil surface for maize cultivation and maize crop residue for wheat cultivation were included as main plots and five K levels (No K, 50% RDK, 100% RDK, 150% RDK and 50% RDK+KSB (Potassium solubilizing bacteria; seeds of both maize and wheat crops were treated with KSB @ 125 ml/ha) in sub-plots and replicated thrice. Maize (cv. PMH 4, seed rate 20 kg/ha) was sown at a row spacing of 60 cm and wheat (cv. HD CSW 18, seed rate 100 kg/ha) was sown at row to row distance of 20 cm with the help of zero seed drill machine (turbo seeder). Recommended dose of chemical fertilizers for maize and wheat were 150 N: 80 P_2O_5 : 60 K_2O kg/ha. In maize and wheat crops full dose of P and K (as per treatments) and half the dose of N were applied as a basal dose at sowing, and remaining dose of N was applied in two equal splits (maize- knee high and tasseling stage; wheat-maximum tillering and panicle initiation stage) as the standard practices (ICAR 2009). Depth of irrigation water was kept at 6-7 cm and number of irrigations applied in maize and wheat 4 and 5 during 2014-15 and 3 and 6 during 2015-16, respectively. The other necessary cultural management practices such as weed control and pest management were followed as per standard package of practices (ICAR 2009). For maize biomass sampling at harvest, three plants in quadrant of $0.70 \text{ m} \times 0.70 \text{ m}$ from sampling rows uprooted, and above ground portions were cut for observations. The sampled plants were first air dried and then dried in hot air oven at 65°C for 48

hr. Biomass production was expressed in g/plant. Similarly, wheat biomass sampling was also done at harvest an area of 0.5 m^2 and was expressed as g/m^2 . The mean depth of irrigation water in each plot as measured at 10 selected spots after irrigation with measuring scale. Rainfall data recorded at the meteorological observatory of ICAR-Indian Agricultural Research Institute, New Delhi was used for different water related calculations. The water use and productivity related parameters such as water use efficiency (WUE), irrigation water productivity (IWP) and total water productivity (TWP) in both crops were calculated as per the procedure suggested by (Ibragimov *et al.* 2011 and Sarma 2014). Total rainfall in crop growing period is considered as the effective rainfall. The rhizosphere enzymatic activities such as alkaline phosphatase (AP), cellulase, dehydrogenase (DHA), fluorescein diacetate (FDA) and microbial biomass carbon (MBC) in soil at 30 days after sowing (DAS) of maize and wheat were analysed by adopting standard procedure as elaborated previously (Miller 1959; Vance *et al.* 1987; Tabatabai 1994; Yadav and Tarafdar 2003). All the data obtained from maize and wheat crops for consecutive 2 years were statistically analysed using the F-test as per the standard procedure.

RESULTS AND DISCUSSION

Crop growth parameter

The maize and wheat biomass production was significantly higher in both 4.0 and 6.0 t/ha crop residue (CR) retention plots compared to 2.0 t/ha CR and No CR (Fig 1-2). Zero tillage with residue retention created favorable soil environments which helped in better germination, seedling establishment and provided more source of energy for soil microbes to improve nutrient recycling that might have enhanced crop growth and consequently added dry matter accumulation in CR retention plots of maize and wheat compared to non-residue retention plots (Ram *et al.*

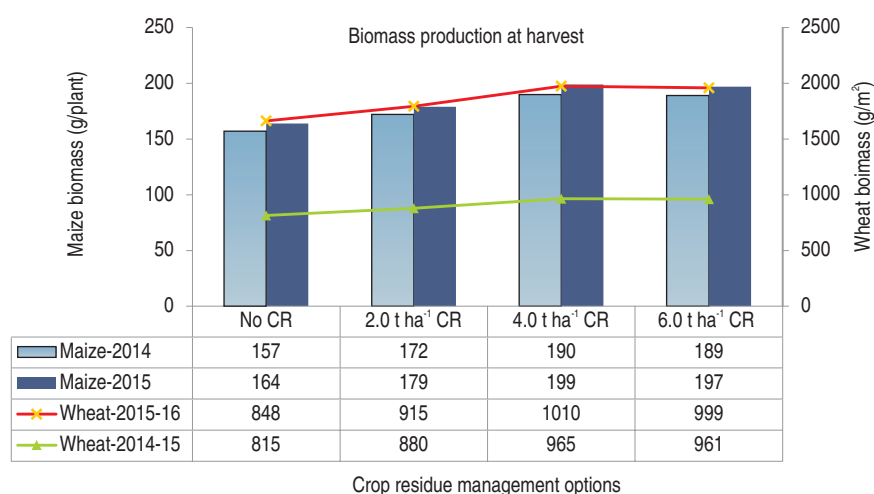


Fig 1 Effect of crop residue management practices on biomass production of maize and wheat under zero till maize-wheat cropping system [Maize 2014, LSD (P=0.05): 11.09; Maize 2015, LSD (P=0.05): 12.94; Wheat 2014-15, LSD (P=0.05): 25.53; Wheat 2015-16, LSD (P=0.05): 36.28].

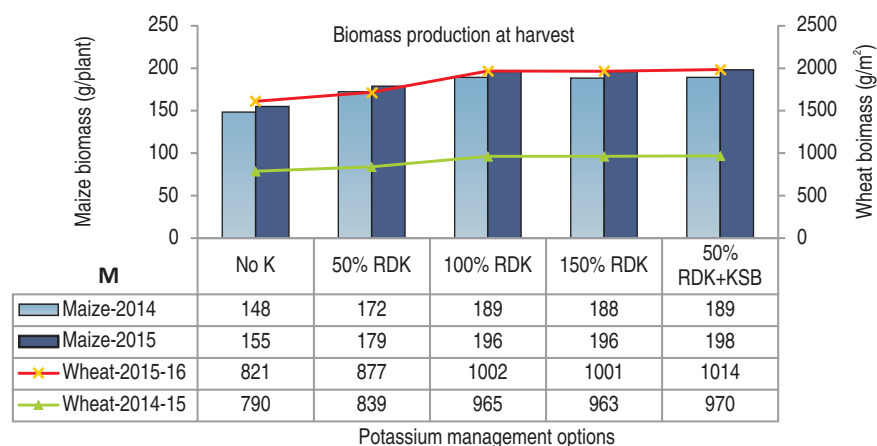


Fig 2 Effect of potassium management practices on biomass production of maize and wheat under zero till maize-wheat cropping system [Maize 2014, (LSD (P=0.05): 7.76; Maize 2015, LSD (P=0.05): 9.72; Wheat 2014-15, LSD (P=0.05): 28.76; Wheat 2015-16, LSD (P=0.05): 33.19].

2012). This result was also in consonance with Raghavendra *et al.* (2017). Among different K management practices 50% RDK+KSB showed significantly higher biomass production at harvest compared to control (No K) and 50% RDK and it remained at par with 100% RDK and 150% RDK in both years of maize and wheat crops. The synergistic interaction of potassium with other nutrients resulted in increased nutrient availability for photosynthetic activity in plants and higher rates of K allowed for the efficient use of more nitrogen, which resulted in better

early vegetative growth (Jiyun *et al.* 2009). The seed inoculation of liquid bio-fertilizer (KSB) for both maize and wheat crops had brought out significant improvement in biomass accumulation which might be due to the ability of microorganisms in the soil to solubilize unavailable forms of K-bearing minerals by production of protons, organic acids, siderophores, exopolysaccharides, and organic ligands so including KSB might have increased the availability and uptake of K by crops in addition to other macro, micronutrient, organic matter, organic carbon content, microbial growth and improved soil aggregate stability in soil has augmented growth of maize and wheat (Meena *et al.* 2016). The similar result was also reported by Raghavendra *et al.* (2017, 2018). There were no-significant interactive effects of residue and K-management found for biomass production in both the crops.

Water use and its productivity

Significantly higher WUE, IWP and TWP were recorded with 4.0 t/ha CR compared to 2.0 t/ha CR treatment and it was statistically non-significant with 6.0 t/ha CR in maize and wheat during both years (Table 1). These results indicated that crop residues have a positive effect

Table 1 Water use efficiency (WUE), irrigation water productivity (IWP) and total water productivity (TWP) of maize and wheat influenced by crop residue and potassium management practice under zero till maize-wheat cropping system

Treatment	WUE (kg/hamm)				IWP (kg/m ³)				TWP (kg/hamm)			
	Maize		Wheat		Maize		Wheat		Maize		Wheat	
	2014	2015	2014-15	2015-16	2014	2015	2014-15	2015-16	2014	2015	2014-15	2015-16
<i>Crop residue management practices (CRM)</i>												
No CR	6.20	7.89	9.79	8.60	1.46	2.13	1.27	1.05	6.29	5.52	6.75	10.06
2.0 t/ha CR	6.50	8.28	10.27	9.04	1.53	2.24	1.33	1.10	6.60	5.79	7.08	10.57
4.0 t/ha CR	6.88	8.77	10.79	9.53	1.62	2.37	1.40	1.16	6.98	6.14	7.44	11.15
6.0 t/ha CR	6.85	8.69	10.72	9.45	1.62	2.35	1.39	1.15	6.95	6.08	7.39	11.06
SEm±	0.08	0.10	0.13	0.11	0.02	0.03	0.02	0.01	0.08	0.07	0.09	0.13
LSD (P=0.05)	0.28	0.36	0.46	0.39	0.07	0.10	0.06	0.05	0.29	0.25	0.32	0.46
<i>Potassium management practices (PM)</i>												
No K	5.61	7.12	8.96	7.80	1.32	1.93	1.16	0.95	5.69	4.98	6.18	9.13
50% RDK	6.33	8.04	9.91	8.71	1.49	2.17	1.29	1.06	6.43	5.62	6.83	10.19
100% RDK	7.04	8.97	11.07	9.77	1.66	2.42	1.44	1.19	7.15	6.27	7.63	11.43
150% RDK	7.00	8.90	10.91	9.69	1.65	2.41	1.42	1.18	7.10	6.22	7.52	11.34
50% RDK+KSB	7.06	9.02	11.11	9.80	1.67	2.44	1.44	1.20	7.16	6.31	7.66	11.47
SEm±	0.05	0.09	0.11	0.10	0.01	0.02	0.01	0.01	0.06	0.06	0.08	0.12
LSD (P=0.05)	0.16	0.26	0.32	0.29	0.04	0.07	0.04	0.04	0.16	0.18	0.22	0.34
CRM × PM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

CR: Crop residue for both crops, RDK: Recommended dose of potassium, KSB: Potassium solubilizing bacteria, NS: Non-significant

Table 2 Effect of crop residue and potassium management practices on soil microbial activities at 30 days after sowing of maize and wheat under zero till maize-wheat cropping system

Treatment	Alkaline phosphatase ($\mu\text{g PNP/g soil/hr}$)				Cellulase activity (IU/g of soil)				Dehydrogenase activity ($\mu\text{gTPF/g soil/d}$)				Fluorescein diacetate ($\mu\text{g fluorescence/g soil/hr}$)				Microbial biomass carbon ($\mu\text{g c/g soil}$)			
	Maize		Wheat		Maize		Wheat		Maize		Wheat		Maize		Wheat		Maize		Wheat	
	2014	2015	2014-15	2015-16	2014	2015	2014-15	2015-16	2014	2015	2014-15	2015-16	2014	2015	2014-15	2015-16	2014	2015	2014-15	2015-16
<i>Crop residue management practices (CRM)</i>																				
No CR	35.5	39.7	46.3	48.2	8.60	11.0	6.80	7.40	40.5	43.9	35.0	37.8	1.31	1.39	2.21	2.39	218	230	222	230
2.0 t/ha CR	42.3	45.0	53.2	55.2	11.4	15.2	7.70	8.40	47.9	51.8	41.6	44.7	1.61	1.71	2.50	2.70	271	286	272	285
4.0 t/ha CR	48.0	54.5	61.8	63.6	14.2	16.7	9.20	10.10	52.0	56.3	53.1	57.0	1.78	1.94	2.64	2.96	293	309	293	308
6.0 t/ha CR	49.5	56.2	63.4	65.5	15.1	16.9	9.60	10.50	53.1	57.5	54.9	58.7	1.82	1.96	2.69	3.00	295	312	297	313
SEm $\pm$	1.03	1.08	0.60	0.78	0.57	0.3	0.21	0.26	0.48	0.60	1.56	1.62	0.03	0.04	0.03	0.06	5.89	5.95	3.40	3.78
LSD (P=0.05)	3.58	3.72	2.07	2.68	1.98	1.2	0.71	0.91	1.67	2.07	5.39	5.62	0.11	0.14	0.11	0.19	20.4	20.6	11.8	13.1
<i>Potassium management practices (PM)</i>																				
No K	25.0	28.1	34.4	36.1	8.00	8.30	6.70	7.30	30.0	32.5	28.5	31.0	0.87	0.93	1.70	1.85	188	198	192	196
50% RDK	41.9	45.3	56.8	58.8	11.4	15.5	7.80	8.50	47.5	51.4	42.8	45.9	1.69	1.81	2.59	2.81	276	290	273	287
100% RDK	50.2	57.0	63.3	65.3	14.0	17.0	9.10	9.90	54.8	59.4	53.2	56.8	1.86	2.00	2.75	3.05	294	312	297	313
150% RDK	49.4	55.9	62.3	64.3	13.3	16.8	8.80	9.70	54.3	58.8	52.8	56.4	1.83	1.97	2.72	3.01	293	309	296	311
50%RDK+KSB	52.5	57.8	64.2	66.2	14.8	17.2	9.20	10.10	55.3	59.9	53.5	57.7	1.89	2.06	2.79	3.10	295	313	298	314
SEm $\pm$	1.13	1.00	1.05	0.98	0.54	0.43	0.31	0.35	0.67	0.75	1.43	1.53	0.03	0.04	0.04	0.06	4.32	4.78	6.97	8.04
LSD (P=0.05)	3.27	2.89	3.03	2.82	1.57	1.24	0.89	1.01	1.92	2.17	4.13	4.4	0.10	0.11	0.12	0.17	12.4	13.8	20.1	23.2
CRM $\times$ PM	S	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

on water saving. In residue retained plots, improvement in water stable aggregates, microbial growth, increased water holding capacity of soil and reduced evaporative losses during cropping period might have enhanced water use efficiency. These results are also in agreement with Saad *et al.* (2015). Among potassium management treatments, 50% RDK+KSB recorded highest WUE, IWP, TWP and it was statistically similar to 100% RDK and 150% RDK. Maximum yield was recorded under these treatments that resulted higher WUE, IWP and TWP compared to other treatments. Potassium played important role in improving crop root system, growth rate, canopy biomass at early stages and lowered losses of unproductive evaporated water (Ahmad *et al.* 2015). This resulted in conserving water uptake and thereby improved crop plant water relation in maize and wheat crop and in turn resulted in higher WUE, IWP and TWP (Ul-allah *et al.* 2020). The similar findings also reported by Witold Grzebisz *et al.* (2013). Relatively lower WUE, IWP and TWP were recorded in K control followed by 50% RDK in both maize and wheat during both years of study. The interaction effect of crop residue and K levels were non-significant for water use efficiency and productivity parameters.

Soil microbial activities

The significantly higher soil microbial activity such as alkaline phosphates, cellulase, dehydrogenase, FDA and microbial biomass carbon were observed with 6.0 t/ha CR over No CR and 2.0 t/ha CR (Table 2) in maize and wheat at 30 DAS during both the years. The markedly increased microbial activities under residue retained plots due to repeated application of organic residues and subsequent stimulation of microbial biomass, enhanced humus content, accumulation of organic matter, abundance of carbohydrates coupled with improved soil physical and chemical properties had a stronger impact on soil microbial activity (Vandana *et al.* 2012). The similar findings were also reported by Raghavendra *et al.* (2018). Among K management, 50% RDK+KSB showed significantly higher soil microbial activity at 30 DAS in maize and wheat during 2014-2016 and it was found non-significant with 100% RDK and 150% RDK. All microbial parameters such as alkaline phosphatase, cellulase, dehydrogenase, fluorescein diacetate activities and microbial biomass carbon were found to be significantly lower in soil with No-K and 50% RDK. The interaction between crop residue and K management was significant for only alkaline phosphatase activity in maize 2014 and 2015 at 30 DAS. The increase in all microbial parameters in 50% RDK+KSB might be due to the growth hormone production and release of organic acid by KSB inoculants with seed in soil. This result is also comparable with Basavesha (2013) and Raghavendra *et al.* (2018). K-fertilizer, in addition to optimum supply of N and P nutrients directly improved the root growth and development and root exudates provided the required nutrients for microbes which in turn enhanced microbial growth and affected the composition of microbial

communities. Similar result was also reported by Naher *et al.* (2013).

Conclusion

It was concluded that crop residue retention @ 4.0-6.0 t/ha along with 50% RDK+ seed inoculation of potassium solubilizing bacteria enhanced maize and wheat biomass production with concomitant increase in water use and its productivity as well as soil biological activities under zero tilled maize-wheat cropping system, hence may be recommended for adaptation by the farmers under IGP of India.

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