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System productivity and economics influenced by residue and potassium management in maize (*Zea mays*)-wheat (*Triticum aestivum*) rotation

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ABSTRACT

A field experiment was conducted during *kharif* and *rabi* 2014-2016 at ICAR-IARI, New Delhi to study the system productivity, economics and energetics of maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) as influenced by crop residue (CR) and potassium (K) management under zero till maize-wheat 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). Results revealed that significantly higher system productivity, output energy, specific energy and highest energy intensiveness, actual change in available K were found with 4.0-6.0 t/ha CR. Maximum B: C ratio in maize-wheat system was observed with No CR followed by 2.0-4.0 t/ha CR. Highest net energy returns, energy use-efficiency, energy productivity and lowest input energy (351-395%) in both crops were registered with No CR fb 2.0-4.0 t/ha CR. Among K management, 50% RDK+KSB was significantly superior over rest levels. The maximum system net returns, B:C ratio, output energy, net energy returns, energy use-efficiency and energy productivity were found in 50% RDK+KSB and consumed only 0.34-0.35% higher input energy over no K in maize and wheat. Change in available K was more in 150% RDK fb 50% RDK+KSB and 100% RDK. Thus, a combination of 2.0-4.0 t/ha CR retention and 50% RDK along with seed inoculation with KSB improved system productivity, net returns and energetic parameters in zero tillage maize-wheat system, and brought positive change in available K and hence can be recommended for adaptation by the farmers.

Key words: Available potassium, Conservation agriculture, Energetics, Indo-Gangetic Plains, Potassium solubilizing bacteria, Zero tillage

Crop residue (CR) is considered as valuable natural resource for agro ecosystem stability (Raghavendra *et al.* 2020). India generates 84-141 million ton (mt) of total surplus CR every year, out of which cereals contribute 23% (MNRE 2009). About 75% of K-uptake by cereals can be retained in CR, making them valuable nutrient sources (Raghavendra *et al.* 2017). Farmers burn CR in open field at Indo-Gangetic Plains (IGP) of India, which leads to emission of harmful gases and air pollutants into atmosphere with loss of plant nutrients (Raghavendra *et al.* 2018). To minimize this problem, recycling of nutrients through CR retention is one of the desirable options in IGP (Prasad 2005). Potassium (K) is the third macro-nutrient required by crop plants and plays a significant role in growth, development and provides resistance to biotic and abiotic stresses (Raghavendra *et al.* 2020). Average yield losses of maize and wheat in farmer's fields due to K-omission were 700 and 715 kg/ha, respectively (Majumdar *et al.* 2012). This suggests that skipping application of K in these two cereals will cause variable yield and economic loss to farmers in the region and will affect overall cereal production of the country (Majumdar *et al.* 2012). Currently, no reserves of K-bearing minerals in India for production of commercial K-fertilizers and whole consumption of K-fertilizers imported, which involves huge amount of foreign exchange. This necessitates, to find an alternate K source that can meet plant's K needs and maintain K status in soils for sustaining crop production. Applied inorganic K fertilizer gets bound with other minerals and only 1-2% available for crop uptake. Under such circumstances, biological extraction of K holds good promise. Potassium solubilizing microorganisms have potential to solubilise K minerals by excreting organic acids (Meena *et al*. 2015). However, the performance of KSB depends upon their establishment in soil niche and may vary with type of strain, crop management practices and test crops and thus needs to be investigated. Keeping this in view present experiment undertaken to study the system productivity and economics of maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) system under conservation agriculture based best management practices.

MATERIALS AND METHODS

The field experiment was conducted during *kharif*

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and *rabi* 2014-15 and 2015-16 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi located at 28.35°N latitude and 77.12°E longitude and 228.6 m (AMSL). There was lot of variation in total rainfall received during *kharif* 2014 and 2015 with 395.4 and 633.10 mm and *rabi* 2014-15 and 2015-16 were 315.80, 19.80 mm of maize and wheat crops respectively. The mean maximum temperature (34.27, 33.47°C), mean minimum temperature (22.83, 22.13°C) for *kharif* maize and similarly for wheat mean maximum temperature (24.27, 26.81°C), mean minimum temperature (10.36, 9.77°C) during both years. Experimental soil has *p*H 8.33, EC 0.37 dS/m, soil organic carbon (SOC) 0.43%, $KMnO_4$ oxidizable N 143 kg/ha, $NaHCO_3$ extractable P (*p*H 8.5) 13.5 kg/ha, and 1N ammonium acetate extractable K 245 kg/ha and bulk density 1.52 Mg/m at the initiation of the experiment. All these parameters were analysed by adopting standard procedures (Boruah and Barthakur 1999). Experiment was laid out in split plot design in 20 treatment combinations with four crop residue (CR) levels (No CR, 2 t/ha CR, 4 t/ha CR and 6 t/ha CR) in main plot and five potassium levels (No K, 50% RDK (recommended dose of potassium), 100% RDK, 150% RDK and 50% RDK+KSB (Potassium solubilizing bacteria) in sub plots and replicated thrice. Maize (PMH 4) and wheat (HD CSW 18) were sown at 60 cm × 30 cm and 20 cm, respectively with the help of turbo-seeder with seed rate of 20 kg/ha for maize and 100 kg/ha for wheat. Recommended dose of fertilizer for both crops (150:80:60 kg N, P_2O_5 and K_2O/ha) was placed below the seed zone at sowing as per treatment. In maize and wheat crops full dose of P and K and half of the dose of N were applied as basal at sowing. Remaining N in wheat was top dressed in two equal splits after the first and second irrigation. In maize remaining N was top dressed at 35 days after sowing. Seeds of both maize and wheat crops were treated with KSB @ 50 ml/acre as per treatment. Sun dried chopped residues of the wheat and maize crops of previous season were applied at different levels to maize and wheat crops, respectively by retaining on the soil surface as mulch in all treatments except control after sowing of crops. To provide an ideal weed free environment to maize crop Pendimethalin @ 1.00 kg a.i./ha along with Atrazine (@ 0.75 kg *a.i.*/ha was sprayed as pre-emergence at 2 days after sowing. To manage weeds in wheat, Isoproturon @ 0.75 kg *a.i.*/ha) along with 2, 4D @ 0.25 kg *a.i.*/ha was applied as post emergence at 30 days after sowing. Grain yield and market price of both maize and wheat crops differ, hence their combined (system) productivity computed by converting wheat grain yield into maize-equivalent yield. Afterwards, the maize-equivalent yield of wheat grain is added with maize grain yield to compute the productivity of the system (Sarma 2014). Maize-wheat system economic parameter (cost of cultivation, net return and B: C ratio) were computed on the basis of prevailing market prices of inputs and minimum support price for outputs of the respective years. For estimation of energy inputs and outputs for each item of inputs used and agronomic practices followed, were adopted from various available literatures (Chaudhary *et al*. 2006, Devasenapathy *et al*. 2009, Azarpour 2012). Net energy, energy-use efficiency and energy productivity were calculated with help of formula as suggested by Mittal and Dhawan (1988) and Mandal *et al.* (2015). Actual change in available K was obtained by subtracting final available K at the end of two years cropping cycle with initial available K. The data obtained from maize and wheat crops were statistically analysed using F-test as per the procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

System productivity: Significantly higher system productivity was recorded with 4.0-6.0 t/ha CR as compared to No CR and 2.0 t/ha CR during both the years of study (Table 1). Zero tillage (ZT) and CR retention has been found to improve overall soil condition, with higher soil water content and other physical, chemical and biological properties of soil (Raghavendra *et al.* 2020). Consequently, ZT along with residue retention throughout the cropping cycle of wheat and maize was most productive showing highest system productivity (Das *et al*. 2013). Further, addition of higher quantity of cereal residues decreased the readily available nutrients through increased immobilization of nutrients not only N but also phosphorus and sulphur in soil for crop uptake at initial stage and also due to wider C: N/C: P/C:S ratio (Eriksen 2005). Among K management practices 50% RDK+KSB was found significantly superior over No K and 50% RDK and this was statistically similar to 100% RDK and 150% RDK for system productivity in both years of experimentation. Seed inoculation of KSB might have helped in mobilization of K from soil because of secretion of organic acids, siderophores, exopolysaccharides and organic ligands by bacterial strain, increased availability of both essential macro and micro nutrients for crop uptake in soil by maintaining soil health (Raghavendra *et al*. 2018). In addition, adequate K nutrition provided to maize and wheat, enhanced the growth and yield attributes, which further might have brought significant improvement in maize-wheat system productivity (Raghavendra *et al*. 2017).The similar results were also reported by Kumar *et al*. (2015).

System economics: Monetary advantage in terms of gross returns, net returns and B: C ratio varied significantly due to residue and K management practices and brought considerable improvement in maize-wheat system economics (Table 1). Highest system cost of cultivation was estimated in 6.0 t/ha CR (34.87 and 34.50%) in both year's followed by (fb) 4.0 t/ha CR and 2.0 t/ha CR. Maximum maize-wheat system net returns were registered with 4.0 t/ha CR (3.76, 4.85%) in both years and it was statistically non-significant with all CR management practices including No CR treatment. Highest maize-wheat system B:C ratio was observed in No CR fb 2.0 t/ha CR and 4.0 t/ha CR. Lowest B:C ratio was observed with 6.0 t/ha CR. The positive effects of ZT and residue retention witnessed on productivity were translated into more favourable economics. Therefore, ZT with residue retention was most remunerative tillage

Table 1 Maize-wheat system productivity and economics influenced by residue and potassium management practices under zero tillage

Treatment	Maize-wheat 2014-15				Maize-wheat 2015-16			
	System productivity (t/ha)	*Cost of cultivation (₹ /ha)	Net returns (₹/ha)	B:C	System productivity (t/ha)	*Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C
Crop residue management practices (CR)								
No CR	9.35	51616	101020	1.95	9.97	52156	111938	2.14
2.0 t/ha CR	9.80	57616	102356	1.77	10.46	58156	113760	1.95
4.0 t/ha CR	10.34	63616	104828	1.65	11.06	64156	117367	1.83
6.0 t/ha CR	10.28	69616	97970	1.41	10.97	70156	110065	1.57
SEm±	0.12		1875	0.03	0.13		2018	0.03
LSD (P=0.05)	0.41		NS	0.11	0.44		NS	0.12
Potassium management practices (PM)								
No K	8.51	58072	81607	1.43	9.03	58612	90505	1.56
50% RDK	9.50	59854	96089	1.63	10.13	60394	106807	1.79
100% RDK	10.59	61636	110442	1.81	11.32	62176	123265	2.01
150% RDK	10.48	63418	107091	1.71	11.23	63958	120231	1.9
50% RDK+KSB	10.62	60104	112488	1.9	11.37	60644	125604	2.1
SEm±	0.07		1209	0.02	0.11		1723	0.03
LSD (P=0.05)	0.21		3483	0.06	0.31		4962	0.09
CR × PM	NS		NS	NS	NS		NS	NS

CR, Crop residue; RDK, Recommended dose of potassium; KSB, Potassium solubilizing bacteria; NS, Non-significant; *Data statistically not analysed.

practice in the maize–wheat cropping system (Raghavendra *et al*. 2017). Similar kind of results in ZT-CR retention under maize-wheat system was reported (Rajkumara *et al.* 2014). Among K management practices highest system gross returns, net returns (37.84, 38.78%) and B:C ratio were registered in 50% RDK+KSB over the control K and 50% RDK. This might be due to higher productivity in this treatment and low cost of KSB (₹125/ha) which reduced the cost incurred on K fertilizer (Raghavendra *et al*. 2017). Majumdar *et al.* (2012) reported the higher returns on investment of applied K in wheat and maize which were ₹4.4 and 3.2, respectively per rupee invested on K.

Energy relationship in maize and wheat: Input energy in maize and wheat was highest with 6.0 t/ha CR and lowest energy was consumed with No CR, saved energy by 395% in maize and 351% in wheat compared to 6.0 t/ha CR (Table 2). Since crop productivity was higher, with 4.0-6.0 t/ha CR, the output energy was also higher with ZT surface residue retention throughout crop cycle. Output energy, specific energy and energy intensiveness were relatively higher with 4.0-6.0 t/ha CR over No CR and 2.0 t/ha in second year of maize and wheat. But net energy returns, energy use-efficiency and energy productivity in maize and wheat were higher with No CR fb 2.0 t/ha CR. Maximum energy consumption through residue application lowered energy return, energy-use efficiency and energy productivity, though 4.0-6.0 t/ha CR were the highest energy producer among residue management treatment. Energy in-flow through residue application in crop production did not maximize much out-flow energy as crop residues improve soil quality when returned to soil. Energy provided by CR was not however included in energetics by some researchers, as it was returned to soil (Khakbazan *et al.* 2009). But in present experiment, residue management was an integral part of the study. Besides quantity, methods of residue application in a particular tillage practice should not be ignored. Surface retained residues had mulch effect, resulting better soil physical, chemical and biological properties, C-sequestration and abiotic stress moderations without any expense of energy and consequently higher crop and system productivity. In this study output energy was significantly higher when residues were retained on soil surface. With this view, ZT and CR retained on soil surface were better than ZT where residues were not retained in soil. About 25–30% of energy was required to field preparation and crop establishment (Tomar *et al*. 2006).

Among K management practices, 50% RDK+KSB recorded significantly higher output energy, net energy returns, energy use-efficiency, energy productivity over control K and it had statistically similar values with 100% RDK and 150% RDK in second year of maize and wheat. The 50% RDK+KSB consumed 0.71% and 0.68% less energy in maize and wheat, respectively as compared to 150% RDK. The biofertilizers have small energy equivalents and their total energy inputs were very low (Mihov and Tringovska 2010).

Table 2 Energy relationships influenced by crop residue and potassium management practices on second year of maize and wheat under zero till maize-wheat cropping system

Treatment	Input energy (MJ)		Output energy (MJ/ha)		Net energy return (MJ/ha)		Energy-use efficiency		Energy productivity (kg/GJ)		Specific energy (kg/GJ)		Energy intensiveness	
	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat
Crop residue management practices (CRM)														
No CR	18977	21350	170838	170109	151861	148759	9.00	7.96	248	224	4065	4513	0.74	0.81
2.0 t/ha CR	43977	46350	179703	177890	135726	131540	4.09	3.84	113	108	8978	9320	1.48	1.64
4.0 t/ha CR	68977	71350	188639	187304	119662	115954	2.73	2.62	76.0	74.2	13279	13596	2.04	2.35
6.0 t/ha CR	93977	96350	187479	186289	93502	89939	1.99	1.93	55.2	54.5	18278	18511	2.49	2.98
SEm±			2104	2036	2104	2036	0.04	0.04	1.20	1.10	173	178		
LSD (P=0.05)			7282	7044	7282	7044	0.14	0.12	4.00	3.90	597	617		
Potassium management practices (PM)														
No K	56195	58568	156665	155975	100470	97407	3.86	3.56	105	98.6	12958	13277	1.74	2.02
50% RDK	56396	58769	177390	174287	120994	115518	4.36	3.96	118	110	11549	11957	1.7	1.97
100% RDK	56597	58970	191340	190679	134743	131709	4.68	4.31	131	123	10407	10717	1.66	1.92
150% RDK	56798	59171	190329	189799	133531	130628	4.62	4.27	129	121	10526	10836	1.62	1.87
50% RDK+KSB	56397	58771	192599	191250	136201	132480	4.74	4.35	133	124	10310	10639	1.69	1.96
SEm±			1814	1793	1814	1793	0.07	0.06	2.00	1.80	151	155		
LSD (P=0.05)			5225	5165	5225	5165	0.20	0.18	5.70	5.20	435	447		
CRM × PM			NS	NS	NS	NS	S	S	S	S	S	S		

CR, Crop residue; RDK, Recommended dose of potassium; KSB, Potassium solubilizing bacteria; NS, Non-significant; S, Significant.

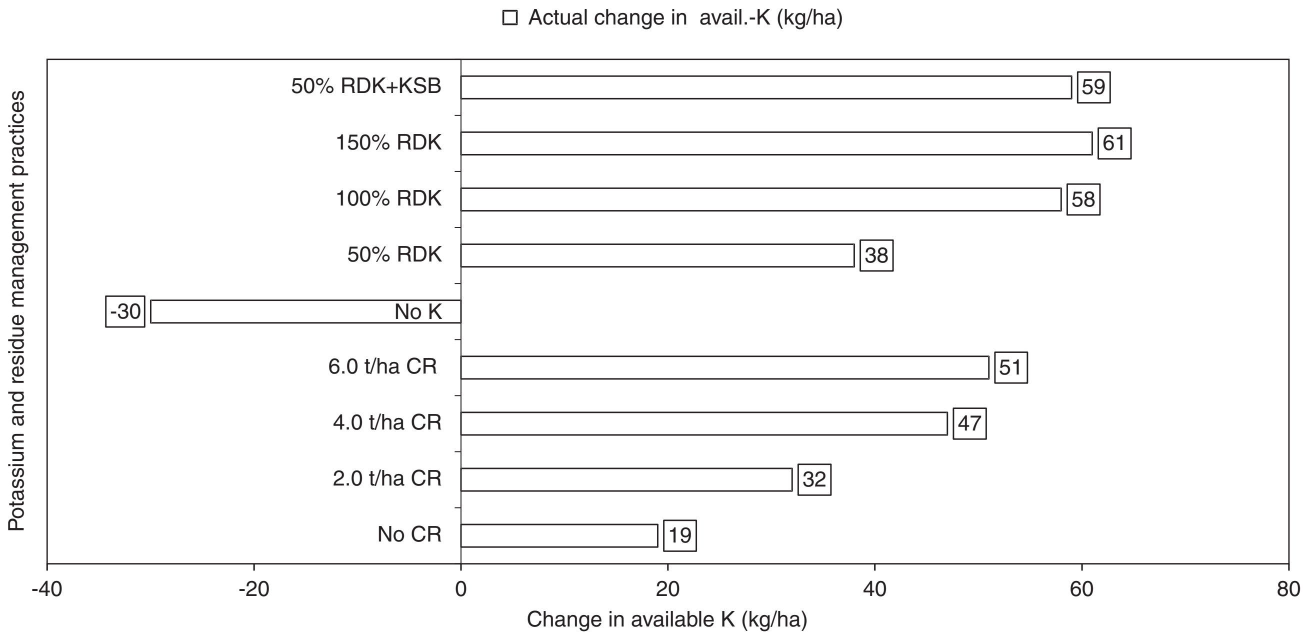

Fig 1 Effect of crop residue and potassium management practices on actual change in available potassium in soil at harvest of second year wheat under conservation agriculture-based maize-wheat cropping system.

Actual change in available K: Marked improvement in actual change of K in soil was observed due to residue and K management practices (Fig 1). Among CR treatments, higher values of actual change in K were found in 6.0-4.0 t/ha CR retention (51-47 kg/ha) compared to No CR and 2.0 t/ha CR. Among K levels 150% RDK showed highest change in available K (61 kg/ha) followed by 50% RDK+KSB (59 kg/ha) and 100% RDK. Similar result was also reported by Saad (2014). Lowest and negative change in available K were found with 50% RDK and K control (-30 kg/ha), respectively at the end of two-year maize-wheat system. Extra K uptake under the NP fertilized treatment was probably either from deeper sub soil or from release of non-exchangeable K which was one of the important K sources for plants under the No K fertilization (Singh and Goulding 1997).

It was concluded that ZT with CR retention at 6.0 t/ha significantly improved system productivity, nutrients and energy related parameters but consumed more input energy along with high cost and lower B:C ratio thus become economically unsustainable. Hence residue retention at 2.0-4.0 t/ha could be better option under ZT environment, as these two treatments showed similar trends for all energy, nutrients, system productivity and economic parameters. Seed inoculation of KSB+50% RDK could curtail 50% inorganic K fertilizers, significantly improved system productivity, economics, energetics and brought positive change in available K. Therefore, under ZT-maize-wheat system residue retention @ 2.0-4.0 t/ha and seed inoculation with KSB biofertilizer alongwith 50% RDK could be sustainable K management practices so may be recommended for farmer's adoption in IGP of India.

REFERENCES

Azarpour–Ebrahim. 2012. Determination of energy balance and energy indices in wheat production under watered farming in north of Iran. *ARPN Journal of Agricultural and Biological Science* **7**(4): 250–5.

Baruah T C and Barthakur H P. 1999. *A Text Book of Soil Analysis*. Vikas Publishing House Pvt Ltd, New Delhi.

Choudhary V P, Gangwar B and Pandey D K. 2006. Auditing of energy use and output of different cropping systems in India. *Agricultural Engineering International: The CIGR E Journal.* Manuscript EE 05 001 Vol. VIII. June, 2006.

Das T K, Bhattacharyya R, Sharma A R, Das S, Saad A A and Pathak H. 2013. Impacts of conservation agriculture on total soil organic carbon retention potential under an irrigated agro-ecosystem of the western Indo–Gangetic Plains. *European Journal of Agronomy* **51**: 34–42.

Devasenapathy P, Senthil Kumar G and Shanmugam PM. 2009. Energy management in crop production. *Indian Journal of Agronomy* **54**(1): 80–90

Eriksen J. 2005. Gross sulphur mineralization-immobilization turnover in soil amended with plant residues. *Soil Biology and Biochemistry* **37**: 2216–24.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research. Second Edition*. An International Rice Research Institute Book. A Wiley–Inter science Publication, John Wiley & Sons, New York.

Ibragimov N, Evett S, Esenbekov Y, Khasanova F, Karabaev I, Mirzaev L and Lamers J. 2011. Permanent beds vs. conventional tillage in irrigated arid Central Asia. *Agronomy Journal* **103**(4): 1002–11.

Khakbazan M, Mohr R M, Derksen D A, Monreal M A, Grant C A, Zentner R P, Moulin A P, McLaren D L, Irvine R B and Nagy C N. 2009. Effect of alternative management practices on economics, energy and GHG emissions of a wheat - pea cropping system in the Canadian prairies. *Soil and Tillage Research* **104**: 30–8.

Kumar S, Shiva Dhar Ashok K and Dileep K. 2015. Yield and nutrient uptake of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system as influenced by integrated potassium management. *Indian Journal of Agronomy* **60**(4): 511–5.

Majumdar K, Kumar A, Shahi V, Satyanarayana T Jat M L, Dalip K, Mirasol P, Naveen G, Singh V, Dwivedi B S, Meena M C, Singh V K, Kamboj B R, Sidhu H S and Adrian J. 2012. Economics of potassium fertiliser application in rice, wheat and maize grown in the Indo–Gangetic Plains. *Indian Journal of Fertilizer* **8**(5): 44–53.

Mandal S, Roy S, Das A, Ramakrishna GI, Lal R, Verma B C, Kumar A, Singh R K and Layek J. 2015. Energy efficiency and economics of rice cultivation systems under subtropical Eastern Himalaya. *Energy for Sustainable Development* **28**: 115–21.

Meena V S, Maurya B R and Verma J P. 2015. Does a rhizospheric microorganism enhance K^+ availability in agricultural soils? *Microbiological Research* **169**: 337–47.

Mihov M and Tringovska I. 2010. Energy efficiency improvement of greenhouse tomato production by applying new biofertilizers. *Bulgarian Journal of Agricultural Science* **16**(4): 454–8.

Mittal J P and Dhawan K C. 1988. Research Manual on Energy Requirements in Agricultural sector. ICAR, New Delhi, pp 20–3.

Prasad R. 2005. Rice–wheat cropping system. *Advances in Agronomy* **86**: 255–339.

Raghavendra M, Singh Y V, Das T K and Meena M C 2017. Effect of crop residue and potassium management practices on productivity and economics of conservation agriculture–based maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agricultural Sciences* **87**: 855–61.

Raghavendra M, Singh Y V, Meena M C, Das T K, Sunita G and Verma R K. 2020. Potassium and residue management options to enhance productivity and soil quality in zero till maize–wheat rotation. *CLEAN–Soil, Air, Water* **48**(03): 1900316.

Raghavendra M, Singh Y V, Sunita G, Meena M C and Das T K. 2018. Effect of Potassium and Crop Residue Levels on Potassium Solubilizers and Crop Yield under Maize–Wheat Rotation. *International Journal of Current Microbiology and Applied Science* **7**(06): 424–35. doi: https://doi.org/10.20546/ijcmas.2018.706.048.

Rajkumara S S, Gundlur S, Neelakanth J K and Ashoka P. 2014. Impact of irrigation and crop residue management on maize (*Zea mays*)–chickpea (*Cicer arietinum*) sequence under no tillage conditions. *Indian Journal of Agricultural Sciences* **84**(1): 43–8.

Saad A A. 2014. 'Conservation agriculture for improving productivity and resource-use efficiency in maize (*Zea mays*)-based cropping system'. Ph D Thesis. ICAR-IARI, New Delhi.

Sarma A. 2014. *Numerical Agronomy*. Kalyani Publishers, New Delhi.

Sheng X F, Xia J J and Cheng J. 2003. Mutagenesis of the *Bacillus edaphicus* strain NBT and its effect on growth of chilli and cotton. *Agricultural Science China* **32**: 258–65.

Singh B and Goulding K W T. 1997. Changes with time in the potassium content and phyllosilicates in the soil of the broadbalk continuous wheat experiment at Rothemsted. *European Journal of Soil science* **48**: 651–9.

Tomar R K, Garg R N and Gupta V K. 2006. Optimum tillage and resource conservation technologies for cropping systems. *Indian Farming* **56**: 27–32.