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Research Articles

Effect of crop residue and potassium management practices on productivity and economics of conservation agriculture based maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted in kharif and rabi seasons of 2014-2016 at ICAR-IARI, New Delhi to study the effect of crop residue and potassium (K) on productivity and economics of maize (Zea mays L.) and wheat (Triticum aestivum L.) under conservation agriculture (CA) based maize-wheat cropping system. The experiment was conducted in split plot design with four levels of crop residue in main plot, viz. no crop residue (CR), 2.0 tonnes/ha CR, 4.0 tonnes/ha CR, 6.0 tonnes/ha CR and five potassium levels, viz. no K, 50% RDK, 100% RDK, 150% RDK, 50% RDK+KSB in sub-plots. Results revealed that the yield attributes, grain and stover/straw yield were significantly influenced by the crop residue and K management practices over the control in both crop during both the years. Treatment with 50% RDK+KSB showed the significantly highest values of all yield attributes like, number of grains/cob, grain weight/cob, test weight and grain (4.91, 5.39 tonnes/ha) and stover yield (8.41, 9.07 tonnes/ha) in maize. In wheat also number of spikes/m2, grains/spike, spike weight, test weight and yield (5.16, 5.45 tonnes/ha) and straw yield were significantly higher over the control and 50% RDK. However this treatment was at par with 100% RDK and 150% RDK. Among the residue management practices 4.0 tonnes/ha CR registered significantly higher yield attributes, grain yield and stover/straw yield over no crop residue and 2.0 tonnes/ha CR and it was on par with 6.0 tonnes/ha CR in maize and wheat crops. The highest cost of cultivation was reported in 150% RDK and lowest cost of cultivation, highest gross returns, net returns and B: C ratios in maize and wheat were recorded in 50% RDK+KSB. Among residue management practices no CR registered the highest net returns and these were on par with 2 tonnes/ha CR in both the years of maize. However, in wheat highest returns were reported with 4.0 tonnes/ha CR and this was statistically at par to all the residue management practices except no CR. In both the crops, no CR showed highest B: C ratio followed by 2.0 tonnes/ha CR and 4.0 tonnes/ha CR. Lowest B: C ratio was recorded with 6.0 tonnes/ha CR. The strong correlation was observed between different yield attributes and yield in both the crops. Thus, application of 4.0 tonnes/ha CR and 50% RDK+KSB was cost effective, eco-friendly and sustainable K management practices under CA based maize-wheat cropping system and this may be recommended to farmers for adaptation.

Key words: Crop residue utilization, Economics, Potassium management, Potassium solubilising bacteria (KSB), Yield attributes, Zero tillage

Maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) is the third most important cropping system after rice (*Oryza sativa* L.)-wheat and rice-rice cropping system in India and occupies about 1.3 mha land (Sinha *et al.* 2014) and contributes 2.3% in food basket (Jat *et al.* 2011). Maize crop is regarded as a queen of cereals occupies a pride place among cereal crops in India. It has emerged as third most important food crop after rice and wheat as it contributes around 24% of total cereal production (Singh *et al.* 2011). Wheat grows in a wide range of weather conditions around the world and it ranks first in cultivation and production of major cereals (wheat, rice, maize and barley) in the world (Nourmohammadi *et al.* 2002).

Crop residues are important natural resource for the stability of agricultural ecosystems (Singh 2003). In cereal-based cropping systems, huge volume of crop residues are produced and large portion of unused crop residues are spread on wheat field by combine-harvester which are not suitable to feed the cattle because soil particles remain adhered to them (Prasad *et al*. 1999). Ironically, about 75% of K-uptake by cereal crops can be retained in crop residues, making them valuable nutrient sources (Singh 2003) and considering high variability in K response of cereal crops the blanket K recommendations may lead to

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economic loss for farmers due to under or over application in most cases. Traditionally, in rice-wheat or other systems of South Asia, straw is fed to cattle, burnt for fuel, or used as building material leaving little for soil incorporation. As a result, soil organic matter levels are declining in these cropping systems which can have serious implications for soil health.

K fertiliser cost has increased considerably over the past three years. The sharp increase in price has raised doubts about the profitability of K application in cereals where the minimum support prices (MSP) is low. On-farm K response studies in rice, wheat and maize, spread across the Indo-Gangetic Plains (IGP), highlighted that grain yield response to fertiliser K is highly variable and is influenced by soil, crop and management factors. Average yield losses in maize and wheat in farmer's fields due to K-omission were 700 and 715 kg/ha, respectively. This suggests that skipping application of K in these two cereal crops will cause variable yield and economic loss to the farmers of the region and will affect overall cereal production in the country. The return on investment of applied potassium in maize and wheat were ₹ 3.2 and 4.4, respectively per rupee invested on K. Economic assessment based on projected cost of K fertiliser and projected MSP of the cereals also showed favourable return on investment for K fertiliser (Majumdar *et al.* 2012). Globally, CA occupies 124.8 mha, but in India, area under zero tillage is approximately 2.2 mha and mostly confined to rice-wheat cropping system only (FAO 2013). The conservation agriculture (CA) systems based on no-till and residue management are considered alternative to ensure double cropping, improved farm income and livelihood (Ghosh *et al.* 2010). Tillage along with the water and nutrient are the most crucial monetary inputs in crop production, the conventional practice of tillage involving 6-8 tillage operations for maize which consume a high proportion (25-30%) of total operational energy in maize and wheat production so conservation tillage practice like zero tillage may reduce production cost and other constraints associated with land preparation (Sinha *et al.* 2014). However, the information on effect of crop residue and K management in maize-wheat system is lacking. Therefore, field investigation was conducted to evaluate the effect of crop residue and K management practices on productivity and economics of zero till maize and wheat.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* and *rabi* seasons of 2014-15 and 2015-16 at the research farm of the ICAR-Indian Agricultural Research Institute, New Delhi located at 28.35°N latitude and 77.12°E longitude and 228.6 m above mean sea level (MSL). Delhi falls under the agro-climatic zone 'Trans-Gangatic plains'. There was a 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 the experimental site was sandy loam and having of 1.52 Mg/m^3 bulk density, 0.43% organic carbon, 143 kg/ha $KMnO_4$ oxidizable N, 13.45 kg/ha 0.5 N $NaHCO_3$ extractable P, 245 kg/ha 1.0 N NH_4OAC exchangeable K, 8.33 pH and 0.37 dS/ m EC at the beginning of experiment. The experiment was laid out in split plot design in twenty treatment combinations with four crop residue (CR) levels (No CR, 2.0 tonnes/ha CR, 4.0 tonnes/ha CR and 6.0 tonnes/ ha CR) in main plot and five potassium levels, viz. no K, 50% RDK (Recommended dose of potassium), 100% RDK, 150% RDK and 50% RDK+KSB (Potassium solubilising bacteria) in sub plots and replicated thrice. Maize (PMH 4) and wheat (HD CSW 18) were sown at 60 × 30 cm and 20 cm, respectively with the help of zero seed drill 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 the 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. The 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 @ 125 ml/ ha 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. Depth of irrigation water was kept at 6-7 cm and number of irrigation applied in maize and wheat 4 and 5 during 2014-15 and 3 and 6 during 2015-16, respectively. To provide an ideal weed free environment to maize crop the Pendimethalin @ 1.00 kg *a.i.*/ha along with Atrazine (@ 0.75 kg *a.i*/ha was sprayed as pre-emergence at 1-2 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. Data on yield attributes recorded at crop maturity and samples of maize and wheat crop were harvested manually from the central net plot area for grain and stover/straw yield assessment. The harvest index was computed by dividing economic yield with biological yield and multiplied with 100. Economic parameter (cost of cultivation, gross return, 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. All the data obtained from maize and wheat crops were statistically analysed using the F-test as per the standard procedure.

RESULTS AND DISCUSSION

Yield attributes

The treatment with 50% RDK+KSB showed the significantly higher values of yield attributes, viz. number of grains/cob, grain weight/cob, test weight (218.6, 232.8 g) in maize and number of spikes/ m^2, grains/spike, spike weight, test weight in wheat over the control and 50% RDK in both the years of study. However this treatment was at par with 100% RDK and 150% RDK (Table 1). Among the residue management practices application of 4.0 tonnes/ha CR has registered significantly higher number of grains/cob, grain weight/cob, test weight in maize and number of spikes/m^2, grains/spike, spike weight, test weight in wheat over no crop residue, 2.0 tonnes/ha CR and this treatment was on par with 6.0 tonnes/ha CR in maize and wheat. The improvement in yield attributes was due to the applied K as it is vital to many plant processes including photosynthesis, translocation of photosynthates, protein synthesis and activation of plant enzymes, etc. Tabatabaii *et al.* (2011) reported that application of K increased the number of grains/cob and 1000- grain weight, grain number per row, grain weight/row in maize. Polara *et al.* (2010) reported that application K at different doses significantly increased number of tillers/plant, number of grain/spike, 1000-grain weight in wheat. Seed inoculation with KSB increased the yield attributes of maize (Basavesha *et al*. 2016) and wheat (Muralikaman 1996). Improvement in yield attributes of maize and wheat due to the application of residue under zero tillage treatments might be due to the maintenance of better and favourable soil moisture, moderate soil temperature, and improved soil water and nutrient conditions. Many researchers have reported the higher value of yield attributes under residue application (Jat 2010, Ram *et al*. 2010, Arif *et al.* 2011, Saad *et al*. 2015). The interaction effect of crop residue and potassium management practices showed no significant difference for different yield attributes.

Grain and stover/straw yield

The treatments with crop residue and potassium management practices showed significant improvement in grain, stover/straw yield over control in both maize and wheat crops during both the years of experimentation (Table 2). The treatment with 4.0 tonnes/ha CR was significantly superior with respect to grain yield (4.79, 5.24 tonnes/ha in maize; 5.01, 5.29 tonnes/ha in wheat) and stover/straw yield (8.31, 8.93 tonnes/ha in maize; 8.26, 8.76 tonnes/ha in wheat) as compared to no CR and it was on par with 6.0 tonnes/ha CR. Similar results were reported by Tripathy and Singh (2004) and Karami *et al*. (2012). This might be due to the fact that well-managed soil under zero till condition with crop residue application can support sustainable crop production through improved soil quality with higher soil organic carbon, available nutrients and regular and appropriate addition of crop residue have essential roles in improving the enzymatic activity of soil that are important for nutrient cycling, as well as increasing crop productivity (Rajkumara *et al*. 2014, Wei *et al*. 2015). Application of 50% RDK + KSB showed significant superiority in maize (4.91, 5.39 tonnes/ha and 8.41, 9.07 tonnes/ha) and wheat (5.16, 5.45 and 8.35, 8.89 tonnes/ha) grain and straw yield over control and 50% RDK. However this treatment was on par with 100% RDK and 150% RDK. These findings are also in conformity with Basavesha et al. (2016). Mobilization of K from soil because of secretion of organic acids, protons, siderophores, exopolysaccharides and

Table 1 Effect of crop residue and potassium management practices on yield attributes of maize and wheat in conservation agriculture based maize-wheat cropping system

Treatment	Maize						Wheat							
	No. of grains/cob		Grain weight/ cob (g)		Test weight (g)		No. of spikes/m^2		Grains/ spike		Spike weight (g)		Test weight (g)	
	2014	2015	2014	2015	2014	2015	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Crop residue management practices (CRM)														
No CR	346.9	353.3	95.6	109.0	195.9	201.7	271.9	272.1	39.5	41.6	2.37	2.53	36.1	36.8
2.0 tonnes/ha CR	375.6	382.6	108.0	120.1	204.0	215.1	286.1	288.9	42.3	45.9	2.58	2.81	36.9	37.8
4.0 tonnes/ha CR	396.9	406.2	116.6	132.0	218.2	232.1	331.7	335.8	49.5	53.3	2.88	3.13	38.3	39.8
6.0 tonnes/ha CR	392.6	403.3	115.0	129.3	215.7	229.3	331.3	330.5	47.1	50.7	2.81	3.08	37.9	39.1
SEm±	4.2	3.7	1.7	2.3	2.0	3.3	1.7	3.8	0.8	1.1	0.05	0.07	0.2	0.3
LSD (P=0.05)	14.5	12.9	5.9	8.0	7.1	11.4	5.8	13.1	2.6	3.7	0.18	0.26	0.8	0.9
Potassium management practices (PM)														
No K	344.1	345.3	90.5	97.1	188.3	192.8	264.9	261.1	38.8	39.2	2.27	2.24	35.6	36.0
50% RDK	371.6	377.6	99.7	114.6	203.3	213.3	292.1	287.2	41.8	43.6	2.55	2.74	36.8	37.9
100% RDK	391.1	402.8	117.8	133.4	216.5	229.8	322.3	327.3	47.3	52.2	2.83	3.15	37.9	39.2
150% RDK	389.0	400.1	117.1	131.9	215.7	229.1	321.4	326.3	46.4	51.0	2.79	3.11	37.7	39.0
50% RDK+KSB	394.3	405.9	119.1	135.9	218.6	232.8	325.5	332.4	48.6	53.4	2.87	3.19	38.4	39.7
SEm±	4.1	4.4	1.9	2.3	2.1	2.4	4.3	4.7	0.8	1.0	0.05	0.07	0.3	0.3
LSD (P=0.05)	11.7	12.6	5.6	6.8	6.1	7.0	12.5	13.4	2.4	3.0	0.14	0.19	0.8	0.8
CRM × PM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

CR: Crop residue, RDK: Recommended dose of potassium, KSB: Potassium solubilising bacteria, NS: Non significant

Table 2 Effect of crop residue and potassium management practices on yield of maize and wheat in conservation agriculture based maize-wheat cropping system

Treatment	Maize						Wheat					
	Grain (t/ha)		Stover (t/ha)		Harvest index (%)		Grain (t/ha)		Straw (t/ha)		Harvest index (%)	
	2014	2015	2014	2015	2014	2015	2014-15	2015- 16	2014-15	2015-16	2014-15	2015-16
Crop residue management practices (CRM)												
No CR	4.32	4.72	7.57	8.12	36.28	36.70	4.55	4.78	7.54	7.99	37.59	37.39
2.0 tonnes/ha CR	4.53	4.95	7.94	8.56	36.28	36.59	4.77	5.02	7.88	8.33	37.66	37.59
4.0 tonnes/ha CR	4.79	5.24	8.31	8.93	36.54	36.96	5.01	5.29	8.26	8.76	37.72	37.65
6.0 tonnes/ha CR	4.77	5.19	8.28	8.90	36.51	36.81	4.98	5.25	8.23	8.73	37.66	37.54
SEm±	0.06	0.06	0.10	0.10	0.15	0.07	0.06	0.06	0.08	0.09	0.19	0.11
LSD (P=0.05)	0.20	0.22	0.33	0.33	NS	0.24	0.21	0.22	0.29	0.31	NS	NS
Potassium management practices (PM)												
No K	3.90	4.26	7.05	7.53	35.66	36.10	4.16	4.33	7.04	7.38	37.15	36.99
50% RDK	4.41	4.80	7.94	8.54	35.70	35.97	4.60	4.84	7.86	8.25	36.94	36.96
100% RDK	4.90	5.36	8.37	9.01	36.95	37.30	5.14	5.43	8.33	8.87	38.15	37.95
150% RDK	4.87	5.32	8.35	8.98	36.84	37.19	5.07	5.38	8.31	8.85	37.87	37.82
50% RDK+KSB	4.91	5.39	8.41	9.07	36.87	37.27	5.16	5.45	8.35	8.89	38.19	37.99
SEm±	0.04	0.05	0.08	0.08	0.28	0.05	0.05	0.06	0.07	0.08	0.14	0.12
LSD (P=0.05)	0.11	0.16	0.24	0.23	0.82	0.15	0.15	0.16	0.20	0.24	0.40	0.34
CRM × PM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3 Effect of crop residue and potassium management practices on economics of maize and wheat in conservation agriculture based maize-wheat cropping system

Treatment	Maize								Wheat							
	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		B:C ratio		Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		B:C ratio	
	2014	2015	2014	2015	2014	2015	2014	2015	2014-15	205-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Crop residue management practices (CR)																
No CR	25820	25820	67893	74675	42073	48855	1.63	1.89	25796	26336	96096	104829	70299	78493	2.72	2.98
2.0 tonnes/ha CR	29820	29820	71203	78391	41383	48571	1.39	1.63	27796	28336	100675	109876	72879	81540	2.62	2.87
4.0 tonnes/ha CR	33820	33820	75199	82846	41379	49026	1.22	1.45	29796	30336	105704	115773	75908	85437	2.54	2.81
6.0 tonnes/ha CR	37820	37820	74887	82107	37068	44288	0.98	1.17	31796	32336	105125	115005	73329	82669	2.30	2.55
SEm±			872	965	872	965	0.03	0.03			1178	1313	1178	1313	0.04	0.05
CD (P=0.05)			3018	3340	3018	3340	0.10	0.11			4075	4544	4075	4544	0.15	0.16
Potassium management practices (PM)																
No K	30548	30548	61725	67678	31177	37130	1.05	1.25	27524	28064	88525	95623	61001	67559	2.23	2.42
50% RDK	31439	31439	69663	76442	38224	45003	1.25	1.47	28415	28955	98190	106802	69775	77847	2.47	2.70
100% RDK	32330	32330	76779	84499	44449	52169	1.41	1.65	29306	29846	107854	118250	78548	88404	2.69	2.97
150% RDK	33221	33221	76336	83895	43115	50675	1.33	1.56	30197	30737	106697	117525	76500	86788	2.54	2.83
50% RDK+KSB	31564	31564	76974	85012	45411	53448	1.48	1.73	28540	29080	108235	118654	79695	89574	2.81	3.09
SEm±			536	846	536	846	0.02	0.03			991	1152	991	1152	0.04	0.04
CD (P=0.05)			1544	2438	1544	2438	0.05	0.08			2854	3319	2854	3319	0.10	0.12
CR×PM			NS	NS	NS	NS	NS	NS			NS	NS	NS	NS	NS	NS

organic ligands by bacterial strain, increased availability of both essential macro and micro nutrients for crop uptake in soil by maintaining good health of soil which might have resulted the improvement in the biomass yield (Basak and Biswas 2009). The harvest index (HI) of wheat did not show any significant difference due to crop residue management practices. However in maize application of 4.0 and 6.0 tonnes/ha CR significantly influenced the HI in different years. Among different K doses significantly higher HI values were found in 50% RDK+ KSB (38.2%, 38.0% and 38.2%, 38.0%) followed by 100% RDK and 150% RDK in both maize and wheat, respectively over control and 50% RDK. The interaction effect of crop residue and potassium management practices showed no significant difference for different yield parameters.

Economic evaluation

The cost of cultivation of maize and wheat crops varied under residue and potassium management practices (Table 3). Variation in values was mainly due to differences in level of residue, potassium application dose and number of irrigation given. In maize and wheat, the costs in the CR management practices were around 15-46% and 8-23% higher than the control (no crop residue) treatment, respectively. The highest cost of cultivation was estimated in 6.0 tonnes/ha CR plot in maize (₹ 37 820, 37 820/ha) and wheat (₹ 31 796, 32 336/ha) in both years followed by (fb) 4.0 tonnes/ha CR and 2.0 tonnes/ha CR plot. The highest gross returns was observed in 4.0 tonnes/ha CR (₹ 75 199, 82 846/ha) and wheat (₹ 105 704, 115 773/ha) fb 6.0 tonnes/ha CR and 2.0 tonnes/ha CR. The highest net returns was registered with no CR (₹ 42 073/ha) in first year of maize and it was on par with 2.0 tonnes/ha CR and 4.0 tonnes/ha CR. In second year, 4.0 tonnes/ha CR gave significantly higher net returns in 4 tonnes/ha CR (₹ 49 026/ha) over the 6.0 tonnes/ha CR and it was on par with no CR and 2.0 tonnes/ha CR. In wheat, highest net returns were reported with 4.0 tonnes/ha CR (₹ 75 908, 85 437/ha) in both the years as compared to no CR and it was statistically on par with 6.0 tonnes/ha CR and 2 tonnes/ha CR. Previous research shows that with zero tillage, farmers were able to save money on land preparation by about ₹ 2 500/ha and reduce diesel consumption by 50–60 litres/ha (Sangar *et al*. 2005) and residue retention under zero tillage enhanced profitability of irrigated maize–wheat (Sharma *et al*. 2009, Ram *et al*. 2012, Rajkumara *et al*. 2014). The highest B: C ratio was observed in no CR in maize and wheat and this treatment was followed by 2.0 tonnes/ha CR. Lowest B: C ratio was observed with 6.0 tonnes/ha CR since the higher cost of residue resulted in higher cost of cultivation.

Among potassium management practices highest gross returns, net returns ₹ 45 411, 53 448/ha) and B: C ratio in maize and in wheat highest gross returns, net returns (₹ 79 695, 89 574 /ha) and B: C ratio were observed in

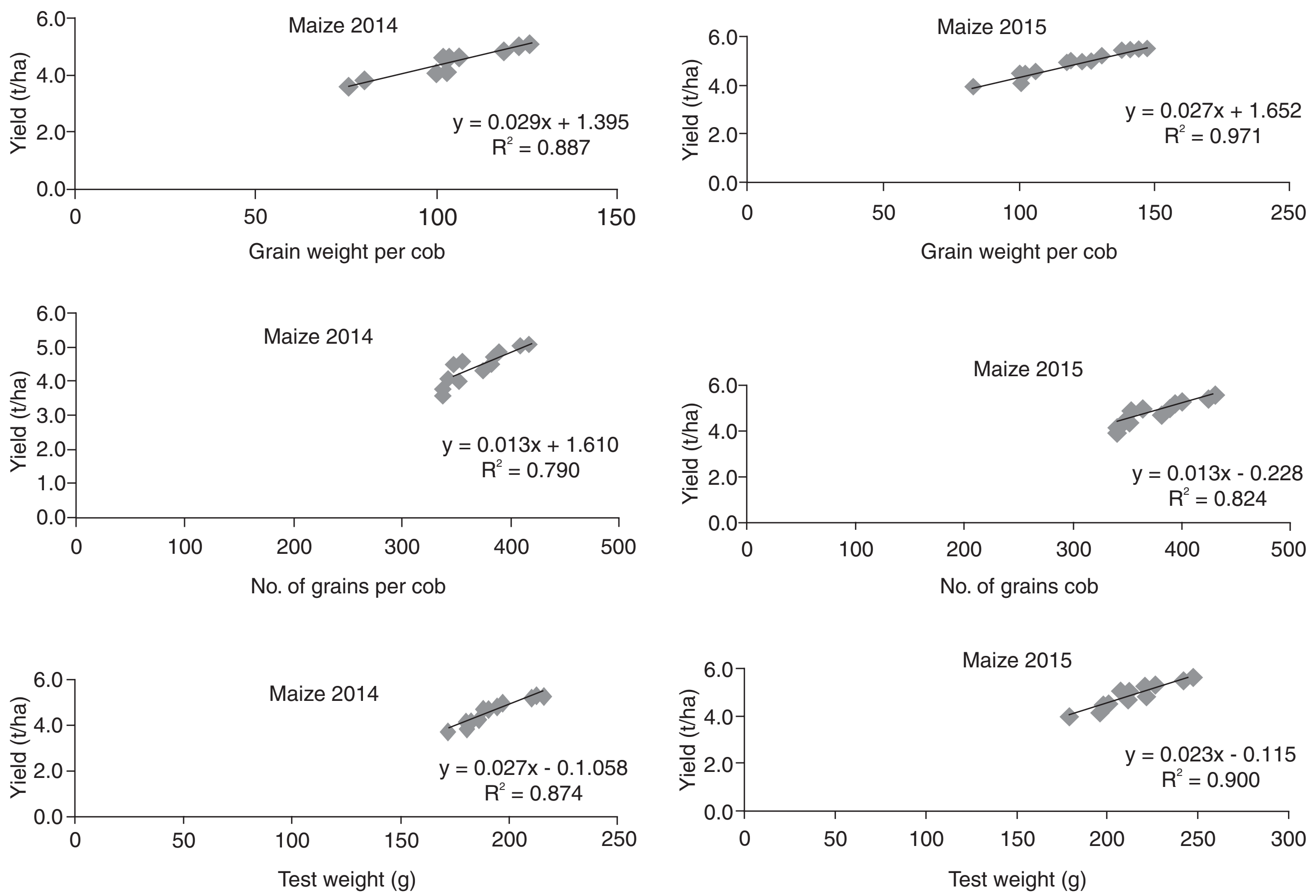

Fig 1 Correlation studies between yield attributes and yield of maize in conservation agriculture based maize-wheat cropping system

50% RDK+KSB over the control 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. Majumdar *et al*. (2012) also reported higher returns on investment of applied K in wheat and maize which were ₹ 4.4 and 3.2, respectively per rupee invested on K. Application of 100% RDK and 150% RDK had the closer values with 50% RDK+KSB for all the economic parameters of the study. Interaction effect of CR and K management were non-significant.

Correlation effect

Strong positive correlation was found between various yield attributes and yield of maize (Fig 1) and wheat crops. The r^2 values of yield attributes like number of grains/cob (0.79, 0.82), grain weight/cob (0.88, 0.97), test weight (0.87, 0.90) in maize and number of spikes/m^2 (0.78, 0.82), grains/spike (0.79, 0.89), spike weight (0.88, 0.87), test weight (0.87, 0.81) in wheat in 2014-15 and 2015-16, respectively. These results are in close conformity with those of Moola Ram (2011). Yield formation in maize and wheat is a complex coordinated process that involves the build up and subsequent re-assimilation of yield components. These processes are under genetic control and strongly affected by environmental conditions and other management practices.

It was concluded that 50% of mineral potassic fertilizer dose may be replaced with potassium solubilising bacteria (KSB) and application of 50% recommended dose of potassium fertilizer along with KSB could give highest crop productivity and profitability under zero till maize-wheat cropping system. Conservation agriculture practices including zero tillage and crop residue retention at 4.0 tonnes/ha could improve crop productivity and profitability of maize-wheat system.

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