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DIFFERENT TILLAGE PRACTICES AND RESIDUE MANAGEMENT ON PRODUCTIVITY AND NUTRIENT UPTAKE OF WHEAT GROWN AFTER SOYBEAN IN SOYBEAN (*GLYCINE MAX*)–WHEAT (*TRITICUM AESTIVUM*) CROPPING SYSTEM

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ABSTRACT

A microplot experiment was conducted during *kharif* and *rabi* seasons of crop years 2010-12in New Delhi, to study the effect of continuous or cyclic tillage on yield performance and nutrient uptake of wheat in soybean–wheat cropping system. The treatments consisted of conventional tillage (CT) and zero-tillage (ZT),and residue management of soybean residue (SR) and/or wheat (WR).The experiment was laid out in microplots (with the size of 4 x 1 m) in RBD with two replications. Plant height at different growth stages was not influenced due to tillage and residue management practices but performance was better in cycling tillage with application of crop residue. All yield attributes were shown variation due to treatments, except spike length. The harmful effects of ZT on yield attributes could be overcome with residue application on soil surface. The grain yield was equal, when CT and ZT were adopted either continuously or alternately, and this was significantly lower than all treatments of ZT+SR irrespective of tillage in the previous crop. The concentration of N, P and K was not varied significantly, but nutrient uptake was changed significantly due to treatments that is because of different plant dry matter production. The improvement may be expected over several years of continuous application of crop residue and ZT.

INTRODUCTION

In India wheat occupy 28.07 million ha of land area and produce 74.89 million tonnes of grain with an average productivity of 2671 kg ha^{-1}. Soybean-wheat cropping system is practised in 4.5 million ha, mainly in central India (Behera *et al*., 2007). Major research and development efforts in the green-revolution era focused on enhancing productivity of a selected food grain crops. In the post-green revolution era, the issues of conservation have assumed greater importance in view of the widespread resource degradation problems and the need to reduce production costs, increase profitability and make agriculture more competitive. Tillage is the basic and most important requirement of crop production. The efficiency of input use, such as water, fertilizers, herbicides and others depend on tillage and crop establishment practices (Behera and Sharma, 2009). So it is essential that the soil environment be manipulated suitably for ensuring a good crop stand and improve resource-use efficiency. Of late, the production costs in agriculture have increased tremendously but the returns have declined due to indiscriminate use of various resources. Studies on no-tillage and bed planting technologies have largely been conducted on wheat in rice–wheat cropping system in the north-western plain zone (Behera *et al*., 2007). There is a great emphasis on crop diversification due to growing concerns about the unsustainability of rice–wheat system in this region. In this context, a crop like soybean has emerged as the promising alternative for rice in rainy season in the northern India. However, some issues are threatening the sustainability of the system including rise in groundwater table, flooded soil conditions and salinization of many canal command areas, imbalanced nutrient use, and high incidence of pest and diseases associated with pesticide usage in soybean to control pod borer and yellow mosaic virus.

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All these conditions call for efficient use of resources like soil, water and other production inputs to achieve sustainable production. Continuous tillage in both the season i.e *kharif* and *rabi* is found to have detrimental effect on soil health and structure. Continuous tillage also make energy requirement quite high. At the same time applying double zero tillage in both *kharif* and *rabi* season is found to be difficult about weed management. Under such situation skipping tillage for soybean in *kharif* season or for wheat in *rabi* season seem to be more beneficial in case of input use efficiency and energy saving. Similarly the detrimental effect of intensive tillage can also be reduced to some extents (Karunakaran. 2011). Crop residue modifies the hydrothermal regime of the soil surface by reducing soil temperature during summer and acting as barrier against the loss of water. Crop residues also increases the soil water storage. Residue keeps the soil surface cool, wetter and mellows for long period of time, which may enhance crop's root and shoot growth. In addition, decomposing residues on soil surface possibly release allelo-chemicals which further have the inhibitory effects on weed seed germination and early growth. It is always beneficial to use crop residues as mulch wherever it is available. It is worth mention here that no-till is presently practiced on about 105 m ha globally (Derpsch and Friedrich, 2009) for improving crop productivity and conserving natural resources through very effective control of soil erosion, controlling soil evaporation, sequestering C in soil and reducing energy needs. According to the less information about the effect of tillage and residue management on performance of wheat in soybean-wheat cropping system, this investigation was conducted entitled "Different tillage practices and residue management on productivity and nutrient uptake of wheat grown after soybean in soybean (*Glycine max*)–wheat (*Triticumaestivum*) cropping system".

MATERIALS AND METHODS

A microplot experiment was conducted in 2010-11 and 2011-12 at the Indian Agricultural Research Institute, New Delhi (28^o 40'N, 77^{0}12'E and altitude of 228 m above mean sea level). The soil of the experimental field was sandy-loam in texture, with neutral pH (7.4), low in organic C (0.46%), alkaline $KMnO_4$-oxidizable N (148 kg ha^{-1}) and $NaHCO_3$-extractable P (10 kg ha^{-1}), and medium in 1 NNH_4OAc - exchangeable K (238 kg ha^{-1}). The moisture content at 1/3 and 15 atmospheric tensions was 18.8 and 7.9%, respectively, with bulk density of 1.64 Mg m^{-3} of surface layer (0-15 cm). Uniform crop of soybean during rainy season, and wheat during winter season was grown during 2008-09 with recommended fertilizer under irrigated condition. In 2009, soybean was raised with different treatments of tillage i.e. conventional tillage (CT) and zero tillage (ZT) with and without wheat straw (WS) application. Although 12 treatments combinations were decided initially and the plots were maintained accordingly, only 4 treatments were applied, viz. CT, ZT, CT+WS and ZT+WS. All 12 treatments combinations with CT and ZT in soybean residue (SR) application were applied in following wheat crop during 2009-10. Therefore, in the 1st cycle of the present experimentation (2010-11), all the 12 treatments combinations were applied to both crops grown in sequence. The treatment plots remained fixed over 2 cropping cycles (2010-11 and 2011-12) and two replications were maintained because all the factors were under control. A randomized block design was followed. The microplots of dimensions4.0 x1.4 m were made of cement bunds all around with no shifting of soil particles from one plot to another during tillage and other operations. In both crops, CT involved digging the soil manually with spade up to a depth of about 20 cm to prepare a fine clod-free seed-bed. No disturbance of soil was done under ZT, except making a slice cut with a knife type tyneattached to hand-drawn seed-drill for placing seed and fertilizer at proper depth. For wheat, finely-chopped soybean straw @ 3 t ha^{-1} (obtained after trashing) was incorporated 15-20 days before sowing under CT, while it was retained on soil surface under ZT condition. Wheat cv. 'HD 2894' was sown using 100 kg seed ha^{-1} (40 g plot^{-1}) at row distance of 20 cm, thus maintaining 7 rows in each plot, leaving 10 cm distance from the side of the bund.

Basel application N, P_2O_5 and K_2O @ 50,60 and 40 kg ha^{-1} was made with seed-cum-fertilizer drill, using urea, DAP and muriate of potash in appropriate combination. Top dressing of 60 kg N ha^{-1} was made in 2 equal parts after 1st and 2nd irrigation. Herbicide is oproturon was applied @ 1.0 kg ha^{-1} at 30 DAS using 500 litter water ha^{-1} with knapsack sprayer for controlling weeds. Irrigations were applied 25, 60,100 DAS in 2010-11; and 20, 60, 75,105 DAS in 2011-12. Application of chloropyriphos was made at 60 DAS to check termite damage. Periodic observations on growth parameters were made. Plant height was measured from 10 tagged plants at 30 days interval in wheat. At maturity, one row from both sides of each plot was removed as border, and data on yield and yield attributes from 5 rows of wheat was recorded. Samples of seed and straw were taken, analyzed for nutrient concentration (N, P and K) by standard methods, and uptake values were calculated. The samples of two replications were composited and a single sample was analyzed in duplicate following standard procedures.

RESULTS AND DISCUSSION

Growth parameters

Plant height of wheat increased progressively with advancement in age. The increased in height was more from 30 to 60 DAS, after which, the height increased slowly up to 120 DAS (Table 1). There was not much difference in height at different stages in 2 years. At 120 DAS, the plants were about 90-92 cm tall in all treatments in both years. Interestingly, there was no significant variation of height of wheat plants due to different tillage and residue management treatments. The height remained similar under all treatments at all stages in both years due to the direct, residual and cumulative effects of tillage and residue management. These results are dissimilar compared with soybean in rainy season when the tillage and residue management effects were significant on height at 30 and 60 DAS. The maybe because of the fact that wheat grown during winter season was a slow growing and deep-rooted crop, and supplied with uniform fertilizer and irrigation in all treatments. Tillage and residue management might have the influenced the physico-chemical and biological properties of soil, but these could not make a difference in the vertical grown of crop plants (Choudhary. 2011).

Table 1. Plant height (cm) of wheat at different growth stages as influenced by tillage and residue management practices in microplot experiment

Treatment		2010-11				2011-12			
		30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
Soybean	*Wheat*								
CT	CT	31.10	74.30	86.80	92.80	33.80	75.50	87.15	92.65
CT	ZT	30.90	75.50	87.90	91.90	33.75	76.15	88.00	93.50
ZT	ZT	31.20	76.20	86.30	93.80	36.85	78.30	85.95	93.45
CT + WS	ZT	32.20	77.10	84.40	89.90	32.30	79.90	89.80	92.30
CT	ZT + SR	29.50	75.90	86.00	92.50	32.15	77.15	88.20	92.70
CT+ WS	ZT + SR	28.60	75.20	87.40	92.40	32.15	75.25	86.70	91.70
ZT+ WS	CT	31.00	77.40	88.60	94.10	33.80	77.85	84.90	92.90
ZT	CT + SR	30.30	77.60	87.10	93.60	33.15	78.85	87.27	92.27
ZT + WS	CT + SR	30.20	77.90	87.50	92.50	33.05	70.65	83.75	91.75
ZT + WS	ZT	30.50	77.50	86.50	92.00	31.85	79.90	89.65	93.65
ZT	ZT + SR	31.00	76.90	85.80	92.30	31.35	74.50	82.80	92.30
ZT + WS	ZT + SR	30.40	78.20	86.10	91.10	31.00	73.35	85.55	92.05
SEm+		0.86	1.21	2.25	2.08	1.34	3.99	2.01	0.67
LSD (0.05)		NS	NS	NS	NS	NS	NS	NS	NS

Yield attributes

There was a significant variation in the yield attributes of wheat, viz. number of spikes m^{-2} and grain $spike^{-1}$ in both years. In 2010-11, the spikes m^{-2} were the highest under ZT alone, followed closely by CT + SR and ZT + SR (Table 2). The spikes were significantly lower when ZT and CT was followed in both years without residue management. Tillage and residue management in pervious soybean also appeared to have made an effect on spike number. When the residues were applied to both crops under ZT, the spike number was lower than when residue was applied to wheat only. On the other hand in 2011, the highest number of spike m^{-2} was under ZT with or without residue to either or both the crops. Spike number was the lowest under CT and ZT without residue application. The spike number remained much lower when ZT + SR or CT + SR was done, irrespective of tillage in previous season. These results suggest that the effect of ZT with residue on spikes m^{-2} became more evident in 2^{nd} cropping cycle, probably due to cumulative effect of these treatments (Gupta *et al.,* 2007).

Number of grain $spike^{-1}$ was nearly similar in the 2 years, but differed significantly due to tillage and residue management. In 2010-11, the highest grain number was under CT + SR, followed closely by ZT + SR when ZT + WS was adopted under both treatments during the previous crop of soybean. The grain number under these treatments was significantly more than when CT or ZT was adopted continuously or alternately in both crops. In general, CT alone or CT + SR resulted in fewer grains $spike^{-1}$. In 2011-12, a similar result was obtained as in 2010-11. The grain number under ZT with and without soybean residue was the highest when ZT with or without wheat straw was adopted in soybean. The other treatments where CT or ZT was adopted without residue to either crop resulted in the lowest number of grain $spike^{-1}$. Adoption of CT in soybean with or without wheat straw along with ZT + SR in wheat also resulted in compatibility lower grains $spike^{-1}$ compared with those treatments, when continuous ZT was adopted with residue to either one or both crops in sequence. Spike length appear to be slightly more in 2011-12 than in 2010-11, but it was influenced significantly due to tillage and residue management in both years. It varied within a narrow range of 11-13 cm in the 2 years. The treatments, in which, ZT with residue was adopted in both years showed relatively more spike length than those where either CT or ZT was adopted without residue management. 1000-grain weight did not show a definite trend of variation in the 2 years, and the values varied with the range of 38-43 g in both years. There was no significant variation in 1000-grain weight in 2011-12 and all treatments resulted in similar weight of grain. However in 2010-11, the differences among tillage and residue management were significant. Continuous adoption of ZT with residue to either one or both the crops resulted in greater 1000-grain weight than when only continuous CT without residue was done. Residue application to previous soybean also had a positive beneficial effect on grain weight of following wheat. Although the differences due to tillage and residue management were not significant in 2011-12, ZT with residue application resulted in compatibility more 1000-grain weight, particularly in those treatments where the residue was also applied to previous soybean crop. It is, therefore, evident that zero tillage and application of residue, preferably to both crops, was essential for improving grain weight of wheat in soybean–wheat system (Gupta *et al.,* 2007 and Mishra and Singh, 2009).

Yield performance

The yield of grain and straw of wheat varied significantly due to tillage and residue management in both years (Table 3). In 2010-11, the highest grain yield was obtained under continuous ZT with residue application to both crops, and the lowest yield was obtained when continuous CT or ZT was adopted without residue application. The grain yield was equal when CT and ZT were adopted either continuously or alternately in the 2 crops, and these were significantly lower than all treatments of ZT + SR, irrespective of tillage in the previous crop of soybean. A similar trend was observed in straw yield, which was the highest when ZT + residue was maintained in both crops. However, this was at par with ZT + SR, irrespective of tillage in the previous crop. As observed for grain yield, the straw yield was also lower under continuous or alternate CT and ZT in the 2 crops without residue. The harvest index did not show greater variation as it varied within a narrow range of 39-44% under different

Table 2. Yield attributes of wheat as influenced by tillage and residue management practices in microplot experiment

Treatment		2010-11				2011-12			
		Spike m^{-2}	Grains $spike^{-1}$	Spike length (cm)	1000-grain weight (g)	Spike m^{-2}	Grains $spike^{-1}$	Spike length (cm)	1000-grain weight (g)
Soybean	*Wheat*								
CT	CT	247.5	38.65	10.25	36.30	240.4	40.00	11.65	38.25
CT	ZT	256.4	37.40	11.15	40.80	230.5	37.85	11.50	39.80
ZT	ZT	245.0	36.70	10.65	41.90	247.2	36.75	11.50	40.90
CT + WS	ZT	262.8	43.45	11.50	40.65	276.8	37.95	12.60	39.65
CT	ZT + SR	258.1	43.25	10.95	40.90	259.0	40.75	12.20	42.90
CT+ WS	ZT + SR	294.2	42.75	11.25	45.15	277.2	40.75	12.40	43.65
ZT+ WS	CT	285.2	38.35	11.50	43.75	269.6	39.00	12.00	42.15
ZT	CT + SR	303.4	39.05	10.90	42.35	270.8	47.55	11.85	41.70
ZT + WS	CT + SR	274.3	46.45	10.25	41.05	250.7	44.30	12.30	39.40
ZT + WS	ZT	307.0	44.65	10.70	41.15	310.1	47.90	12.85	42.85
ZT	ZT + SR	292.6	43.65	11.50	43.05	301.2	48.45	12.60	40.85
ZT + WS	ZT + SR	276.4	46.25	11.35	42.50	319.3	46.05	11.75	41.40
SEm±		4.36	0.59	0.28	0.70	8.63	1.61	0.40	1.37
LSD (0.05)		13.56	1.84	NS	2.17	26.86	5.01	NS	NS

Table 3. Yield performance of wheat (g m^{-2}) as influenced by tillage and residue management practices in microplot experiment

Treatment		2010-11				2011-12			
		Grain yield	Straw yield	Total	Harvest index	Grain yield	Straw yield	Total	Harvest index
Soybean	*Wheat*								
CT	CT	382	574	956	39.98	405	607	1012	39.98
CT	ZT	386	522	908	42.55	425	530	955	44.47
ZT	ZT	402	604	1007	39.96	406	507	914	44.47
CT + WS	ZT	461	670	1131	40.79	458	621	1079	42.47
CT	ZT + SR	434	651	1085	39.98	466	645	1111	41.91
CT+ WS	ZT + SR	435	653	1087	39.96	488	683	1170	41.73
ZT+ WS	CT	453	658	1111	40.81	425	648	1073	39.71
ZT	CT + SR	415	624	1039	39.96	458	572	1030	44.47
ZT + WS	CT + SR	434	630	1065	40.79	453	658	1111	40.79
ZT + WS	ZT	411	617	1029	39.98	432	541	973	44.47
ZT	ZT + SR	408	612	1019	39.98	430	646	1077	39.98
ZT + WS	ZT + SR	474	710	1184	40.00	474	593	1068	44.47
SEm±		8.51	17.79	24.59		13.49	31.27	37.36	
LSD (0.05)		26.50	55.38	76.53		41.98	97.32	116.28	

Table 4. Nitrogen uptake (g m^{-2}) in wheat as influenced by tillage and residue management practices in microplot experiment

Treatment		2010-11			2011-12		
		Grain	Straw	Total	Grain	Straw	Total
Soybean	*Wheat*						
CT	CT	6.08 (1.59)	2.55 (0.44)	8.62	6.33 (1.56)	2.76 (0.45)	9.09
CT	ZT	6.08 (1.57)	2.29 (0.44)	8.37	6.69 (1.58)	2.41 (0.45)	9.10
ZT	ZT	6.36 (1.58)	2.51(0.41)	8.86	6.44 (1.59)	2.12 (0.42)	8.56
CT + WS	ZT	7.38 (1.60)	2.98 (0.44)	10.36	7.22 (1.58)	2.92 (0.47)	10.14
CT	ZT + SR	6.95 (1.60)	2.91 (0.45)	9.85	7.27 (1.56)	2.79 (0.43)	10.06
CT+ WS	ZT + SR	6.79 (1.56)	2.88 (0.44)	9.67	7.77 (1.59)	2.86 (0.42)	10.63
ZT+ WS	CT	7.21 (1.59)	2.74 (0.42)	9.95	6.46 (1.52)	2.98 (0.46)	9.44
ZT	CT + SR	6.64 (1.60)	2.78 (0.45)	9.42	7.14 (1.56)	2.69 (0.47)	9.83
ZT + WS	CT + SR	6.90 (1.59)	2.83 (0.45)	9.74	7.17 (1.58)	3.05 (0.46)	10.22
ZT + WS	ZT	6.46 (1.57)	2.74 (0.44)	9.21	6.93 (1.60)	2.47 (0.46)	9.40
ZT	ZT + SR	6.49 (1.59)	2.57 (0.42)	9.06	7.03 (1.63)	2.90 (0.45)	9.93
ZT + WS	ZT + SR	7.55 (1.59)	3.20 (0.45)	10.74	7.61 (1.60)	2.75 (0.46)	10.36
SEm±		0.14 (0.01)	0.11 (0.01)	0.23	0.24 (0.04)	0.14 (0.01)	0.290
LSD (0.05)		0.44 (NS)	0.33 (NS)	0.71	0.74 (NS)	0.44 (NS)	0.903

Figures in parentheses indicate N concentration

treatments in the 2 years. In 2011-12 the yield was almost same as in 2010-11, and showed significant variation among the tillage and residue management treatments. The highest yield was obtained under the treatments when ZT + residue was maintained either to wheat alone or both the crops in sequence. The treatment of CT + SR also gave at par yield with the best performing treatment, but all of these were significantly lower than continuous or alternate CT and ZT to wheat without residue application.

Straw yield followed the trend of grain yield under most treatments, the highest being under ZT + SR but on par with CT + SR, when ZT + WR was given to soybean. The treatment of continuous ZT with residue to wheat also resulted in similar yield as the best performing treatment. The straw yield was the lowest under continuous ZT without residue, and it increased significantly when residue was applied along with ZT. The harvest index showed relatively greater variation than in 2010-11 and varied from 39-44% under different

Table 5. Phosphorus uptake (g m^{-2}) in wheat as influenced by tillage and residue management practices in microplot experiment

Treatment		2010-11			2011-12		
		Grain	Straw	Total	Grain	Straw	Total
Soybean	*Wheat*						
CT	CT	1.26 (0.331)	0.337 (0.053)	1.57	1.38 (0.341)	0.337 (0.056)	1.72
CT	ZT	1.27 (0.328)	0.278 (0.054)	1.55	1.40 (0.331)	0.278 (0.053)	1.68
ZT	ZT	1.31 (0.325)	0.274 (0.050)	1.61	1.35 (0.333)	0.274 (0.054)	1.63
CT + WS	ZT	1.54 (0.333)	0.332 (0.055)	1.90	1.53 (0.335)	0.332 (0.054)	1.86
CT	ZT + SR	1.43 (0.330)	0.339 (0.054)	1.78	1.75 (0.343)	0.339 (0.053)	2.09
CT+ WS	ZT + SR	1.43 (0.328)	0.353 (0.054)	1.77	1.62 (0.333)	0.353 (0.052)	1.98
ZT+ WS	CT	1.48 (0.326)	0.353 (0.052)	1.82	1.45 (0.342)	0.353 (0.055)	1.81
ZT	CT + SR	1.47 (0.354)	0.309 (0.054)	1.80	1.54 (0.337)	0.309 (0.054)	1.85
ZT + WS	CT + SR	1.42 (0.326)	0.360 (0.055)	1.76	1.53 (0.338)	0.360 (0.055)	1.89
ZT + WS	ZT	1.38(0.336)	0.288 (0.052)	1.70	1.44 (0.333)	0.288 (0.053)	1.73
ZT	ZT + SR	1.33 (0.326)	0.355 (0.053)	1.65	1.45 (0.338)	0.355 (0.055)	1.81
ZT + WS	ZT + SR	1.55 (0.327)	0.322 (0.053)	1.92	1.60 (0.336)	0.322 (0.054)	1.92
SEm±		0.044 (0.008)	0.011 (0.0011)	0.053	0.057 (0.006)	0.011 (0.001)	0.069
LSD (0.05)		0.14 (NS)	0.05 (NS)	0.15	0.18 (NS)	0.05 (NS)	0.20

Figures in parentheses indicated P concentration

Table 6. Potassium uptake (g m^{-2}) in wheat as influenced by tillage and residue management practices in microplot experiment

Treatment		2010-11			2011-12		
		Grain	Straw	Total	Grain	Straw	Total
Soybean	*Wheat*						
CT	CT	1.71 (0.448)	9.27 (1.616)	10.98	1.84 (0.455)	9.90 (1.630)	11.74
CT	ZT	1.74 (0.452)	8.41 (1.610)	10.15	1.95 (0.459)	8.70 (1.641)	10.64
ZT	ZT	1.83 (0.454)	9.74 (1.611)	11.57	1.87 (0.461)	8.38 (1.651)	10.25
CT + WS	ZT	2.05 (0.445)	10.75 (1.605)	12.80	2.07 (0.452)	10.31 (1.661)	12.38
CT	ZT + SR	1.97 (0.453)	10.67 (1.639)	12.64	2.14 (0.458)	10.72 (1.663)	12.86
CT+ WS	ZT + SR	1.99 (0.457)	10.66 (1.632)	12.64	2.25 (0.462)	11.30 (1.656)	13.55
ZT+ WS	CT	2.08 (0.460)	10.74 (1.633)	12.83	1.97 (0.465)	10.74 (1.657)	12.71
ZT	CT + SR	1.87 (0.451)	10.15 (1.627)	12.02	2.09 (0.455)	9.56 (1.671)	11.65
ZT + WS	CT + SR	1.92 (0.442)	10.14 (1.608)	12.05	2.06 (0.454)	10.72 (1.629)	12.77
ZT + WS	ZT	1.88 (0.456)	9.99 (1.618)	11.87	1.95 (0.451)	8.87 (1.640)	10.82
ZT	ZT + SR	1.79 (0.440)	9.97 (1.629)	11.76	1.99 (0.461)	10.67 (1.651)	12.65
ZT + WS	ZT + SR	2.13 (0.451)	11.64 (1.639)	13.78	2.19 (0.462)	9.85 (1.661)	12.04
SEm±		0.05 (0.006)	0.30 (0.009)	0.34	0.07 (0.007)	0.51 (0.008)	0.53
LSD (0.05)		0.16 (NS)	0.92 (NS)	1.05	0.22 (NS)	1.59 (NS)	1.65

Figures in parentheses indicated K concentration

treatments. No definite trend in harvest index was observed among the treatments. Yadav *et al* (2005) reported that significantly higher (7.7 %) yield of wheat was recorded with ZT in comparison to CT was mainly attributed to increase ineffective tillers, grains/ear and 1000- grain weight. Similar results were also reported by Tripathi and Chauhan (2000).

Nutrient concentration and uptake

Nitrogen concentration in grain and straw of wheat did not vary significantly due to tillage and residue management in both years (Table 4). The concentration was also more or less similar in the 2 years. The concentration of N in grain was about 3-4 times more than straw. Non-significant variation in the N concentration of the grain and straw of wheat may be due to fact that, a common dose of recommended N (120 kg ha^{-1}) was applied to all the treatments which was sufficient to meet the nutrient requirement of the crop. The additional fertility under the treatments of continuous residue application did not alter the N concentration. However, the N uptake of grain and straw showed significant variation in both years. This was due to fact that different treatments brought about significant changes in the biomass production of wheat. The N uptake by grain was about 2.5 times more than in straw. In 2010-11, the highest N uptake was under ZT + residue application to both crops, which was on par with ZT to wheat and CT + WS to soybean. Under both these treatments, the total N uptake was more than 10 g m^{-2}, which was significantly more than CT or ZT alone without residue application to either crop. In general, the treatments were residue was applied resulted in higher N uptake. This may be due to fact that residue application modified the hydro thermal regime of the soil and enable better growth and productivity of the crop (Behera *et al*., 2007). In 2011-12 the N uptake by straw followed same trend as in 2010-11, but the treatments under CT with or without residue to soybean, followed by ZT + SR or without residue to wheat resulted in higher N uptake by seed. Phosphorus concentration did not vary significantly in grain and straw of wheat at harvest (Table 5). These values also did not show greater variation in the 2 years. The grain P concentration was about 6-7 times more than in straw. Although the differences were not significant, the trend of the variation among the treatments was also not consistent. Application of P was made @ of 60 kg P_2O_5 ha^{-1}, which was common to all the treatments. Experimental soil was also medium in available P content (10.3 kg ha^{-1}), and adequate amount of P applied through P fertilizer made-up the requirement of the crop. Despite non-significant differences in P concentration, the grain and straw P uptake differed significantly among the tillage and residue management practices. The uptake values did not vary significantly in the 2 years, and followed almost similar trend.

In 2010-11, the highest total P uptake was under ZT + residue to both crops, which was on par with ZT to wheat and CT + WS to soybean. Continuous CT or ZT without residue resulted in the lowest P uptake. In 2011-12, the highest total P uptake was under ZT + SR to wheat and CT to soybean, followed by the treatments ZT + residue to both crops. The treatments of continuous CT or ZT without residue remained at the lowest in terms of P uptake. Potassium concentration remained unaffected due to tillage and residue management in both years. The concentration also did not show greater variation in the 2 years (Table 6). The trend of variation in K concentration was opposite to that of N, i.e. the K concentration in straw was about 4 times higher than the grain. This indicated that a greater part of the K was stored in the straw, while grain was the major sink for N in crops like wheat. The concentration of K in both grain and straw varied within a narrow range among the treatments, and differences were not significant. Potassium uptake by grain and straw differed significantly due to tillage and residue management in both years. This was due to the variation in biomass production in the grain and straw of wheat with respect of tillage and residue management.

In 2010-11, the highest total K uptake was under ZT + residue, which was on par with ZT + WS to soybean and CT to wheat, and CT + WS to soybean and ZT to wheat. These 3 treatments were significantly superior to all other treatments. The lowest K uptake was under continuous CT or ZT without residue application. In 2011-12, the highest K uptake was under CT + WS to soybean and ZT + SR to wheat, which was on par with ZT + SR to wheat irrespective of tillage treatments to previous soybean. The treatments of continuous CT or ZT without residue resulted in lower value of K uptake. These results suggested that ZT + residue to wheat resulted in increasing K uptake of wheat, and the effect was more when the residue was also applied under either CT or ZT to previous soybean. Vedprakash *et al*. (2001) found that values of net depletion of K (sum total of available and non-exchangeable K) from soil profile after 27 cropping cycles of soybean-wheat were quantitatively much higher than the expected K depletion values suggesting considerable depletion of K from soil. There has been a wide gap between recommendations of K application vis-à-vis its uptake.

Conclusion

Skipping tillage either in *kharif* to soybean or in *rabi* to wheat resulted similar performance of wheat which implies that tillage can be skipped and crop can be raised successfully by skipping the tillage without yield loss. Application of wheat + soybean residue along with recommended fertilizer dose responded significantly for growth and yield parameters.

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