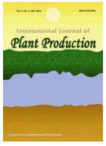

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Effect of tillage and residue management on productivity of soybean and physico-chemical properties of soil in soybean–wheat cropping system

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Abstract

A microplot experiment was conducted in soybean–wheat cropping system at New Delhi during 2010-11 and 2011-12 to study the effect of continuous or cyclic tillage, *viz.*, conventional tillage (CT) and zero-tillage (ZT) and residue management of either soybean (SR) and/or wheat (WR) on yield performance and soil physico-chemical properties. The experiment was laid out in randomized block design with two replications in microplots of size 4×1.4 m. Plant height of soybean was influenced due to tillage and residue management at different growth stages. All yield attributes of soybean were showed variation due to treatments. The harmful effects of ZT on yield attributes could be overcome with residue application on soil surface. The results indicated that tillage and residue management to the immediate crop of soybean was more important for increasing grain yield (26%) and stover production (32%) of soybean and the residual effect of residue to previous soybean was relatively small. The change in organic C was relatively small even with regular addition of crop residues. There was no change in available nutrients (N, P and K) due to tillage and residue management treatments. The variation in soil physical properties was also small and a significant improvement may be expected over several years of continuous application of crop residue and ZT.

Keywords: Conventional tillage; Residue management; Soybean; Wheat; Zero tillage.

Introduction

Under the emerging challenges of degradation of natural resource base, declining crop productivity and ecological problems with the rice–wheat system, soybean-based cropping systems are emerging as alternative option for diversification. In India, soybean and wheat occupy 8.3 and 28.1 million ha of land area and produce 8.9 and 74.9 million tonnes of grain, with an average productivity of 1.06 and 2.67 t ha^{-1}, respectively (Behera et al., 2007). Soybean-wheat cropping system is practiced on 4.5 million ha, mainly in central India (Behera et al., 2007). In order to popularize the soybean-wheat cropping system and to get maximum sustainable production from this system, it is vital to standardize various agronomic management practices for north-west plain zone of the country. Both soybean and wheat, being protein and energy rich crops have high nutrient requirements and deplete the essential nutrients of soil. Conservation tillage is a system of managing crop residues on the soil surface with minimum or no tillage. Goals of conservation tillage are to leave enough plant residues on the soil surface for control of water and wind erosion, to reduce energy requirements; and to conserve soil water (Sharma et al., 2005). Although the use of crop residues on the soil surface has been widely practiced for many years, additional information is needed on the influence of tillage systems on physical, chemical and biological soil environment. With the development of effective chemical weed control and suitable planting equipment, the potential for conservation tillage systems has increased. Crop residue is important to soil nutrient cycling and soil fertility. Crop residue removal causes the depletion of soil nutrients, such as N, P, K; which could decrease agronomic productivity and increase soil degradation (Blanco-Canqui and Ral, 2009; Tarkalson et al., 2009). The information on the effect of tillage and residue management on growth and yield of soybean-wheat cropping system and physico-chemical properties of soil is not available. Therefore, an attempt has been made to examine the impact of sequential tillage and residue management on the performance of soybean-wheat 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^{o} 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 N NH_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. A randomized block design was followed. The biometric data were analyzed by standard statistical techniques and treatment means was compared at P=0.05.

The microplots of dimensions 4.0×1.4 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 tyne attached to hand-drawn seed-drill for placing seed and fertilizer at proper depth. For soybean, finely-chopped wheat straw @ 5 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.

Soybean cv. ‘DS 9814’ was sown at 30 cm row spacing and 5 rows in each plot with 10 cm distance from the side of bunds. A plant to plant spacing of 5 cm was maintained after thinning at 15 days, thus having 18-20 plants m^{-2} row length. Uniform dose of 18 kg N and 46 kg P_2O_5 ha^{-1} (100 kg DAP ha^{-1}) was applied basally along the crop rows using manually-drawn seed-cum-fertilizer drill. Pendimethalin @ 0.75 kg ha^{-1} was sprayed within 2 DAS using 500 litter water ha^{-1} with a knap sack sprayer. Further, the manual weeding was given after about a month of sowing for removing late-emerged weeds. Irrigation was given as per need and only 2 irrigation were required in 2010 and 2011, which were given 40 and 65, 35 and 60 days of growth respectively. No insecticide was applied in both years.

Periodic observations on growth parameters were made. Plant height was measured from 10 tagged plants at 30 days interval in both crops. At maturity, one row from both sides of each plot was removed as border and data on yield and yield attributes from 3 rows of soybean were recorded. Samples of seed and stover were taken, analyzed for nutrient concentration (N, P and K) by standard methods and uptake values were calculated. At the end of 2^{nd} cropping cycle, soil samples were taken from each plot from 0-15 cm of soil depth for estimation of available N, P, K and pH. Organic C was determined from 2 soil depths (0-5 and 5-15 cm). The samples of two replications were composited and a single sample was analyzed in duplicate following standard procedures.

Results and Discussions

Growth parameters

Plant height of soybean increased progressively with advancement of crop age up to 90 DAS (Table 1). There were significant difference in plant height among the treatments at 30 and 60 DAS, but at 90 DAS, the height was equal under all treatments. In 2010, the tallest plants at 30 DAS were recorded under ZT and the height was comparatively lower under CT and also when wheat straw was applied. At 60 DAS, the height was significantly more under ZT+WS compared with CT with or without WS. In 2^{nd} year (2011) when the cumulative effect of tillage and residue applied to previous wheat was also studied, the maximum height at 30 DAS was noticed under continuous ZT and residue application to both crops, which was significantly more than all other treatments. A similar trend was observed in 60 DAS. Cyclic tillage did not appear to have a significant effect on plant height. It was also evident that straw incorporation under CT did not prove much beneficial for increasing plant height. The results suggested that the growth of soybean plants in terms of plant height could be significantly increased under continuous ZT and residue application of both crops compared with CT alone or with residue incorporation. Direct application of residue to the immediate crop was also more beneficial than residual effect to the previous crop.

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

Treatment		2010			2011		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Soybean	*Wheat*						
CT	CT	36.3	70.3	96.2	48.6	78.1	93.0
CT	ZT	40.1	69.7	95.1	45.9	77.9	89.1
ZT	ZT	41.7	73.7	91.1	43.9	78.6	101.1
CT + WS	ZT	39.4	70.7	93.0	43.6	77.6	95.6
CT	ZT + SR	40.7	73.2	95.0	44.8	71.2	95.1
CT+ WS	ZT + SR	38.7	69.0	93.6	45.8	70.4	96.6
ZT+ WS	CT	40.6	75.6	94.9	46.8	73.5	99.8
ZT	CT + SR	39.4	71.5	92.2	46.4	68.6	91.1
ZT + WS	CT + SR	39.6	71.0	93.6	43.4	77.2	92.9
ZT + WS	ZT	34.7	72.7	92.3	40.3	80.4	96.2
ZT	ZT + SR	41.3	70.1	92.9	47.6	78.0	97.0
ZT + WS	ZT + SR	37.6	80.1	94.6	53.4	83.2	96.7
SEm+		0.70	0.86	1.19	1.15	0.94	2.25
CD (0.05)		2.17	2.68	NS	3.57	2.93	NS

Yield attributes

Tillage and residue management practices resulted in significant variation in yield attributes of soybean, viz. pod plant^{-1}, seed pod^{-1} and 1000-seed weight (Table 2). In 2010, pods plant^{-1} were maximum under ZT + WS and were considerably decreased when ZT alone were adapted. In fact the pods plant^{-1} were significantly less under ZT without crop residue than CT. Contrary to this Monsefi (2009) reported that the yield attributes in soybean was significantly influenced by the tillage and crop establishment treatments and maximum for these traits were recorded in CT-Bed than the ZT-Flat. However, these parameters were influenced significantly with the application of residues. Incorporation of wheat straw under CT also did not result in significant improvement over CT alone. The pods plant^{-1} were comparatively more in 2011 and were also significantly more when ZT was adapted with residue application. The lowest pods were under ZT without residue, presumably due to soil compaction and increased infestation of weeds. In the 2nd year, CT with residue incorporation appeared to be comparatively better than CT alone. This suggested that the beneficial effect of residue incorporation may be visible on pods plant^{-1} in the long-run.

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

Treatment		2010			2011		
Soybean	*Wheat*	Pods plant^{-1}	Seeds pod^{-1}	1000-seed weight (g)	Pods plant^{-1}	Seeds pod^{-1}	1000-seed weight (g)
CT	CT	62.2	1.6	108.0	64.5	1.7	110.0
CT	ZT	64.4	1.9	106.5	68.9	1.6	115.0
ZT	ZT	56.6	1.2	101.5	54.9	0.9	99.5
CT + WS	ZT	64.2	1.7	120.5	69.1	1.6	120.5
CT	ZT + SR	63.5	1.9	117.5	69.3	2.1	122.0
CT+ WS	ZT + SR	64.0	2.1	111.0	67.9	1.9	111.0
ZT+ WS	CT	67.4	1.4	103.0	78.7	1.3	118.0
ZT	CT + SR	59.5	1.7	125.0	71.1	1.7	125.0
ZT + WS	CT + SR	65.7	1.9	108.0	71.5	1.9	112.0
ZT + WS	ZT	62.5	1.6	108.0	72.9	1.6	113.0
ZT	ZT + SR	61.3	1.5	109.5	67.7	1.8	114.5
ZT + WS	ZT + SR	64.3	2.0	124.0	72.0	1.7	126.5
SEm±		0.73	0.05	1.76	0.96	0.07	2.14
CD (0.05)		2.26	0.14	5.49	2.99	0.22	6.65

In 2010, number of seeds pod^{-1} was significantly more when wheat straw was applied under CT as well as ZT. The seed number was much less when only ZT was done compared with CT. On the other hand in 2011, residue application under ZT resulted in equal number of seeds pod^{-1} as that under CT with or without wheat straw. Residue application to both crops under ZT had almost similar effect as to the immediate crop of soybean. Tillage or residue application to the previous crop of wheat did not appear to have a significant effect on seeds pod^{-1}. The number of seeds pod^{-1} in both years was similar and did not vary significantly.

1000-seed weight varied significantly due to tillage and residue management in both years. However, the absolute values were more or less similar in the two years and also varied identically. The maximum 1000-seed weight was under continuous ZT and residue application to both crops, while the lowest seed weight was under continuous CT without residue. Incorporation of wheat straw under CT also showed an improvement over CT alone. There also appeared to be residual effect of residue application in both crops on increasing the 1000-seed weight, especially in the 2nd cropping cycle. It was evident from the results that harmful effect of ZT on yield attributes could be overcome with residue application and could be even better than CT in successive cropping cycles.

Yield performance

There was significant variation in seed and stover yield of soybean due to tillage and residue management in both years (Table 3). In 2010, the highest seed yield was under ZT+WS, closely followed by that under CT+WS, both of which, were significantly more than CT or ZT alone. The seed yield was the lowest under continuous ZT alone, which was significantly lower than all other treatments. Stover yield followed different trend. In general, the stover yield was maximum under CT and was somewhat decreased when wheat straw was incorporated. Further, ZT also decreased stover yield compared with CT, but showed an improvement when wheat straw was retained on soil surface under ZT. In other words, the treatments which resulted in higher yield did not have higher straw production. In fact, in most legumes crops like soybean, the higher foliage growth and biomass production does not necessary lead to higher seed yield because of mutual shading effects and poor translocation of accumulated carbohydrates.

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

Treatment		2010			2011		
Soybean	*Wheat*	Seed yield	Stover yield	Total	Seed yield	Stover yield	Total
CT	CT	170.6	410.6	581.3	186.2	410.6	596.8
CT	ZT	171.8	415.8	587.5	186.2	452.4	638.6
ZT	ZT	150.6	399.4	550.0	147.1	388.5	535.6
CT + WS	ZT	196.5	393.5	590.0	186.2	508.4	694.6
CT	ZT + SR	181.4	381.1	562.5	188.9	429.8	618.8
CT+ WS	ZT + SR	205.9	387.9	593.8	210.0	492.8	702.8
ZT+ WS	CT	187.4	387.6	575.0	215.3	458.5	673.8
ZT	CT + SR	192.1	364.1	556.3	210.1	444.9	655.0
ZT + WS	CT + SR	193.5	431.5	625.0	187.2	482.7	669.9
ZT + WS	ZT	191.0	427.8	618.8	186.2	542.2	728.4
ZT	ZT + SR	180.1	369.9	550.0	190.0	392.0	582.0
ZT + WS	ZT + SR	208.3	373.0	581.3	218.6	453.0	671.6
SEm±		3.66	9.77	10.17	2.13	12.04	12.35
CD (0.05)		11.40	30.40	31.66	6.63	37.46	38.46

In 2011, the seed yield was the highest under continuous ZT + residue application to both crops, followed by ZT+WS to soybean only and it was on par with CT+WS. The other treatments with residue resulted in the comparatively lower seed yield and the lowest seed yield was obtained when continuous ZT was adopted without residue. Residue application to the previous crop of wheat also appeared to have a beneficial effect on seed yield of soybean under both tillage practices and the cumulative effect was more than to either crop. As observed in 2010, the stover yield under different treatments followed a different trend compared with seed yield. Although the lowest stover yield was recorded under continuous ZT as observed of seed yield, the highest stover yield under ZT+WS was closely followed by CT+WS when these treatments were under ZT during the previous season. Continuous ZT with residue to both crops resulted in comparatively lower stover yield, but on par with ZT+WS treatments to soybean. Zero tillage alone to soybean with residue had lower stover production even though residue was applied to previous wheat crop. These results indicated that residue application to the immediate crop of soybean was more important for increasing stover production of soybean and the residual effect of residue to previous wheat was relatively small. Crop residue incorporation increased the soybean grain yield by 1.31 times and straw yield by 1.39 times (Tsuji et al., 2006; Bakht et al., 2009).

Residual soil fertility

Soil pH did not vary significantly due to different treatments at the end of two cropping cycles compared with the initial value. The pH remained virtually constant at 7.4-7.5 in the all treatments (Table 4). The organic C was much higher in 0-5 cm soil depth than sub-soil (6-15 cm). There was some improvement in organic C with residue application and the increase was more visible when residue was retained on soil surface with ZT. The lower layer of soil did not show perceptible changes in organic C content. These was due to fact that residue was retained on surface under ZT and incorporated in the surface soil (0-5 cm) under CT. Nonetheless, the increase in organic C content in the surface soil was small, despite addition of the large quantity of residue especially under continuous residue application treatments. There was no change in available nutrients (N, P and K) due to tillage and residue management treatments. The range of variation was only 147.6-151.2 kg ha^{-1} for available N, 10.86-11.97 kg ha^{-1} for available P and 237.4-241.4 kg ha^{-1} for available K. These results suggested that under tropical condition the increases in organic C are relatively small even with addition of OM due to rapid oxidation of applied organic matter under conditions of high temperature and moisture and the resultant microbial activity (Verhulst et al., 2009).

Table 4. Residual soil fertility as influenced by tillage and residue management practices in soybean-wheat cropping system (and the end of two cropping cycles).

Treatment		Organic C (%)		Available nutrients (kg ha^{-1})			Soil pH
Soybean	*Wheat*	0-5 cm	5-15 cm	N	P	K	
CT	CT	0.474	0.378	149.15	10.71	238.24	7.45
CT	ZT	0.475	0.373	150.21	11.05	239.19	7.44
ZT	ZT	0.474	0.382	147.64	10.86	237.43	7.49
CT + WS	ZT	0.479	0.388	148.65	10.85	240.21	7.45
CT	ZT + SR	0.482	0.390	149.77	10.91	240.46	7.42
CT+ WS	ZT + SR	0.486	0.369	151.24	11.03	239.72	7.46
ZT+ WS	CT	0.487	0.378	150.43	11.11	241.22	7.49
ZT	CT + SR	0.483	0.382	149.33	10.95	239.45	7.45
ZT + WS	CT + SR	0.482	0.391	150.81	11.02	240.43	7.46
ZT + WS	ZT	0.483	0.395	149.49	11.86	240.54	7.44
ZT	ZT + SR	0.482	0.365	150.12	11.92	241.28	7.46
ZT + WS	ZT + SR	0.490	0.369	150.24	11.97	241.47	7.49
Initial		0.469	0.365	148.29	10.03	237.61	7.44

Soil physical properties

Bulk density (BD) and hydraulic conductivity (HC) at two soil depths (0-15 and 15-30 cm) and infiltration rate were measured at termination of study in April 2012 (Table 5). The results showed no appreciable variation in these parameters over the initial status. However, some differences due to tillage and residue management treatments have been reported (Bhattacharyya et al., 2008). The bulk density in the 0-15 cm depth varied from 1.66-1.69 Mg m^{-3} and that at 16-30 cm depth from 1.68-1.73 Mg m^{-3}. Evidently, the effect of tillage and residue management on BD was not large and consistent. Similarly, HC varied from 0.966-1.061 in 0-15 cm depth and 0.841-0.934 in 16-30 cm depth. The trend of variation in BD was opposite, i.e. relatively lower BD in the 0-15 cm depth was associated with high HC and vice-versa in the 16-30 cm soil depth. The variations in infiltration rate were quite apparent, with lower values under ZT without residue than under CT + residue. The variations in soil physical parameters were so small that no meaningful conclusions can be drawn based on 2 years of experimentation. As such the soil physical parameters are fairly constant over a long period and significant improvement may be expected over several years of continuous application of residue and zero tillage.

Table 5. Soil physical properties as influenced by tillage and residue management practices in soybean-wheat cropping system (and the end of two cropping cycles).

Treatment		Bulk density ($Mg\ m^{-3}$)		Hydraulic conductivity ($cm\ hr^{-1}$)		Infiltration rate ($cm\ hr^{-1}$)
Soybean	*Wheat*	0-15 cm	16-30 cm	0-15 cm	16-30 cm	
CT	CT	1.69	1.70	1.061	0.934	1.124
CT	ZT	1.67	1.71	1.019	0.841	1.021
ZT	ZT	1.68	1.70	1.024	0.896	0.782
CT + WS	ZT	1.67	1.69	1.051	0.921	0.986
CT	ZT + SR	1.66	1.71	1.001	0.882	1.039
CT+ WS	ZT + SR	1.69	1.73	0.966	0.854	1.102
ZT+ WS	CT	1.68	1.71	1.016	0.845	1.214
ZT	CT + SR	1.66	1.67	1.008	0.911	1.189
ZT + WS	CT + SR	1.66	1.69	0.969	0.872	1.014
ZT + WS	ZT	1.67	1.68	0.976	0.901	0.659
ZT	ZT + SR	1.68	1.70	1.008	0.872	0.598
ZT + WS	ZT + SR	1.68	1.71	1.026	0.869	1.064
Initial		1.64		1.012		1.024

Conclusion

Skipping tillage in *kharif* to soybean resulted similar performance of soybean 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. Soil organic carbon, pH and available NPK were similar in zero and conventional tillage in sequential tillage.

Application of crop residues (wheat, soybean and both) brings the desirable changes in soil physical and chemical properties.

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