



Effect of conservation agricultural practices and nitrogen management on soil properties

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ABSTRACT

A field experiment was carried out to evaluate the effect of conservation agricultural practices and nitrogen management on soil physical, chemical and biological properties after 2 years of continuous soybean (*Glycine max* L.) – wheat (*Triticum aestivum* L.) sequence. The experiment was conducted with 4 main plot treatments, i.e. Zero till without residue (ZT-R), Zero till with soybean residue (ZT+SR), Zero till with soybean and wheat residues (ZT+SWR) and Conventional till without residues (CT-R) and 4 sub plot treatments, i.e. 100% recommended dose of nitrogen (RDN) as basal (N1), 125% RDN as basal (N2), 100% + 25% top dressing (N3) and 75% basal + 25 % top dressing (N4). ZT+SWR recorded significantly higher soil organic carbon, microbial biomass carbon, and improved physical, chemical and biological properties compared to other treatments. ZT+SWR recorded 16.5 % and 25.9 % higher microbial biomass carbon than ZT-R and CT-R respectively. The same treatment also enhanced the available N, P and K in soil. Nitrogen management practices did not exert significant influence on soil properties, however, application of extra dose of nitrogen in residue added plots, enhanced the biological activity and thus improved the microbial biomass carbon, dehydrogenase activity and alkaline phosphatase activity which in turn contributed for better physical and chemical properties. Therefore, we conclude that ZT+SWR and 125% RDN as basal in conservation agriculture plots was found to be beneficial for improving soil health.

Key words: Conservation agriculture, Residue, Soil, Soybean–wheat, Zero tillage

Soil organic matter (SOM) is an important indicator of soil fertility because of its effect on physical, chemical and biological properties of soil. SOM can be increased by either increasing carbon input or decreasing organic carbon decomposition and these can be achieved through adopting appropriate management practices. Conservation agriculture (CA) is one such practice that simultaneously preserves soil and water resources (Zheng *et al.* 2014). CA is characterized by three interlinked principles, namely minimum mechanical soil disturbance, permanent organic soil cover and diversified crop rotations (Rusinamhodzi 2015). CA can lead to improved resource use efficiency through residue decomposition, improvement of soil physical, chemical and biological properties through soil structural improvement, increased recycling and availability of plant nutrients and play important roles in improving soil quality (Bhan and Behera 2014). The role of conservation agriculture is well recognized by most of the developed countries and many developing countries in order to conserve soil and water resources and overcome the agrarian challenges. The main focus to promote conservation agriculture in IGP of India was

to minimize the soil degradation due to intensive agriculture and diversify the rice-wheat cropping system. Soybean is an ideal *kharif* crop in IGP of India because of its ability to fix N in low N soils, fast decomposition rates and rapid release of nutrients for the benefit of subsequent crops (Murungu *et al.* 2010). Thus, soybean–wheat system has emerged as a good alternative both as a part of crop diversification as well as for maintaining the sustainability of the soils under conservation agriculture (Karunakaran and Behera 2016).

Application of nitrogen fertilizers is often recommended to increase SOM. A higher N fertilization has a positive impact on crop yields on start-up of CA (Grigoras *et al.* 2012). CA alter nitrogen requirements by changing the dynamics as there is a hypothesis that ZT reduces the nitrogen availability because of the immobilization effect caused by applied residues (Abail *et al.* 2013) while others stated that ZT and crop residues provides habitat for useful micro-organisms and increase enzymatic activity and enrich soil carbon and nitrogen (Bhattacharya *et al.* 2013). Despite numerous studies carried out on tillage and residue effects on soil properties and crop productivity, there is a paucity of information in respect to the likely changes in soil properties with respect to CA and nitrogen management for the system as a whole. Hence, the present investigation was undertaken to study the effect of conservation agricultural practices and nitrogen management on soil physical, chemical and

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biological parameters in soybean-wheat cropping system in the North Western Indo-Gangetic Plains (IGP) of India.

MATERIALS AND METHODS

Field experiments were conducted during 2014–16 at Indian Agricultural Research Institute (IARI), New Delhi, situated at 28°38'N latitude and 77°10'E longitude and at an altitude of 228.61 m above mean sea level. The soil of the experimental field was a sandy clay loam in texture, neutral in reaction (pH 7.6), low in organic carbon (0.38%), low in available N (150 kg/ha), medium in available P (11.2 kg/ha) and available K (245 kg/ha). The total rainfall during the study period was 451.00 and 710.72 mm during 2014 and 2015 respectively. The experiment was laid out in split plot design with three replications in a fixed lay out. The main plot treatments consisted of four conservation agricultural practices, viz Zero Tillage without residue (ZT - R), Zero Tillage with soybean residue in wheat crop (ZT+SR), Zero Tillage with soybean and wheat Residue (ZT+SWR) (soybean residue is applied to the wheat crop and wheat residue to soybean crop) and Conventional Tillage without residue (CT - R), while the subplot treatments were four nitrogen management practices, viz. 100% recommended dose of nitrogen (RDN) as basal (N1), 125% RDN as basal (N2), 100% basal + 25% top dressing at flowering stage (N3) and 75 % basal + 25% top dressing at flowering stage (N4). Under conventional tillage, the plots were ploughed 4 – 5 times (2 disc harrowing + 2 cultivators + 1 planking), while in zero-tillage the crop was sown without any tillage operations. The soybean variety Pusa 9712 during *khariif* and wheat variety HD 2967 during *rabi* were grown at row to row spacing of 35 cm and 20 cm, respectively. Well dried crop residues of wheat and soybean of previous season were applied @ 3 t/ha to soybean and wheat crop respectively by spreading the material uniformly a week after sowing for residue plots. The N, P and K were given in the form of urea, single super phosphate and muriate of potash, respectively in soybean @ 25:60:40 and wheat @ 120:60:40 N, P₂O₅ and K₂O kg/ha.

Soil physical, chemical and biological parameters were recorded at end of the research experiments. Bulk density of surface (0–15 cm) soil was determined by the core sampler method (Piper 1950) from three randomly chosen areas of each plot. The procedure for determining bulk density was followed as described by Chopra and Kanwar (1991). Hydraulic conductivity was estimated by using the following formula $K = QL/HAT$, where, Q is the quantity of water collected, L is the length of sample (cm), and H is the loss in head (cm). Soil aggregation stability was measured by adopting wet sieving techniques. Soil samples collected from individual plots were separated for content of organic carbon by wet digestion method, available nitrogen by alkaline KMnO₄ method, available phosphorous by 0.5 M sodium bicarbonate extraction method and available potassium by Flame photometry method. Microbial activity in terms of fluorescein diacetate (FDA) hydrolysis in soil was measured by procedure described by Green *et al.* (2006). The procedure

given by Casida *et al.* (1964) was used for estimation of dehydrogenase activity. Microbial biomass carbon in soil samples was estimated by the method described by Nunan *et al.* (1998). All the data obtained were statistically analysed using the F-test as per the standard procedure.

RESULTS AND DISCUSSION

Soil physical properties: Soil physical properties except bulk density were significantly influenced by conservation agricultural practices and were non significant under nitrogen management practices (Table 1). In general, the bulk density of soil decreased with the application of crop residues. The maximum value of BD was recorded with ZT - R followed by CT - R and the lower values with ZT+SWR and ZT+SR. The B D under ZT+SWR was decreased by 4% and 2% over ZT - R and CT - R. Higher values of B D in ZT - R was due to lack of soil disturbance by tillage operations which resulted in reduced porosity. This can also be attributed to denser packing of top soil caused by natural consolidation and mechanical compaction (Abail *et al.* 2013). The decreased B D in residue added plots was due to increased soil organic carbon content and biotic activity (Karlen *et al.* 1994). And among the nitrogen management practices, application of higher doses of nitrogen resulted in reduction of bulk density values. Basal application of 125% RDN and 100% basal + 25% top dressing treatments gave relatively less B D values compared to 100% basal and 75% basal + 25% top dressing.

Hydraulic conductivity (HC) was significantly influenced by conservation agricultural practices. The maximum values of HC were observed with ZT+SWR followed by ZT+SR and CT-R. Significantly the lower values were observed with ZT-R. This increase of HC in ZT+SWR was probably due to continuous channels formed by decaying plant roots which serve as routes linking the soil surface to deeper layers (Karunakaran and Behera 2016). The lower HC in ZT-R might be due to higher BD and compaction in surface as well as sub surface layers which restrict the water flow in the soil (Choudhary and Behera 2014). The HC was non-significant with different nitrogen management practices. Conservation agricultural practices exerted a significant influence on mean weight diameter of soil. The maximum values of MWD (0.86 mm) were recorded with ZT+SWR which was found on par with ZT+SR and significantly superior to ZT-R and CT-R. The lowest values of MWD were recorded with CT-R (0.54 mm). The reduced MWD in CT-R was due to the reduced aggregation as a result of direct and indirect effects of tilling the soil. The higher MWD in residue added plots was due to the improvement in soil organic matter which is associated with aggregate formation (Abail *et al.* 2013). There was a significant improvement in total WSA and percentage of macroaggregates in ZT+SWR and ZT+SR. In both these treatments there was less disturbance of soil and the retention of residues enhance and protect soil organic matter content and thus improve soil structure. ZT protected the soil structure from destructive tillage effects resulting in

Table 1. Effect of conservation agricultural practices and nitrogen management on physical properties of soil in soybean-wheat cropping system

Treatment	B D (g/cm ³)	Hydraulic conductivity (cm/hr)	MWD (mm)	Percentage of macro aggregates (> 0.25 mm)	Percentage of micro aggregates (< 0.25mm)	Total WSA (%)
<i>Conservation agricultural practices</i>						
ZT - R	1.52	1.10	0.69	27.23	48.59	75.81
ZT + SR	1.47	1.16	0.71	29.63	46.69	76.32
ZT + SWR	1.46	1.25	0.86	32.56	46.05	78.61
CT = NR	1.49	1.14	0.54	21.33	49.47	70.80
SEm±	0.03	0.023	0.02	0.16	0.20	0.34
LSD (P=0.05)	NS	0.068	0.05	0.54	0.71	1.17
<i>Nitrogen management</i>						
N1 (100% Basal)	1.49	1.10	0.67	27.50	47.80	75.30
N2 (125% Basal)	1.48	1.19	0.72	27.96	48.11	76.06
N3 (100% Basal + 25% top dressing)	1.48	1.19	0.71	27.96	47.49	75.45
N4 (75% Basal + 25% top dressing)	1.49	1.14	0.70	27.34	47.39	74.73
SEm±	0.03	0.031	0.02	0.23	0.34	0.36
LSD (P=0.05)	NS	NS	NS	NS	NS	NS

ZT-R: Zero till without residues; ZT+SR: Zero with soybean residues in wheat crop; ZT+SWR: Zero till with soybean residue in wheat and wheat residue in soybean crop; CT-R: Conventional till without residues

decreased percentage of microaggregate while concurrently improving the percentage of macro-aggregates (Choudhary and Behera 2014). Nitrogen management practices did not exert significant influence on MWD and WSA.

Soil chemical properties: Soil chemical properties at the end of the cropping system were markedly influenced by conservation agricultural practices (Table 2). Soil pH was not significantly influenced due to various treatments however, slight variations within the treatments exhibit the impact of conservation agricultural practices. However the maximum soil pH was recorded in CT-R followed by ZT-R and the lowest pH was recorded in ZT+SWR followed by ZT+SR. The added residue undergoes a series of physical churning with soil and microbial facilitated decomposition which ultimately resulted in change in soil pH (Karunakaran and Behera 2016). And among the nitrogen management practices, higher doses of nitrogen increased the pH values compared to 100% RDN treatments. The maximum values of pH were recorded with 125% RDN treatments and the minimum pH values with 100% RDN treatments. The non-significant variation in pH might be due to buffering capacity of soil which offered resistant against change in pH (Choudhary and Behera 2014).

The soil organic carbon content was significantly improved in residue retention plots. ZT+SWR recorded higher organic carbon content and this was at par with ZT+SR. This was due to the more residue (12 t/ha) added to the system which might have resulted in higher soil organic matter content. The improved organic carbon content in zero tilled residue retention plots can also be attributed to better preservation of the soil organic matter

present in soil and reduced mineralization of SOM due to the presence of crop residues on the surface (Karunakaran and Behera 2016). Nitrogen management practices did not exert significant influence on soil organic carbon content. However the maximum values were observed with higher recommended doses of nitrogen compared to 100% RDN treatments. Basal application of 125% RDN gave maximum values of organic carbon followed by 100% basal + 25% top dressing, 100% basal and 75% basal + 25% top dressing. This might be due to the beneficial effect of N fertilizers in increasing the above ground and root biomass and hence organic matter (Rasool *et al.*, 2007). Shah *et al.* (2003) reported that SOC was increased by N inputs, from both fertilizer and by residue application.

The soil available NPK after the harvest of crops were not varied much from the initial status of nutrients. This was due to the addition of considerable amounts of NPK nutrients from crop residue decomposition. Conservation agricultural practices exert significant influence on available N and K of soil. Significantly higher values of available N and K were observed with ZT+SWR and it was on par with ZT+SR. The level of K in the wheat straw comprised approximately 80% of that in the whole plant, most of which was returned to the soil, thereby increasing the K content in soil. Addition of organic crop residues might have created conducive environment for formation of humic acid, stimulated the activity of soil microorganism resulted in an increase in the SOC. Crop residues application significantly increased the SOC, and total as well as available N, P and K contents of soil (Bajpai *et al.* 2006). Nitrogen management practices did not have significant influence on soil available nitrogen.

Table 2 Effect of conservation agricultural practices and nitrogen management on chemical properties of soil in soybean-wheat cropping system

Treatment	pH	OC (%)	Availbale N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
<i>Conservation agricultural practices</i>					
ZT - R	7.73	0.40	150.53	10.17	233.00
ZT + SR	7.90	0.42	175.09	11.75	247.02
ZT + SWR	7.87	0.44	188.68	13.17	260.46
CT = NR	7.62	0.39	166.21	10.50	245.47
SEm±	0.07	0.01	4.72	0.95	4.65
LSD (P=0.05)	NS	0.03	16.32	NS	16.09
<i>Nitrogen management</i>					
N1 (100% Basal)	7.71	0.40	157.32	11.00	238.08
N2 (125% Basal)	7.78	0.43	177.71	11.58	249.00
N3 (100% Basal + 25% top dressing)	7.95	0.41	183.46	12.00	251.90
N4 (75% Basal + 25% top dressing)	7.69	0.40	162.03	11.00	246.95
SEm±	0.09	0.01	9.95	1.02	4.68
LSD (P=0.05)	NS	NS	NS	NS	NS

ZT-R: Zero till without residues; ZT+SR: Zero with soybean residues in wheat crop; ZT+SWR: Zero till with soybean residue in wheat and wheat residue in soybean crop; CT-R: Conventional till without residues

Soil biological properties: The different conservation agricultural practices differed significantly with respect to soil enzymatic activities (dehydrogenase, alkaline phosphatase, FDA and MBC) estimated after harvest of second season wheat crop (Table 3). ZT+SWR resulted in significantly highest activity of dehydrogenase, alkaline phosphatase, FDA and MBC in soil after harvest of second season soybean and wheat crop of the soybean-wheat cropping system. Critical examination of data further revealed that application of residues significantly increased the enzyme activities in soil after harvest of crops as

compared to no residue treatments. The balanced amount of nutrients supplied, maintained and slightly increased the nutrients availability and organic carbon content in soil after the decomposition of residues served as a substrate for better activity of microbes that ultimately reflected in higher enzymatic activity in soil. The balanced nutrient supply improves the root biomass and rhizosphere leading to higher microbial and enzymatic activities in soil. Dong *et al.* (2009) reported that the mean annual MBC was highest under no-tillage with residue, while lowest in conventional tillage. The no tillage system having crop residue showed increase

Table 3. Effect of conservation agricultural practices and nitrogen management on biological properties of soil in soybean-wheat cropping system

Treatment	FDA (ug fluorescein g/ soil/hr)	Alkaline phosphatise (ug/hr/g soil)	Dehydrogenase (TPF/hr/g soil)	Microbial biomass carbon (ug/ g soil)
<i>Conservation agricultural practices</i>				
ZT - R	3.60	8.83	6.50	131.86
ZT + SR	4.34	10.91	7.21	143.81
ZT + SWR	4.71	11.96	7.97	153.55
CT = NR	3.30	7.99	5.74	121.91
SEm±	0.14	0.39	0.14	5.27
LSD (P=0.05)	0.48	1.36	0.49	18.25
<i>Nitrogen management</i>				
N1 (100% Basal)	3.78	9.32	6.76	129.15
N2 (125% Basal)	4.16	10.41	7.27	154.41
N3 (100% Basal + 25% top dressing)	4.13	10.33	7.05	139.07
N4 (75% Basal + 25% top dressing)	3.89	9.64	6.34	128.49
SEm±	0.08	0.24	0.16	4.82
LSD (P=0.05)	0.25	0.70	0.48	14.08

ZT-R: Zero till without residues; ZT+SR: Zero with soybean residues in wheat crop; ZT+SWR: Zero till with soybean residue in wheat and wheat residue in soybean crop; CT-R: Conventional till without residues

of 103 %, 54 % and 36% for MBC, N and P, respectively at the 0 to 5 cm depth than CT (Balato *et al.* 2003).

Among the nitrogen management practices, application of 125% RDN treatments either as basal or top dressing resulted in significantly higher activity of dehydrogenase, alkaline phosphatase, FDA and MBC. This shows that higher rate of N fertilization enhanced the activities of soil enzymes without any detrimental effect on the enzyme dynamics of the soil. This is because nitrogen not only provide necessary mineral elements for plant growth, but also act as important indicator for soil natural fertility as there is a close relationship between soil nutrients and soil enzyme activity.

It is concluded that soybean-wheat cropping system has great opportunity to diversify the predominant rice-wheat system in IGP of India. For sustainability of the system, adoption of conservation agricultural practices coupled with appropriate nitrogen management is the need of the hour. Zero tillage with combined application of soybean and wheat crop residues (ZT+SWR) was found promising as an effective management practice which helps in enhancing the soil physical, chemical and biological parameters. Under CA practices, top dressing of fertilizer N does not give added advantage over basal application. Application of 25% higher recommended dose of nitrogen as basal resulted in improvement of soil properties with its beneficial effect on decomposition of residues and sustained release of nutrients to the subsequent crop.

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