

Influence of tillage practices and phosphorous management on productivity of soybean (*Glycine max*) and soil properties in soybean–wheat cropping sequence under conservation agriculture

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ABSTRACT

The field experiment was conducted at ICAR-Indian Agricultural Research Institute, New Delhi during rainy (*kharif*) season of 2017 to study the influence of different tillage practices and phosphorous management on productivity of soybean and soil properties in soybean–wheat rotation under conservation agriculture. The experiment was laid out in split plot design with three replications. Tillage and residues treatments were assigned in main plots which consisted of conventional tillage without residue (CT–R), zero tillage without residue (ZT–R), zero tillage with wheat residues @ 3 t/ha (ZT + R) and zero tillage-bed planting with wheat residues @ 3 t/ha (ZT–B + R) and phosphorus levels were assigned in sub-plots as basal application of 0, 40, 80, 120 kg P₂O₅/ha. The study revealed that higher seed yield was recorded in ZT–B + R (2.28 t/ha) and yield improvement with ZT–B + R was 16.2%, 11.0% and 5.3% compared to CT–R, ZT–R and ZT + R, respectively. ZT–B + R recorded the highest soil aggregate stability, soil organic carbon, microbial biomass carbon and dehydrogenase activity and it was statistically at par with ZT + R. Among the phosphorous management practices, basal application of 80 kg P₂O₅/ha, being at par with 120 kg P₂O₅/ha recorded significantly higher seed yield. Phosphorous management practices did not influence significantly the soil properties, however application of 80 kg P₂O₅/ha enhanced the biological activities of soil, viz. microbial biomass carbon (MBC) and dehydrogenase activity (DHA). Therefore, it was concluded that ZT–B + R and basal application 80 kg P₂O₅/ha is effective for improving soybean productivity and soil quality indicators in soybean–wheat cropping sequence under conservation agriculture.

Key words: Conservation agriculture, Phosphorous management, Soil properties, Soybean, Tillage

The food grain production in India has increased from 50 million tonnes in 1950–51 to 285 million tonnes in 2018–19 (DES, 2019) in post ‘Green Revolution’ period. Indian agriculture is facing multiple problems like soil health deterioration, saturation of high yielding varieties in terms of yield, a declining water table, soil salinity, decline in factor productivity and a virtual halt in further expansion of the irrigated area. These are caused mainly by intensive tillage induced soil organic matter decline, soil structural degradation, water and wind erosion, reduced water infiltration rates, surface sealing and crusting, soil compaction, insufficient return of organic material, continuous monocropping etc. Therefore, a paradigm shift in

farming practices through eliminating unsustainable parts of conventional agriculture is crucial for future productivity gains. Conservation agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Globally the area under conservation agriculture has increased significantly in recent years. At present, CA occupies around 156.9 million ha in the world (FAO, 2017). In India CA has spread considerably in recent years occupying an area of 2.0 million ha mainly in north Indian situations and especially in rice–wheat cropping system and with few other crops (Bhan and Behera, 2015). 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 (Karunakaran and Behera, 2015). Soybean [*Glycine max* (L.) Merr.] is one crop, which builds up the soil fertility by atmospheric nitrogen fixation through the root nodules and also

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through leaves litters on the ground at maturity. In soybean, phosphorus management plays important role as it stimulates rhizobial activity, nodule formation and helps in N_2 -fixation (Sharma and Vyas, 2001). CA may improve P availability in long-term because of reduced tillage and residue retention which could reduce P fixation, increase labile P, and increase organic phosphorous accumulation and its mineralization by phosphatases (Palm *et al.* 2014). Despite numerous studies carried out on tillage and residue management on soil properties and crop productivity, there is a paucity of information regarding changes in soil properties and soybean productivity due to conservation agriculture and phosphorus management practices. Hence, the current investigation was designed to determine the effect of different tillage practices and phosphorous management on soybean productivity and soil properties in soybean-wheat cropping sequence under CA.

A field experiment was conducted during rainy (*khari*) season of 2017 at research farm of the ICAR-Indian Agricultural Research Institute, New Delhi. This experiment was continued after completion of 2 years of soybean-wheat rotation at the fixed site. The soil of the experimental site was sandy clay loam in texture (sand 61.7%, silt 11.9% and clay 26.4%) with the pH of 7.9. The initial organic carbon (0.38%) and N (152 kg/ha) content of soil was low, P (11.2 kg/ha) and K (224 kg/ha) content were medium. The mean annual rainfall was about 650 mm, of which nearly 80% was received during the monsoon period from July to September. The experiment was laid out in split plot design with 3 replications including conservation agricultural practices in main plots and phosphorous management practices in sub-plots. Main plot treatments consisted of conventional tillage without residue (CT-R), zero tillage without residues (ZT-R), zero tillage with wheat residues @ 3 t/ha (ZT + R) and zero tillage-bed with wheat residues @ 3 t/ha (ZT-B + R). The sub-plot treatments involved basal application of 0, 40, 80 and 120 kg P_2O_5 /ha. Different tillage practices as mentioned for the main plots were followed and soybean variety 'Pant Soybean' (PS 1225) was sown by zero till seed drill at the seed rate of 80 kg/ha at an inter-row spacing of 45 cm and in bed at 35 cm row to row spacing. The N, P and K were given in the form of urea, di-ammonium phosphates and muriate of potash, respectively. The entire dose of nitrogen and potassium was applied as basal @ 40 and 45 kg/ha, respectively. Different doses of phosphorous were also applied as basal in sub-plots as per treatment details. All fertilisers were band placed along with sowing, by hand. At the end of experiment the soil physical, chemical and biological parameters were recorded. Field bulk density was measured by the core sampler method from the 3 randomly chosen areas of each plot. Aggregate stability was

measured using a wet sieving technique (Haynes, 1993). Soil samples collected from individual plots were separated for determination of organic carbon content by wet digestion method, available nitrogen by alkaline $KMnO_4$ method, available phosphorous by 0.5 M sodium bicarbonate extraction method and available potassium by Flame photometry method (Prasad *et al.* 2006). Dehydrogenase activity of soil samples was estimated as per described by Casida *et al.* (1964). Microbial biomass carbon in soil samples was estimated by the method described by Nunan *et al.* (1998). The data collected on different parameters were subjected to statistical analysis.

Seed and stover yield of soybean differed significantly due to different tillage and phosphorous management practices (Table 1). The highest seed and stover yields were recorded with ZT-B + R. Maximum seed yield was recorded in ZT-B + R and yield improvement with ZT-B + R was 16.2%, 11.0% and 5.3% compared to CT-R, ZT-R and ZT + R, respectively. However, there was no significant interaction between tillage and phosphorous management practices under this study. Adequate supply of moisture due to favourable effect of crop residue leads to greater nutrient uptake, efficient partitioning of metabolites and adequate accumulation and translocation of photosynthates which resulted in higher yield (Sinha, 2015). Zhao (1991) reported that soybean grown on beds with three rows, 35 cm apart from each bed in a wetland soil recorded higher dry matter and increased seed yield due to better soil aeration and higher soil temperature. Among the phosphorous management practices, basal application of 80 kg P_2O_5 /ha, being par with 120 kg P_2O_5 /ha recorded significantly higher seed yield. However basal application of 120 kg P_2O_5 /ha resulted into higher stover yield, which remained statistically at par with 80 kg P_2O_5 /ha. The yield improvement due to application of 80 kg P_2O_5 /ha was 21.6% and 13.9% compared to 0 and 40 kg P_2O_5 /ha, respectively. The increase in seed yield due to phosphorus application might be due to improvement in plant growth and vigour as P plays important role in plant metabolism, leading to enhanced seed yield. However, application of 120 kg P_2O_5 /ha did not show increment in yield over 80 kg P_2O_5 /ha, which might be due to genetic potential of crop or phosphate fixation in soil or antagonistic effect of phosphorous on other essential plant nutrients.

Soil physical properties except bulk density (BD) were significantly influenced by different tillage practices and were non-significant under phosphorus management practices (Table 1). In general, the bulk density of soil decreased with the application of crop residues. The highest value of BD was recorded with ZT-R followed by CT-R. Zero tillage with no residue treatment had higher values of BD because of minimum soil disturbance by tillage opera-

tions and mechanical compaction which resulted in reduced porosity. The decreased BD in residue added plots was due to increased soil organic carbon content and biotic activity (Karlen *et al.* 1994). Mean weight diameter (MWD) was significantly influenced by different tillage practices. ZT-B + R recorded maximum values of mean weight diameter which was statistically at par with ZT + R. The reduced MWD in conventional tilled plots was due to the repeated disturbance of soil as a result of direct and indirect effects of tilling the soil. In CT the formation of aggregates is interrupted, each time the soil is tilled with the corresponding destruction of aggregates. 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).

No significant change in soil chemical properties except soil organic carbon and nitrogen content was found due to tillage management practices (Table 1). However, minimum pH was recorded in ZT-B + R. The added residue undergoes a series of physical churning with soil and microbial facilitated decomposition which ultimately resulted in change in soil pH. The soil organic carbon content was improved in residue retention plots. ZT-B + R recorded 6.9% and 13.9% higher organic carbon than ZT-R and CT-R, respectively and this was at par with ZT + R. This was due to more residues added to the system which might have resulted in higher soil organic matter content. Moreover, the minimum soil disturbance in zero tilled

plots had reduced mineralization of soil organic matter (SOM) and preserved the SOM present in better way. Maximum soil available N was observed with ZT-B + R which was found statistically at par with ZT + R, which was due to the addition of N nutrient from crop residue decomposition. Addition of organic crop residues might have created conducive environment for formation of humic acid and stimulated the activity of soil microorganism which led to increase 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). Phosphorous management practice affected post harvest soil available P. Application of 120 kg P₂O₅/ha resulted in the highest available phosphorous. No significant changes were recorded in case of available N and K. Due to low fertiliser use efficiency under most of cropping systems, soil receiving successive application of P fertiliser can accumulate large amounts of residual P. Phosphorous exceeding the crop removal is retained mainly as adsorbed P on surfaces of soil particles and as P associated with amorphous Al³⁺ and Fe³⁺ oxides. Formation of these intermediate phosphorus products is reversible and some phosphate returns to the soil solution when solution P is reduced (Beck and Sanchez, 1994). And this process can be accelerated through residue addition and proper P fertiliser management in long-term considering whole cropping system.

The different tillage and phosphorus management practices had significantly influenced soil biological param-

Table 1. Influence of tillage practices and phosphorous management on productivity of soybean and physical, chemical and biological properties of soil in soybean-wheat rotation under conservation agriculture

Treatment	Yields		Soil physical parameters		pH	Soil chemical parameters				Soil biological parameters	
	Seed yield (t/ha)	Stover yield (t/ha)	BD (g/cm ³)	MWD (mm)		OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	MBC (µg/g/soil)	Dehydrogenase (TPF/hr/g soil)
<i>Tillage practices</i>											
CT-R	1.91	3.32	1.48	0.57	7.90	0.37	155.3	19.7	226.8	120.2	5.9
ZT-R	2.03	3.28	1.50	0.65	7.81	0.40	161.3	18.6	230.8	135.9	6.7
ZT + R	2.16	3.80	1.48	0.76	7.71	0.43	175.5	17.3	231.0	148.4	7.9
ZT-B + R	2.28	3.94	1.46	0.81	7.71	0.43	178.0	17.1	230.8	154.7	7.9
SEm±	0.03	0.04	0.04	0.02	0.05	0.01	2.91	0.65	4.43	6.01	0.14
CD (P=0.05)	0.11	0.12	NS	0.06	NS	0.03	10.07	NS	NS	19.32	0.51
<i>Phosphorus management practices</i>											
0 kg P ₂ O ₅ /ha	1.81	3.42	1.48	0.69	7.72	0.39	169.6	3.4	227.0	128.3	6.6
40 kg P ₂ O ₅ /ha	1.99	3.49	1.49	0.68	7.82	0.40	167.8	11.5	228.0	145.8	7.1
80 kg P ₂ O ₅ /ha	2.31	3.69	1.49	0.68	7.75	0.39	165.6	24.8	231.8	154.2	7.3
120 kg P ₂ O ₅ /ha	2.27	3.74	1.50	0.72	7.83	0.39	167.2	33.1	232.5	152.2	7.1
SEm±	0.03	0.04	0.03	0.02	0.05	0.01	2.09	0.64	4.25	5.56	0.13
CD (P=0.05)	0.10	0.12	NS	NS	NS	NS	NS	1.88	NS	15.13	0.48

CT-R, Conventional tillage without residue; ZT-R, zero tillage without residues; ZT + R, zero tillage with wheat residues @ 3 t/ha; ZT-B + R, zero tillage-bed with wheat residues @ 3 t/ha; OC, organic carbon; BD, bulk density; MWD, mean weight diameter; MBC, microbial biomass carbon; NS, non-significant

eters (dehydrogenase activity and MBC) after harvest of soybean crop in 3rd year of soybean–wheat cropping system (Table 1). ZT–B + R resulted in the highest activity of dehydrogenase and MBC in soil which was statistically similar to ZT + R. 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 the lowest in conventional tillage. Among the phosphorus management practices, application of 80 kg P₂O₅/ha as basal application resulted in higher MBC and it was statistically at par with 120 kg P₂O₅/ha. The highest dehydrogenase activity was found with application of 80 kg P₂O₅/ha and it was statistically similar with 120 and 40 kg P₂O₅/ha. This indicates that higher rate of P fertilisation had enhanced the activities of soil microbes. As phosphorus is an essential mineral element for plant growth as well as a component of soil natural fertility, it enhances microbial population in soil and their enzymatic activity.

Based on the experiment, it can be concluded that soybean–wheat cropping sequence under conservation agriculture is a sustainable alternative which can diversify the predominant rice–wheat system in Indo-Gangetic plains of India. Zero tillage bed planting with wheat crop residue addition along with application of 80 kg P₂O₅/ha is effective management practice which helps in improving soybean productivity and enhancing the soil, physical, chemical and biological parameters.

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