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# Soil physical properties as influenced by different conservation agriculture practices in rice-wheat system

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## Abstract
Rice-wheat cropping system is the predominant and most profitable cropping system and emerges as the major cropping system in the Indo-gangetic plains, contributing more than 70 % of total cereal production in India. There are several constraints related to this system, like depletion of water resources, reduction in soil health, burning of residue and environmental pollution. Due to these constraints, the sustainability of soil health under rice-wheat system is great threat. Therefore, to enhance the soil physical properties for the sustainable soil health by alternative tillage practices a field experiment was conducted at N.E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (Uttarakhand) during two consecutive years from 2015 to 2017. The experiment was conducted under strip plot design with three replications. Study revealed that bulk density was increased under zero till rice and wheat with *Sesbania* utilized as brown manure at 0-15 cm soil depth, while it was reversed at 15-30 cm soil depth during both the years. However, more soil moisture content was higher with zero till situation of both rice and wheat with retention of residues and *Sesbania* utilized as brown manure due to retention of residues that moderate the moisture fluctuations and thus reduce both evaporation and runoff. Among weed management practices, the higher values of soil bulk density and moisture content at different depths, after the harvest of rice and wheat crop were observed under weedy check, during both the years under rice-wheat system.

**Keywords:** Bulk density, conventional tillage, moisture, *Sesbania,* zero till

## Introduction
Rice (*Oryza sativa*)-Wheat (*Triticum aestivum*) cropping system is the most important predominant and profitable cropping system of the Indo-Gangetic plains (IGP) in India (Singh *et al.*, 2014) [26], considered as backbone of India's food security. It is the "food bowl" or "food basket" of India having 13.5 million ha area, which covers about 48.4% of the total rice and 74.7% of the total wheat area in IGP (Mahajan and Gupta, 2009 and Koshal, 2014) [18,15]. India need to produced about 130 and 105 million tonnes of rice and wheat, respectively by 2025 to feed the ever growing population (Prasad, 2011) [21], which is a challenging task. Efforts of humans to feed the ever increasing population by production of greater amounts of food grain leaves mark on the environment. Traditionally, rice is grown by transplanting in puddled situation since years. Continuous puddling thus leads to breakdown of soil aggregates and creates a poor physical condition for the following wheat crop. Also, long and persistent uses of conventional practices lead to soil erosion losses and steadily degrading the soil resource base (Montgomery, 2007) [20]. Thus, to sustain rice-wheat system researchers need to find an alternative production system which could eliminate the limitations being encountered in the existing mode. Thus, resource conserving technologies (conservation agriculture) like direct seeding of rice and zero-till wheat along with retention of residues and *Sesbania* growing between harvesting wheat and sowing/planting of rice has been proposed in rice-wheat cropping system that can ensure future productivity gains and more sustainable agricultural production by conserving natural resources. The main principles of conservation agriculture include minimum soil disturbance by adopting minimum/no tillage, proper crop rotation and minimum traffic for agricultural operations.
From a paradigm shift to conservation agriculture from that of conventional, the performance of crop with soil health may vary. As it ensures timely sowing of wheat after rice under the single pass of tractor, minimizes compaction and improves natural structural formation,

improve soil physical properties like bulk density with retention of crop residues. Soil quality is primarily governed by the tillage practices (Mohanty *et al.,* 2007) [19], which also affects the sustainable use of soil resources through its influence on soil properties *viz.* moisture, aeration, temperature etc., may reduce weeds in annual cropping systems and ultimately the soil quality. Green/Brown manuring of *Sesbania* also helps smothering weeds, conserving moisture and adding about 15 kg N/ha without adding much on cost of production (Gaire *et al.,* 2013) [11]. Thus, it requires practices to enhance the sustainability of this system, by reducing the intensity of tillage and inclusion of organic material in soil, that improves soil health *i.e.* soil structure, reduce bulk density and increase the productivity in the long run (Kumar and Goh, 2000) [16], that leads to improved soil quality and overall enhancement of resources-use efficiency. Considering all these facts, the present study was designed to find out alternative tillage practices with appropriate weed management opportunities to enhance the soil physical properties in rice-wheat cropping system.

## Materials and Methods

A field study was conducted at D-2 block of N.E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (Uttarakhand) during two consecutive years from 2015 to 2017. Pantnagar falls in the *tarai* zone, adjoining the foothills of 'Shivalik' range of the Himalayas and is situated at 29°N latitude and 79.32°E longitude having an altitude of 243.8 m above the mean sea level. The soil of the experimental site was clay loam in texture having high organic carbon (0.76%), low in available nitrogen (212.6 kg/ha), medium in available phosphorus (17.2 kg/ha) and available potassium (203.1 kg/ha) with slightly alkaline pH (7.86).

The experiment was laid out in strip plot design, with three replications, on a fixed layout with 15 treatment combinations, comprising 5 tillage methods in vertical strip *viz.,* transplanted rice-conventional till wheat (TPR-CTW), transplanted rice-zero till wheat-*Sesbania* green manuring (TPR-ZTW-ZTS), direct seeded rice-conventional till wheat-*Sesbania* incorporation (DSR-CTW-ZTS), zero till rice-zero till wheat-*Sesbania* brown manuring (Residue removed) (ZTR-ZTW-ZTS) and zero till rice-zero till wheat-*Sesbania* brown manuring (Residue retained) (ZTR+R-ZTW+R-ZTS) and 3 weed management practices in horizontal strip *viz.,* post-emergence alone application of bispyribac-Na @ 20 g a.i./ha, post-emergence application of bispyribac-Na @ 20 g a.i./ha fb1 HW at 45 DAS/DAT (IWM) and weedy check (for rice); and post-emergence ready mix application of clodinafop propargyl 15% + metsulfuron-methyl 1% @ 60+4 g a.i./ha, post-emergence ready mix application of clodinafop propargyl 15% + metsulfuron-methyl 1% @ 60+4 g a.i./ha fb 1 HW at 45 DAS (IWM) and weedy check (for wheat). The field had history of conservation agriculture being adopted in rice-wheat system with and without *Sesbania* and residue retention of rice and wheat since the rainy season 2012. *Sesbania* was grown between the harvesting of wheat and sowing of rice by zero till ferti seed drill in all the establishment system of rice except conventional system of rice and wheat crop. Under conventional transplanted rice-zero till wheat (TPR-ZTW)-*Sesbania* utilize as green manure under puddled situation. While, under conventional direct seeded rice-zero tillage wheat (DSR-ZTW)-*Sesbania* directly incorporated into the soil under well moist condition of the soil. However, under zero till rice and wheat (ZTR-ZTW)-*Sesbania* knocked out by the application of 2,4-D @ 0.5 kg a.i./ha and utilized as brown manuring. The crop was fertilized based on recommended fertilizer dose (150:60:40 kg N:P:K/ha) through urea (46 per cent N) and NPK mixture (12:32:16 per cent nitrogen, phosphorus and potassium). Zinc at 25 kg/ha was applied only in rice as $ZnSO_4$ (23.5 per cent zinc). In rice, full dose of phosphorus, potassium and zinc and half of nitrogen fertilizer was applied as basal while remaining nitrogen was top dressed in two split doses at the time of tillering and panicle initiation stage. Urea and zinc was sprayed in rice to mitigate zinc deficiency. In wheat crop, half of nitrogen, full dose of phosphorus and potassium was applied as basal while remaining nitrogen was applied in two split at the time of tillering and heading. Plant protection measures and irrigations were scheduled as per the crop need basis. After sowing of the crop, residue of the previous crop (wheat residue in rice and *vice versa*) was retained as much in each plot as per treatments allocation. Soil sampling from field was done from a particular depth i.e. 0-15 and 15-30 cm from the soil surface by using core sampler before planting and after the harvest of the crop. Bulk density and moisture content was determined by core sampler method (Braver, 1956) [7].

For determining the statistical difference between the treatments and to draw conclusions, the data obtained during the course of investigation were subjected to statistical analysis adapted in statistical package CPCS-1, designed and developed by Punjab Agricultural University, Ludhiana (Cheema and Singh, 1991) [8].

## Results

### Bulk density ($Mg/m^3$)

The bulk density of soil at different depths after the harvest of rice and wheat owing to different establishment methods was influenced significantly during both the years (2015 to 2017), except at 15-30 cm soil depth after wheat harvest (Table 1). Significantly highest bulk density at 0-15 cm soil depth was recorded with zero till rice and wheat followed by *Sesbania* brown manure (ZTR-ZTW-ZTS) during both the years after the harvest of rice and wheat. It was at par with zero till condition of rice and wheat with retention of residues and brown manuring of *Sesbania* (ZTR+R-ZTW+R-ZTS) after the harvest of rice, during 2016.

However, at 15-30 cm soil depth, conventional cropping system of rice-wheat (TPR-CTW) recorded higher bulk density which was at par with transplanted rice followed by zero till wheat along with introduction of *Sesbania* as green manure (TPR-ZTW-ZTS), after the rice harvest during 2015 and 2016. While, there was no significant difference after wheat harvest regarding the bulk density of soil at 15-30 cm soil depth. Both the establishment method of wheat except direct seeded rice followed by conventional till wheat with incorporation of *Sesbania* (DSR-CTW-ZTS) and zero till rice and wheat with retention of residues followed by *Sesbania* brown manuring (ZTR+R-ZTW+R-ZTS), during 2015-16 recorded higher bulk density; while, during 2016-17, TPR-CTW recorded higher bulk density.

Different weed management practices significantly influenced the bulk density of soil at different depths after the harvest of rice and wheat during 2015-16 and 2016-17, while, at 0-15 cm depth, after wheat harvest, during 2015-16, the bulk density was found non significant (Table 1). Weedy check recorded significantly higher bulk density of soil at 0-15 and 15-30 cm soil depth. It was at par to alone application of bispyribac-Na 20 g/ha as post-emergence after rice harvest, while significantly superior over IWM practice *i.e.* application of bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat at 45 DAS/DAT and alone application of ready mix clodinafop + MSM 64 g/ha applied as post-emergence after wheat harvest, during both the years.

**Soil moisture content (%)**

Different establishment methods significantly influenced the soil moisture content at different depths after the harvest of rice and wheat during both the years (Table 2). Significantly high soil moisture was recorded with zero till rice and wheat with retention of residues followed by *Sesbania* brown manuring (ZTR+R-ZTW+R-ZTS) during both the years of study at 0-15 and 15-30 cm soil depth, after the harvest of rice and wheat. It was at par with zero till rice and wheat followed by *Sesbania* brown manure (ZTR-ZTW-ZTS) at 0-15 cm soil depth, during 2016, after the harvest of rice.

Different weed management practices significantly influenced the moisture content of soil at different depths after the harvest of wheat crop during 2015-16 and 2016-17, while, it was found non significant at different depths after the harvest of rice during both the years (Table 2). Weedy check recorded higher soil moisture content at 0-15 and 15-30 cm soil depth followed by IWM practices (application of bispyribac-Na 20 g/ha PoE 45 DAS/DAT in rice and ready mix application of clodinafop + MSM 64 g/ha PoE in wheat at 45 DAS), during both the years.

**Table 1:** Soil bulk density as influenced by establishment methods and weed management practices in rice-wheat system after harvest at different soil depths during two years (2015-16 and 2016-17)

| Treatment | Bulk density ($Mg/m^3$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0-15 cm | | | | 15-30 cm | | | |
| | After rice harvest | | After wheat harvest | | After rice harvest | | After wheat harvest | |
| | 2015 | 2016 | 2015-16 | 2016-17 | 2015 | 2016 | 2015-16 | 2016-17 |
| Establishment Methods | | | | | | | | |
| TPR-CTW | 1.37 | 1.37 | 1.34 | 1.34 | 1.74 | 1.72 | 1.43 | 1.43 |
| TPR-ZTW-ZTS | 1.32 | 1.33 | 1.35 | 1.35 | 1.69 | 1.68 | 1.43 | 1.40 |
| DSR-CTW-ZTS | 1.39 | 1.38 | 1.31 | 1.31 | 1.60 | 1.60 | 1.40 | 1.42 |
| ZTR-ZTW-ZTS | 1.47 | 1.46 | 1.41 | 1.42 | 1.55 | 1.54 | 1.43 | 1.42 |
| ZTR+R-ZTW+R-ZTS | 1.40 | 1.41 | 1.36 | 1.37 | 1.53 | 1.52 | 1.41 | 1.41 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| LSD (P=0.05) | 0.05 | 0.05 | 0.02 | 0.03 | 0.05 | 0.04 | NS | NS |
| Weed Management | | | | | | | | |
| Bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat | 1.39 | 1.39 | 1.36 | 1.36 | 1.62 | 1.61 | 1.42 | 1.41 |
| IWM (bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat fb 1 HW at 45 DAS/DAT) | 1.36 | 1.37 | 1.33 | 1.32 | 1.59 | 1.58 | 1.39 | 1.39 |
| Weedy check | 1.42 | 1.41 | 1.38 | 1.39 | 1.66 | 1.65 | 1.45 | 1.45 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| LSD (P=0.05) | 0.03 | 0.02 | NS | 0.02 | 0.05 | 0.04 | 0.02 | 0.03 |

Transplanted rice-Conventional till wheat (TPR-CTW); Transplanted rice-Zero till wheat-*Sesbania* green manuring (TPR-ZTW-ZTS); Direct seeded rice-Conventional till wheat-*Sesbania* incorporation (DSR-CTW-ZTS); Zero till rice-Zero till wheat-*Sesbania* brown manuring (Residue removed) (ZTR-ZTW-ZTS); and Zero till rice-Zero till wheat-*Sesbania* brown manuring (Residue retained) (ZTR+R-ZTW+R-ZTS)

**Table 2:** Soil moisture content as influenced by establishment methods and weed management practices in rice-wheat system after harvest at different soil depths during two years (2015-16 and 2016-17)

| **Treatment** | Soil moisture content (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0-15 cm | | | | 15-30 cm | | | |
| | After rice harvest | | After wheat harvest | | After rice harvest | | After wheat harvest | |
| | 2015 | 2016 | 2015-16 | 2016-17 | 2015 | 2016 | 2015-16 | 2016-17 |
| Establishment Methods | | | | | | | | |
| TPR-CTW | 23.9 | 24.2 | 11.7 | 11.4 | 27.8 | 28.9 | 12.3 | 11.8 |
| TPR-ZTW-ZTS | 23.0 | 24.5 | 12.2 | 11.5 | 26.4 | 29.0 | 12.6 | 11.7 |
| DSR-CTW-ZTS | 22.3 | 24.3 | 11.8 | 11.0 | 23.2 | 25.5 | 11.8 | 12.4 |
| ZTR-ZTW-ZTS | 24.0 | 24.8 | 13.1 | 12.8 | 28.3 | 30.5 | 13.6 | 13.2 |
| ZTR+R-ZTW+R-ZTS | 25.0 | 25.5 | 15.2 | 14.4 | 29.2 | 31.5 | 14.2 | 13.7 |
| SEm± | 0.09 | 0.17 | 0.10 | 0.06 | 0.17 | 0.15 | 0.09 | 0.16 |
| LSD (P=0.05) | 0.4 | 0.7 | 0.4 | 0.3 | 0.7 | 0.6 | 0.4 | 0.7 |
| Weed Management | | | | | | | | |
| Bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat | 23.4 | 24.4 | 12.2 | 11.4 | 26.6 | 29.1 | 12.4 | 12.1 |
| IWM (bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat fb 1 HW at 45 DAS/DAT) | 23.6 | 24.7 | 12.6 | 12.0 | 26.9 | 28.9 | 12.9 | 12.5 |
| Weedy check | 23.9 | 25.0 | 13.6 | 13.3 | 27.4 | 29.3 | 13.4 | 13.1 |
| SEm± | 0.21 | 0.17 | 0.11 | 0.17 | 0.28 | 0.23 | 0.11 | 0.12 |
| LSD (P=0.05) | NS | NS | 0.3 | 0.5 | NS | NS | 0.3 | 0.4 |

Transplanted rice-Conventional till wheat (TPR-CTW); Transplanted rice-Zero till wheat-*Sesbania* green manuring (TPR-ZTW-ZTS); Direct seeded rice-Conventional till wheat-*Sesbania* incorporation (DSR-CTW-ZTS); Zero till rice-Zero till wheat-*Sesbania* brown manuring (Residue removed) (ZTR-ZTW-ZTS); and Zero till rice-Zero till wheat-*Sesbania* brown manuring (Residue retained) (ZTR+R-ZTW+R-ZTS)

## Discussion

Tillage practices greatly influence the soil physical properties which in turn affects the soil structure. Under conventional tillage system a plough pan layer is developed that impose changes in soil physical properties and lead to a decrease in soil physical quality (Bertolino *et al*., 2010) [3]. Bulk density is a soil physical parameter mostly related to management factors such as planting machinery, used to quantify soil compactness. Bulk density of soil increased with soil depth. Research results revealed that bulk density was higher under zero till rice and wheat followed by *Sesbania* brown manure at 0-15 cm soil depth, while at 15-30 cm soil depth, it was reversed and increased under conventional system of rice-wheat (TPR-CTW) during both the years of study (Table 1). It might be due to more compactness of soil under zero till at surface soil, while the soil became more porous with the increased intensity of tillage in conventional practice (Ram *et al.,* 2010; Janušauskaite *et al.,* 2013; Gholami *et al.,* 2014 and Shyam *et al.,* 2014) [22, 14, 12, 25]. Puddling induced high bulk density in subsurface layers (15-30 cm) in rice based systems (Hobbs and Gupta, 2002) [13]. In a study, under rice-wheat system, zero-tilled plots were more compact after rice harvest (Bhattacharyya *et al*., 2006a; Bhattacharyya *et al*., 2008 and Kumar *et al.,* 2012) [5, 4, 17].

Soil moisture is an important factor affecting plant growth, especially under conditions of a limited water supply (Chintala *et al.,* 2012a, b) [9, 10]. Residue retained plot under zero till rice and wheat followed by *Sesbania* brown manuring (ZTR-ZTW-ZTS) resulted in more soil moisture content during both the years of study at 0-15 and 15-30 cm soil depth and lower was recorded under direct seeded rice followed by conventional wheat with incorporation of *Sesbania* (DSR-CTW-ZTS) (Table 2). It might be due to reduced water evaporation (Bhattacharyya *et al.,* 2006b; Bhattacharyya *et al*., 2008 and Bazaya *et al.,* 2009) [6,4,2]. Residue retention showed higher soil moisture compared to residue removal (Sah *et al.,* 2013) [23]. Surface residues maintained under zero tillage system moderate the moisture fluctuations and thus reduce both evaporation and runoff. Sharma *et al.* (2011) [24] reported that no-tillage retained the highest moisture. Addition of sufficient biomass with tillage made surface soil loose and porous, which then enhanced the capacity of soil to store and retain more moisture (Alam *et al.,* 2013) [1].

## Conclusion

The conservation tillage system is an ecological approach to soil surface management as it conserves soil water, minimizes soil erosion risks but on other hand, increases surface bulk density. Thus, based on the results of present investigation, it can be concluded that adoption of conventional transplanted rice with conventional/zero till wheat either with *Sesbania* inclusion as green manure along with integrated approaches of weed management (application of bispyribac-Na 20 g/ha PoE in rice and ready mix clodinafop + MSM 64 g/ha PoE in wheat at 45 DAS/DAT) was found effective alternative in lowering the bulk density of the soil under rice-wheat cropping system. However, more soil moisture content was higher with zero till situation of both rice and wheat with retention of residues and *Sesbania* utilized as brown manure due to residues that moderate the moisture fluctuations and thus reduce both evaporation and runoff.

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