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Soil Physicochemical Properties as Affected by Organic Weed Management and Conservation Agriculture in Rice- Maize Cropping System of IGP

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ABSTRACT: Soil health is vital for agriculture, both in the short and long term. To sustain plants, animals and humans, soil need to have a sustained capacity to function as a dynamic living ecosystem. Thus, to maintain soil health, integrating the goods of both conservation agriculture and organic crop management practices can be a potential area of research. To explore this idea, an investigation was conducted at Research Farm, Rajendra Agricultural University, Pusa during *kharif* and *rabi,* 2020. The experiment was planned as a split-plot design and was replicated thrice. There were twenty treatment combinations, with four tillage practices as main-plot and five organic weed management treatments in the sub-plot. Soil from the experimental field (0-15 cm depth) was sampled and laboratory analysis following the standard procedures of various physico-chemical properties was conducted to study the combined effects of organic weed management and conservation agriculture. The results showed a reduction in pH and EC by 1.9 % and 30.3% in the plots where crop residue was retained on permanent beds with an application of P- enriched vermicompost mulch @5t/ha over control. In that treatment, Soil organic carbon was also improved by 20.9 % over the initial. CEC was also considerably improved. The increased organic matter content improved the soil water holding capacity eventually (15.3 %) and had a reducing effect on the bulk density (12.6%) in the residue retained permanent bed plot with an application of P-enriched vermicompost mulch @5t/ha over the control plot. Thus, we can observe that conservation tillage practice with residue retention and mulching have a positive effect on the soil physico-chemical properties and can assuredly increase crop growth and yield.

Keywords: Conservation tillage; Organic weed management; P- enriched vermicompost mulch, Soil organic carbon (SOC); Cation exchange capacity (CEC), water holding capacity (WHC)

INTRODUCTION

Rice- maize cropping system has received noteworthy acceptance among the smallholder farmers of IGP of South Asia and spreads over around 1.5 Mha (Timisina *et al.,* 2010). One-third of the total area under the rice maize cropping system in IGP is in India (Timisina *et al*., 2011). To feed the ever-increasing population, intensive cultivation and inclusion of crops with higher productivity in the cropping system pose to be the only way out. To increase productivity, a system that is more labour, energy, capital and resource-intensive is required which eventually takes a toll over the ecological balance affecting the physico-chemical properties of soil adversely (Bhatt *et al.,* 2019; Srinivasrao *et al.*, 2019).

Intensive tillage practices are often acknowledged for the reduction of soil organic matter, increased chances of water and wind erosion and soil compaction (Noor *et al*., 2020). Cultivating the soil in a regulated and controlled manner can optimize the soil for good and sustainable crop growth. Considering, the economical and ecological aspects, an in-depth discussion regarding conventional and conservational practices is imperative. Studies had evidence of the positive impact of conservation agriculture on rice-maize and rice-wheat cropping system in Northern India and suggested that adoption of an alternate method for tillage and crop establishment can be relied on to address the challenges in conventional tillage in the rice-maize cropping system in Eastern India (Jat *et al.,* 2013). Experiments conducted at various locations in the north-eastern IGP of India revealed that conservation agriculture (CA) based management practices can stabilize crop yield and reduce production costs (Parihar *et al.,* 2017), increase the soil organic matter content and can improve the soil quality in long term (Parihar *et al.*, 2016). Adopting CA-based practices with residue retention can ultimately improve soil health and sustain the environment (Singh *et al.,* 2016). Conservation agriculture is accredited to provide ecological and agronomical benefits, by buffering the soil pH and EC (Alijani *et al.*, 2021, Noori *et al.,* 2021), Increasing the SOM content (Jat *et al.,* 2018), porosity, aeration and WHC (Govindaswamy *et al.,* 2021) of the soil and decreasing the soil bulk density (Jat *et al.,* 2018) for good root growth.

Conservation agriculture holds to its principle of maintaining a permanent soil cover throughout the lifecycle of the crop. The use of organic amendments to enhance the soil quality and overall soil health is environmentally, economically and agriculturally justifiable (Rekaby *et al.,* 2020). Thus, the adoption of mulching as a conservation technology seems appropriate (Manna *et al.,* 2017). Experimental evidence shows that using organic mulches as a protective soil cover and due decomposition enhances the soil organic matter content (Awopegba *et al.,* 2017), improves the soil physico-chemical properties (Kumar *et al.,* 2014a). Live mulching or cover crops have multiple effects on the soil physico-chemical properties (Harasim *et al*., 2016). The addition of organic mulches eventually increases the soil organic matter, which is crucial to maintain soil ecosystem as it acts as a nutrient source to soil microbes, improves soil texture, porosity and WHC and supplies nutrients (mostly N and P) thus can improve the mineral nutrient status and crop growth in saline soils (Rekaby *et al.,* 2020).

Still, there is a paucity of information regarding the combined effect of organic weed management and conservation tillage practices on the various physical and chemical properties of soil. These, irregularities in collected works emphasize more research in this field under various cropping system. Considering the above-stated facts, the present study was conducted to critically assess the impact of both conservation tillage and organic weed management and the traditional management practice on the rice-maize cropping system prevalent in the eastern IGP. It is hypothesized that growing rice and maize on permanent beds with residue retention and mulch cover can considerably improve the soil physical and chemical properties.

MATERIALS AND METHODS

A. Experimental Site characteristics

The experimental field is located at Research Farm, Rajendra Agricultural University, Pusa, Samastipur, Bihar (25.58, 51°N, 85.4°, 313E). The long term experiment was initiated during monsoon 2007 on the clayey loam calcareous soil of Pusa. The site usually experiences hot and humid summers and cold winters with an annual rainfall of 1344mm, two-third of which isconcentrated around July to September (Jat *et al.,* 2019). The experimental soil (0-15cm) was clayey loam in texture with pH (1:2 soil: water) 8.3, EC 0.32dS/m, bulk density 1.31 g/cc and Walkley black carbon content 7.1 g/kg.

B. Treatments and Experimental Design

Four tillage practices and five organic weed management treatments were tested in a split-plot design with three replications. Tillage and residue management practices were assigned to the main plots and organic weed management practices to the sub-plots. Four tillage practices considered are as follows Zero-till direct-seeded rice followed by Zero-till maize [ZTDSR *fb.* ZTM], ZTDSR followed by maize both on permanent raised beds with residue [PBDSR+R *fb.* PBDSM+R], PBDSR followed by maize on permanent beds without residue [PBDSR-R *fb.* PBDSM-R] and Conventional tilled puddled transplanted rice followed by conventional tilled maize [CTR *fb.* CTM].

The five organic weed management treatments applied were unweeded control, Vermicompost mulch @ 5 t/ha, Phosphorus enriched Vermicompost mulch @ 5 t/ha, Live mulch (*Sesbania* spp. @ 40 kg/ha in Rice crop and *Pisum sativum* @ 100 kg/ha in Maize crop) and Weed-free (Hand weeding at 20, 40 and 60 DAS). Sixty plots each of 6.0 $m^2 \times 2.6$ m^2 were prepared according to the treatment.

C. Crop establishment

Monsoon rice crop *cv.* Rajendra Mahsuri was grown with a seed rate of 12 kg/ha, 20 kg/ha and 25 kg/ha under transplanted, PBDSR and ZTDSR treatments, respectively. Winter maize *cv.* DKC 9081 with a uniform seed rate of 25 kg/ha in all treatments was planted during the first week of December. Rice and Maize crops are been grown with a spacing of 20cm x 10 cm and 60 cm × 20 cm, respectively.

A common fertilizer dose of N:P:K (150: 26: 17.5 kg /ha) for *kharif* rice and N:P:K (200:35:26 kg/ha) for *rabi* maize was applied in the form of urea, di-ammonium phosphate, muriate of potash. In both seasons, a basal dose of 11%N, total P, K and $ZnSO_4$. $5H_2O$ @ 10kg/ha was applied with seed cum fertilizer drill while remaining N was top-dressed as urea in two equal splits at tillering and PI stage in rice and at V5 and VT growth phases in maize (Jat *et al.* 2019). No herbicides were applied during the study. Hand weeding was done at 20, 40 and 60DAS on the weed-free plots. Mulch application was done after a week of sowing as per respective treatments.

D. Sample collection and Analysis

Composite representative soil samples from each plot were collected as triplicates from 0-15cm depth after the completion of the cropping cycle in 2020. The collected samples were then shade dried and ground then sieved through a 2mm sieve. Soil pH was estimated with a glass electrode pH meter from the soil: water suspension (1:2) as suggested by Jackson (1973). EC [dS/m] was measured using an electrical conductivity meter from the clear extract (1:2 soil: water ratio) (Jackson, 1973). Soil organic carbon [g/kg] was calculated using the Walkley and Black wet oxidation method (1934) using diphenylamine indicator (Jackson, 1973). Cation exchange capacity [cmol(p+)/kg] was determined by method 9080 using an excess of 1N Ammonium acetate at pH 7 (Chapman, 1965). The water holding capacity [w/w %] was calculated by using Keen's Raczkowski box method (Piper, 2005). Bulk density [g/cc] of soil was measured by the core method using metalcorein the middle of each soil layer (Blake and Hartage, 1986).

E. Statistical Analysis

The statistical analysis of variance for the various physico-chemical properties was done using ANOVA for split-plot (Snedecor and Cochran, 1967). Treatment effects were further calculated using the 'F' test by Gomez and Gomez (1984). The mean values were adjudged for testing significance using a critical difference value at $P \leq 0.05$. Microsoft Excel 2010 was used for the computation and preparation of graphs.

RESULTS AND DISCUSSION

A. Effect of organic weed management and tillage practices on soil pH, EC and soil organic carbon after rice-maize cropping system

Tillage practices had a positive impact to balance the soil pH. The soil pH was reduced from 8.3 (initial) to 8.25 after treatment. The soil pH was lowest under the treatment T_2: PBDSR+R *fb.* PBDSM+R(8.25), while the treatment T_4: CTR *fb.* CTM recorded the highest pH value (8.36). The conservation tillage practices (T_1, T_2 and T_3) recorded 0.8- 1.3 % reduction in soil pH value over the conventional (T_4) (Table 1). The application of mulches had a positive but non-significant effect on soil pH. The treatment W_3: P- enriched Vermicompost mulch [5t/ha] recorded the lowest soil pH (8.25). The reduction in soil pH in mulched plots (W_2, W_3 and W_4) was by 0.5-1% over the unweeded control (W_1) (8.33) (Table 1). Soil EC was significantly affected by the tillage and organic weed management practices. EC followed a similar trend as soil pH. The decrease in soil EC was by 21% and 19% under treatment T_2: PBDSR+R *fb* PBDSM+R (0.25 dS/m) over initial (0.32 dS/m) and T_4: conventional control (0.31 dS/m). The unweeded control recorded the highest EC (0.30 dS/m). While, there was a reduction in the EC value by 16% and 13% in the treatments T_3: P- enriched vermicompost mulch @ 5t/haand T_2: Vermicompost mulch @ 5t/ha, respectively (Table 1). Both main plot and sub-plot treatments had a significant effect on Soil Organic Carbon (SOC). Treatment T_2: PBDSR+R *fb* PBDSM+R recorded the maximum Soil organic carbon (8.38g/kg) and the treatment T_4: CTR *fb* CTM recorded the lowest SOC (7.62g/kg). The percent increase in SOC in T_4 was by 9% over the conventional control (Table 1). The increase in SOC over the unweeded control (7.31g/kg) in mulched plots was by 11-16%. Maximum SOC was recorded under treatment W_3: P- enriched vermicompost mulch @ 5t/ha (8.72 g/kg). There was an increase in SOC by 18.5% over the initial (7.1 g/kg).

Table 1: Effect of organic weed management and tillage practices on soil pH, EC [dS/m] and soil organic carbon[g/kg] after rice-maize cropping system (2020).

Treatments	Soil pH	Soil EC [dS/m]	SOC [g/kg]
Tillage			
T_1: ZTR *fb* ZTM	8.27	0.26	8.25
T_2: PBDSR+R *fb* PBDSM+R	8.25	0.25	8.38
T_3: PBDSR-R *fb* PBDSM-R	8.29	0.28	8.17
T_4: CTR *fb* CTM	8.36	0.31	7.62
SEm±	0.08	0.01	0.13
CD ($p \leq 0.05$)	NS	0.02	0.44
Organic Weed Management			
W_1: Unweeded control	8.33	0.30	7.31
W_2: Vermicompost mulch [5t/ha]	8.28	0.26	8.56
W_3: P- enriched vermicompost mulch [5t/ha]	8.25	0.25	8.72
W_4: Live mulch [*Sesbania* spp. in rice and *Pisum sativum* in maize]	8.29	0.28	8.22
W_5: Weed free (3HW@ 20, 40, 60DAS)	8.32	0.29	7.72
SEm±	0.05	0.01	0.10
CD ($p \leq 0.05$)	NS	0.02	0.28
CD ($p \leq 0.05$) (Interaction)	NS	NS	NS

In a CA-based cropping system the accumulation of soil organic matter was increased (Malecka *et al*., 2012, Jat *et al*, 2017, Jat *et al.,* 2018). The soil pH and EC values were also reduced by tillage practice. Decomposition of organic matter present in the surface layer can produce organic acids which can reduce the pH (Singh *et al*., 2014, Li *et al.,* 2020, Noori *et al.,* 2021). Upon decomposition, organic acids synthesized can solubilize the salts which were then subjected to leaching with irrigation water hence, reducing the soil EC (Kumar *et al.,* 2014b, Alijani *et al.,* 2021). Application of organic mulches or bio-mulches also incorporates the organic matter into the soil and improves soil microbial population which then hastened decomposition then increased the SOC content (Timisina *et al.,* 2018, Ngangom *et al*., 2020, Singh *et al.,* 2021). Application of vermicompost and live mulch enhanced microbial activity led to increased production of organic acids like humic acid in soil that then decreased the pH and EC value (Stratton *et al*., 1995, Ansari, 2008, Mohan Babu *et al.,* 2021).

B. Effect of organic weed management and tillage practices on CEC after rice-maize cropping system

The CEC of soil is a reliable indicator of soil quality and productivity (Ross and Ketterings, 2011). The cation exchange capacity of the soil was significantly influenced by the tillage and weed management practices (Fig. 1). The treatment T_2: PBDSR+R *fb* PBDSM+R recorded significantly highest CEC (11.23 cmol (p+)/kg) and was at par with T_1: ZTDSR *fb.* ZTM (11.15 cmol (p+)/kg). The treatment T_4: CTR *fb.* CTM recorded lowest CEC (10.07 cmol (p+)/kg). The percent increase in CEC of T_4 over control is 10.3%. While, in the organic weed management treatments, the treatment W_3: P- enriched vermicompost mulch @ 5t/ha recorded the significantly highest CEC (11.68 cmol (p+)/kg). There was a percent increase in CEC by 20.4% over the unweeded control (9.29 cmol (p+)/kg) (Fig. 1).

CEC is highly sensitive to residue retention and mulching. Organic matter like vermicompost (Kay, 1998) is a product of accelerated bio-oxidation (Le *et al.,* 2018) and crop residues act as SOC reserve.

Application of organic matter increases the soil CEC (Solly *et al.*, 2020) and thus releases nutrients slowly for a longer duration (Sharma and Banik, 2014, Das *et al.*, 2021).

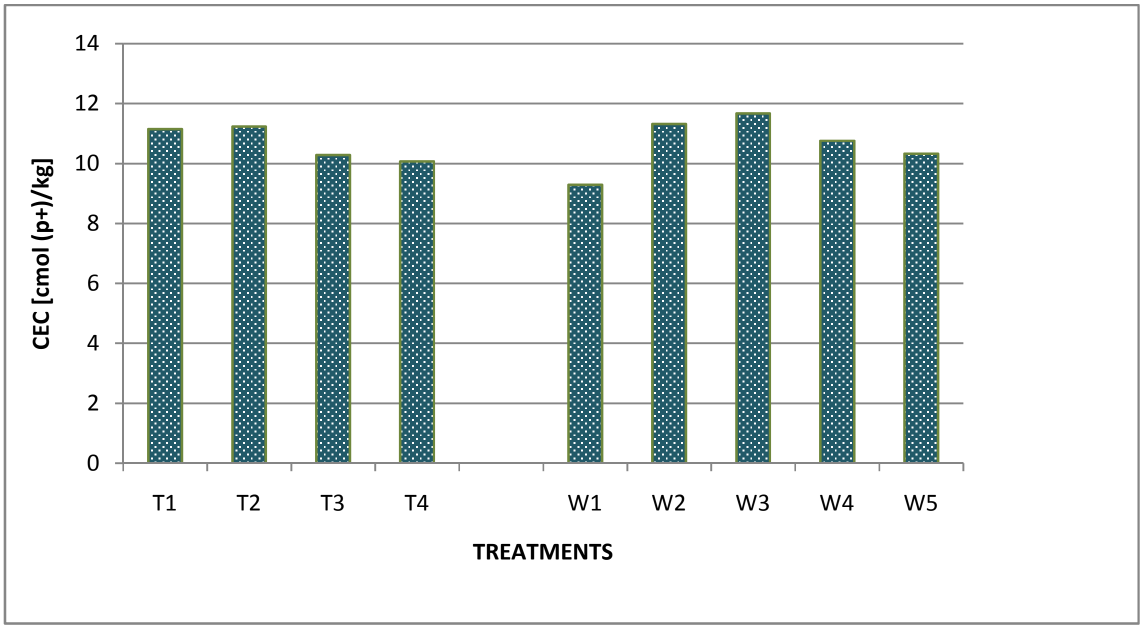

Fig. 1. Effect of organic weed management and tillage practices on CEC [cmol (p+)/ kg] of soil after rice- maize cropping system (2020).

C. Effect of organic weed management and tillage practices on WHC and bulk density after rice-maize cropping system

Comparing the data of bulk density [g/cc] and WHC [w/w %], an alternate trend was noted (Fig. 2). The initial bulk density was 1.31 g/cc, which was considerably affected by various tillage and weed management treatments. The treatment T_2: PBDSR+R *fb*. PBDSM+R witnessed a decrease of 8.5 % over the control. Applying P- enriched vermicompost mulch @5t/ha decreased the bulk density by 4.4% over the unweeded control. However, the WHC of the conservation tillage treatments was higher than conventional control by 2.5-6.5%. Mulching in general is known to improve the water retention capacity of the soil (Leary and DeFrank, 2000). The mulched plots showed a higher WHC over the weed-free and unweeded control by 1.2- 6% and 5.5-10%, respectively.

In the CA system, there is minimal disturbance to soil gradually had a positive impact on bulk density (Jat*et al.*, 2018). Bulk density is reduced with the addition of organic matter and reduced compactness and increased pore space in soil (Pandey, 2020, Kumar *et al.*, 2020). CA system with minimal tillage and increase in SOC concentration increase the percent of soil micropores (<500µm) that readily hold water (Govindaswamy *et al.*, 2021).

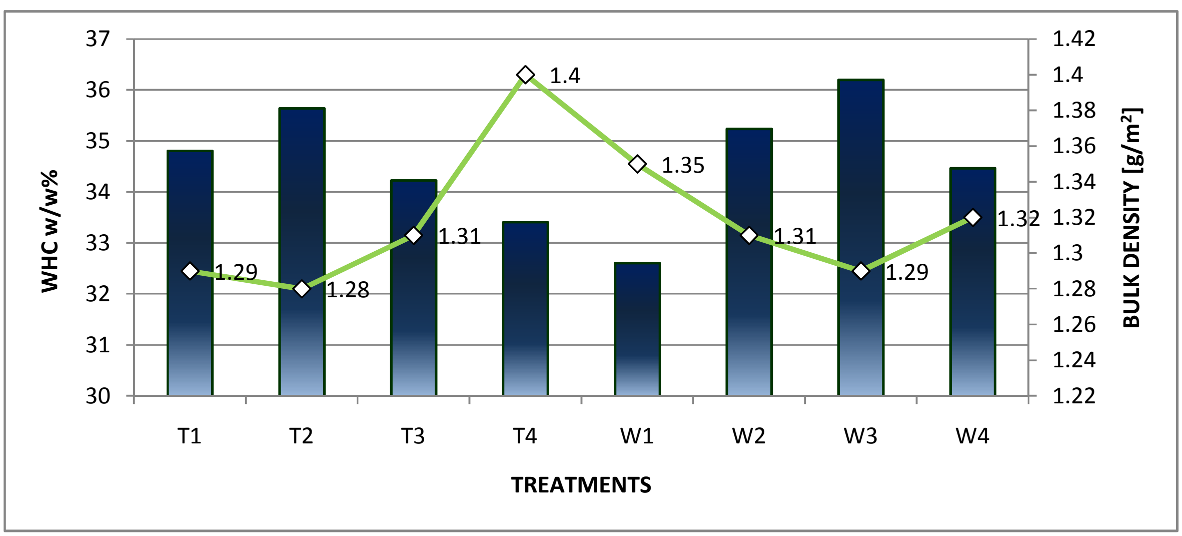

Fig. 2. Effect of organic weed management and tillage practices on WHC [w/w%] and bulk density [g/cc] of soil after rice- maize cropping system (2020).

Retention of crop residue in the tillage system and application of mulch cover on soil reduces exposure of soil to the environment, hence reduces evaporation and surface runoff, increases water in filtrability (Das *et al.*, 2015), SOM content in soil and porosity (Pagliai *et al.*, 1980, Das *et al.*, 2021), conserving the water in the soil profile (Ngangom *et al*., 2020) and can thus stimulate crop growth and yield.

CONCLUSION

Organic weed management and tillage influenced all the physico-chemical properties. The soil under study is calcareous so a reduction in soil pH and EC with the adoption of conservation tillage and mulch application can create an appropriate environment for many soil biochemical processes. There was an increase in the SOC content due to the application of mulch and residue retention in CA plots. While bulk density reduced there was an increase in WHC in mulched and residue retained permanent bed plots. Better soil physical condition will have good soil aeration, thus can promote easy crop establishment, root penetration water availability during crop growth. Increased SOC and microbial activity can increase the availability of soil nutrients. Higher CEC indicates better nutrient absorption and crop growth. From the present investigation, it can be concluded that adopting conservation tillage practice with residue retention along with organic mulching can substantially improve soil health and thus, can have a positive impact on crop growth and yield.

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