Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 6[10] September 2017 : 93-101

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.876
Universal Impact Factor 0.9804
NAAS Rating 4.95

ORIGINAL ARTICLE **OPEN ACCESS**

Periodic Soil Chemical Changes in Wheat under Tillage, Residue Management and Green Manure in Rice-Wheat System in North-West India

Rituparna Saikia[1*]. Sandeep Sharma[1] . H S Thind[1]. Neemisha[1]
[1] Department of Soil Science, Punjab Agricultural University,
Ludhiana 141004, Punjab, India
[*]Corresponding author: Telephone : +918876878353; E-mail: rsaikia32@gmail.com

ABSTRACT
To attain sustainability in exhaustive rice-wheat system in north-west India, adopting conservation agriculture based management practices is vital for recuperating soil and environmental quality and to maintain social ecosystem. A 5-year field study evaluated the effects of four combinations of two wheat straw (no wheat straw; w_0 and 25% wheat straw; w_{25}) and two Sesbania green manure (no GM and GM) treatments in puddled transplanted rice (PTR) as main plot treatments and three combinations of tillage and rice residue management options in subsequent wheat as subplot treatments on soil chemical changes in a rice-wheat rotation. The results showed that PTR with residue retention and GM and zero tillage wheat with 100% residue retention (ZTW_{R100}) significantly increased oxidisable soil organic carbon, available nitrogen, available phosphorus and available potassium in surface (0-7.5 cm) and sub-surface (7.5-15 cm) soil layer. Averaged across five wheat growth stages, oxidizable organic carbon, available N, P and K increased under PTR_{W25}+GM/ZTW_{R100} by 50.1%, 69.3%, 75.2% and 67.9% in surface soil layer and 52.05%, 78.7%, 76.5% and 52.9% in sub-surface soil layer, respectively, as compared to PTR without residue and GM followed by conventionally tilled wheat. Principal component analysis of assayed variables clearly discriminated PTR with residue retention or GM and zero tillage from PTR without residue or GM and conventional tillage in both the soil layer. The results of the present study depicted that conservation agriculture based management practices are plausible option to increase organic carbon content, nutrient content and improve soil fertility in conventional rice-wheat system.
Keywords *Green manure. Rice residues. Zero tillage wheat. Chemical properties*

Received 11.05.2017 Revised 29.06.2017 Accepted 05.07.2017

INTRODUCTION

Rice-wheat system (RWS) is an important cropping sequence for food security, employment, income and livelihood for millions of people in Asia [1, 26]. This system occupies about 13.5 million hectares (M ha) in the Indo-Gangetic plains (IGP) of South Asia [8]. Intensive tillage, imbalance use of fertilizers, depletion of water resources and environment pollution have led to stagnation or declining trends in yields of the RWS in many parts of South Asia [28]. This calls for immediate solution by adopting better management practices for improving soil and environment quality, and maintain social ecosystem.
In-situ burning of whole of the rice residue is the normal and easiest method of residue management because it interferes with tillage and seeding operations for the next wheat crop and has no alternate use [36]. The burning of crop residue in open field has detrimental effect on air quality (particulates, smoke, greenhouse gases), which may leads to human respiratory ailments in intensive rice-wheat production regions in north-west India. Burning lead to complete loss of organic matter and nitrogen, 25 % loss of phosphorus, 20 % potassium loss and 50-60 % sulphur losses [5, 37]. Conservation agriculture (CA) practices (zero tillage, residue retention) are gaining momentum as alternate to conventional practices for addressing the issues of energy, labour, water scarcity, environment quality and climate change [7, 14], and improved productivity of RWS in South Asia [4, 39]. The ecological concern over deteriorating soil and environment quality and sub-optimal water management in RWS could be addressed by promoting the practice of leaving crop residues on the soil surface as mulch. This required development and promotion of a ZT machine that could seed crops into heavy load of crop residues thus avoiding

harmful effects of burning. The development of 'Turbo Happy Seeder' that enables ZT seeding of wheat in rice residue without burning became a significant step towards filling this gap [25]. Retention of crop residues on soil surface facilitates conservation of soil moisture, suppression of weeds, enrich soil organic matter and improve soil structure [15, 16, 38] resulting in higher wheat yield in numerous on-farm trials.
Leguminous green manure is a standard management tool in cropping systems, because it highly affects soil productivity and N dynamics in the soil–plant system and provides nitrogen to subsequent crops [1, 26]. The addition of green manure with low C/N ratio to lowland rice brings about many changes in chemical properties of soil and various nutrient transformations which can improve the sustainability of soil N fertility in lowland rice. Incorporating wheat straw with green manure may be a means for reducing fertilizer N needs and improving crop yields.
Considering the regional, national, and global importance of rice-wheat system, understanding how common field management practices influence near-surface and sub-surface soil properties will provide insight into the sustainability of these cultural practices. Despite the importance of insuring sustainability in modern cropping systems, there are limited researches being conducted on the long-term effects of tillage, straw management and crop growth stages on soil chemical properties in rice-wheat system in north-west India. Therefore, the objective of this study was to assess the effect of tillage, straw management and green manure on soil chemical properties at different wheat growth stages crop after 5 year of continuous rice-wheat cycle. It was hypothesised that retention of 25% wheat residue and green manure in rice as well as zero tillage with residue retention in subsequent wheat would increase soil organic carbon and available N, P and K in soil.

MATERIAL AND METHODS

Site Description

A 5-year field experiment on irrigated rice-wheat cropping system was established in 2011 starting with rice on a Typic Ustochrept sandy loam soil (135 g clay, 160 g silt and 705 g sand kg^{-1}) at the experimental farm of the Punjab Agricultural University, Ludhiana, Punjab (30°56′N and 75°52′E) in the Indo-Gangatic plains in the north-western India. The experimental field was under conventional rice-wheat cropping system for the last more than 10 years. The region has a sub-tropical climate, with hot, wet summers and cool dry winters. Annual mean rainfall is 760 mm, about 80% of which received in June to September. Mean minimum and maximum temperatures (averaged across 30 years) in wheat (November to April) are 6.7 and 22.6 ^{0}C and in rice (June to October) are 18 and 35 ^{0}C, respectively.

Experimental Design and Field Treatments

The experiment was laid out in split plot design with 3 replications. Treatments comprises of four combinations of wheat straw and *Sesbania* green manure (GM) management ($PTR_{W0,}$ puddled transplanted rice with no wheat straw retained; PTR_{W25}, puddled transplanted rice with 25% anchored wheat straw (12-15 cm high stubbles) retained; PTR_{W0} + GM, and PTR_{W25}+GM) in main plots and three combinations of tillage and rice residue management in sub plots in subsequent wheat (CTW_{R0}, CT wheat with rice residue removed; ZTW_{R0}, ZT wheat with rice residue removed and ZTW_{R100}, ZTW with 100% rice residue retained as mulch with 'Turbo Happy Seeder'). The treatment details are summarized in Table 1. The sub-plot size was 3.6 m x 19.0 m. Rice received a uniform dose of 13 kg P ha^{-1} as diammonimum phosphate, 25 kg K ha^{-1} as MOP (muriate of potash) and 10 kg Zn ha^{-1} as zinc sulphate (21% Zn). Rice received only 75 kg N ha^{-1} in GM treatments (PTR_{W0}+GM and PTR_{W25}+GM) and 150 kg N ha^{-1} in no-GM treatments. Fertilizer N was applied in three equal split doses at transplanting and at 3 and 6 weeks after transplanting.
Wheat received a uniform dose of 150 kg N, 26 kg P as diammonium phosphate and 25 kg K as muriate of potash ha^{-1}. One-third of total N and entire amount of P and K fertilizers were drilled at wheat sowing. The remaining 2/3 of N was applied in two equal split doses immediately before first irrigation applied at 3 weeks (crown root initiation) and immediately before second irrigation applied at 8 weeks (maximum tillering) after sowing.

Soil sampling and analysis

Soil samples were collected from surface (0-7.5 cm) and sub-surface (7.5-15 cm) soil layer at five wheat growth stages viz. before sowing (BS), crown root initiation (CRI), maximum tillering (MT), flowering(FL) and harvesting(H). Collected soil samples were air dried, passed through 2 mm sieve and analysed for pH and EC [13], soil organic carbon [33], available P [22], 1M NH_4OAC extractable available K [13].

Statistical analysis

All the dataset were analysed using analysis of variance (ANOVA) for split plot design and differences among treatment means were separated by least significant difference at $p<0.05$ level of significance using IRRISTAT data analysis package [12]. Principal component analysis (PCA) [35] was performed on the data set to reveal the similarities and differences between samples and to assess the relationships between the observed variables.

Table 1. Description of treatments

Abbreviation	Treatment detail	Method of crop establishment
A. Rice (main plot treatments)		
PTR_{W0}	Conventional till puddled transplanted rice (PTR)	Residue of preceding wheat was removed. Pre- puddling tillage operations included two discings and two harrowings followed by plankings. Puddling (wet tillage) was done twice in 6-8 cm of standing water using a tractor-mounted puddler followed by planking. Rice seedlings were manually transplanted at 15 x 20 cm spacing
PTR_{W25}	PTR with anchored wheat straw	Anchored (10-12 cm high) wheat straw (25%) of preceding wheat was retained. All the tillage and rice crop establishment operations were same as in RT1
PTR_{W0}+GM	PTR with green manure	Residue of preceding wheat was removed and zero till *Sesbania* green manure after wheat harvest. Green manure was chopped by two discings and then incorporated using two harrowings followed by planking. Puddling and rice establishment operations were same as in RT1
PTR_{W25}+GM	PTR with anchored wheat straw + green manure	Anchored wheat residue of preceding wheat was retained and zero till *Sesbania* green manure was sown in standing stubbles. Green manure incorporation and puddling operations were same as in RT3. Rice seedlings were manually transplanted at 15 x 20 cm spacing
B. Wheat (sub-plot treatments)		
CTW_{R0}	Conventional till wheat after removal of rice residue	All the residue of previous rice crop was removed. Tillage operations included two passes of harrows and two passes of tyne plough followed by plankings. After pre-sowing irrigation, seed bed was prepared by two passes of tyne plough followed by planking. Wheat was sown using seed cum fertilizer drill in rows 20 cm apart
ZTW_{R0}	Zero till wheat (ZTW) after removal of rice residue	Residue of previous rice crop was removed. Wheat was direct seeded in the no till plots in rows 20 cm apart using zero till seed cum fertilizer drill.
ZTW_{R100}	ZTW with 100% rice residue as mulch	Residue of previous rice crop was retained. Wheat was direct seeded in rows 20 cm apart into rice residues using Turbo Happy Seeder [12].[a]

[a]M/S Kamboj Machinery Manufacturers, Ramdas, Amritsar, Punjab, India

RESULTS AND DISCUSSIONS

The main effects of different treatments on soil chemical properties were not significant in sub-surface (7.5-15 cm) soil layer at all growth stages of wheat. Therefore, main effects of four treatments applied to rice and three sub-plot treatments applied to wheat in the surface soil layer (0-7.5 cm) are reported and discussed in the following sections.

Soil pH and EC

The effect of different wheat straw and green manure practices in rice and tillage and rice straw management practices in subsequent wheat and their interaction was not significant on soil pH at all the growth stages of wheat in both the soil layer. This is in agreement with Monsefi et al. (2014); they reported that soil pH was not affected by different tillage and wheat residue management practices in a soybean-wheat cropping system. Similar results were reported by Villamil and Nafziger (2015) in continuous corn system.

Oxidizable soil organic carbon

Oxidizable soil organic carbon (SOC) content in soil varied across different wheat straw and green manure practices in rice and tillage and rice straw management practices in wheat. The SOC content in both the soil layer was higher under ZTW_{R100} as compared with ZTW_{R0} and CTW_{R0} at all the growth stages (Fig. 1). Similarly, PTR with residue retention and green manure produced significantly higher SOC in soil as compared with treatments without residue retention or green manure. SOC was significantly affected by wheat growth stages in both the soil layer. Maximum SOC content was recorded at harvesting stage, which was 27.6% and 93.9% higher than before sowing of wheat in surface (Table 2) and sub-surface soil layer (Table 3), respectively. Significant interaction between wheat growth stages and treatments was observed. Averaged across the five growth stages, SOC content in PTR_{W25}+GM/ZTW_{R100} treatments was increased by 50.1% and 52.05% as compared with PTR_{W0}/CTW_{R0} at surface and sub-surface soil layer, respectively. As hypothesized, in the present investigation SOC increased under zero tillage with 100% residue retention in both the soil layer as compared with CTW with no residue. This result was expected because the elimination of soil disturbance by tillage enables a greater quantity of above-and below-ground biomass to be stored in the soil, whereas tillage aerates the soil and promotes a greater rate of aerobic SOM decomposition [3]. SOC in the surface soil layer was higher than the sub-surface soil layer. Conservation tillage leads to increase of organic carbon in surface soil layer than sub-surface soil layers [24]. This increase of SOC in the surface soil layer is possibly due to poor residue-soil contact, less decomposition of structural plant constituents because of delay in colonisation by microbes [11]. Tillage breakdown the crop residues into smaller particles, incorporate them into greater soil depth and exposes a larger surface area for microbial attack [29]. In agreement with our results, significantly higher SOC concentration under no tillage as compared to conventional tillage practices was reported in previous studies by Martinez *et al.* [18], Syswerda *et al.* [30] and Heidari *et al.* [10]. In a long term rice-wheat system, Yadvinder Singh et al. [38] recorded significant increase of SOC after rice residue incorporation than its removal or burning. In the present investigation, significant effect of wheat growth stages was observed on SOC content in soil. The maximum SOC content in soil was observed at harvesting stage in both the soil layers which may be due to accumulation of organic matter with accumulation of crop residues over time. Soil organic matter (SOM) content is directly correlated with the nutrient content of the soil as it contains 90–95% of the N, 90% of the S, and 40% of the P in the soil [27]. Organic matter serves as a source of replenishment to the plant available soil nutrient pool after mineralization.

Available nitrogen

In both the soil layer (Table 2 and 3), available N in soil was significantly higher at CRI stage as compared to other growth stages. Available N content in soil was significantly affected by wheat straw and green manure practices in rice and tillage and rice straw management practices in wheat at all the growth stages of wheat (Fig. 2). Averaged across the five growth stages, PTR_{W25}+GM/ZTW_{R100} increased available N content in soil by 69.3% and 78.7% than PTR_{W0}/CTW_{R0} in surface and sub-surface soil layer, respectively. At all the growth stages, available N in soil was significantly higher under ZTW_{R100} as compared with ZTW_{R0} and CTW_{R0} in both the soil layer. Interaction between wheat growth stages and treatments was not significant. Soil management practices such as tillage, residue management and crop rotations greatly influences nutrient availability and cycling [6]. Available nitrogen content in our study followed the similar trend as SOC. Zero tillage, residue retention and green manure had positive impact on available N content in soil. Conservation tillage practices such as zero tillage or reduced tillage with crop residue retention increases nitrogen availability [9]. Previous studies by Nagar *et al.* [20] and Nivelle *et al.* [21] observed positive impact of legume crop on available N content in soil. Similar findings were reported by Das *et al.* [2]; they observed significant increase of available N in a rice crop after 4 years of no tillage as compared with conventional tillage practices. Maximum value of available N content in soil was recorded at CRI stage in both the soil layer. This is possibly because of application of one third of fertilizer nitrogen at this stage.

Available phosphorus and potassium

Available P (AVP) content in soil was significantly affected by wheat growth stages. In the surface soil layer, available P content reached maximum value at maximum tillering stage, which was 48.7% higher than before sowing of wheat crop (Table 2). In the sub-surface soil layer maximum available P content was recorded at flowering stage of wheat crop (Table 3). Interaction effect of wheat growth stages and treatments was significant in the sub-surface soil layer (Table 3). Wheat straw and green manure practices in rice significantly affected available P content in soil at all the growth stages of wheat in the surface soil layer (Fig. 3) Similarly, tillage and rice straw management practices in wheat significantly affected available P in soil at crown root initiation and flowering stage in surface soil layer. Averaged across five wheat growth stages, available P in soil was maximum under PTR_{W25}+GM/ZTW_{R100} treatment, which was 75.2% and 76.5% higher than PTR_{W0}/CTW_{R0} in surface and sub-surface soil layer, respectively. The concentration of available potassium varied significantly with wheat growth stages, wheat straw and green manure practices in rice and tillage and rice straw management practices in subsequent wheat (Fig. 4). Among wheat growth stages, available K in the surface soil layer was significantly higher (31.6%) at harvesting stage as compared with before sowing of wheat (Table 2). But in the sub-surface soil layer the difference was not significant (Table 3). Significant interaction was observed between wheat growth stages and treatments in both the soil layer. Averaged across five growth stages, PTR_{W25}+GM/ZTW_{R100} treatment significantly increased available K content in soil than PTR_{W0}/CTW_{R0} by 67.9% and 52.9% in surface and sub-surface soil layer, respectively. PTR with GM and wheat residue retention and ZTW_{R100} increased available phosphorus and potassium content in soil. Previous studies by Roldan *et al*. [23] and Khushwah *et al.* [17] reported higher available P content under conservation tillage practices under maize based system and soybean-wheat system, respectively. Increase in available P and K under no tillage than conventional tillage in rice crop was also reported by Das *et al*. [2]. Available P content in surface soil layer was significantly higher at maximum tillering stage of wheat growth. This may be related to higher root exudation and biomass due to vigorous vegetative growth of wheat at this stage. This is in agreement with Tamilselvi *et al.* [31], they observed continuous increase of available P with growth of maize up to vegetative stage, and then it decreased gradually up to maturity. The increase in available K under CA-based practices may be attributed to higher soil organic matter. The increased SOM content allows a greater amount of K^+ ions to be adsorbed to exchange sites on the organic material, which allows a greater quantity of K to be readily available for plant uptake as opposed to being leached below the surface soil layer. Retention of rice residue used to have positive effect on available K content in soil because 80-85% of K uptake by rice and wheat plant is retained in its straw [36-38]. Increase in available K in 0-40 cm soil layer with wheat straw incorporation was previously reported by Wei *et al*. [34] in a wheat-fallow cropping system. Likewise, Villamil and Nafziger [32] reported significantly higher exchangeable K in 0-15 cm soil layer under no tillage and corn (*Zea mays* L.) residue retention than chisel plough and residue removal after 5 years of continuous corn cropping.

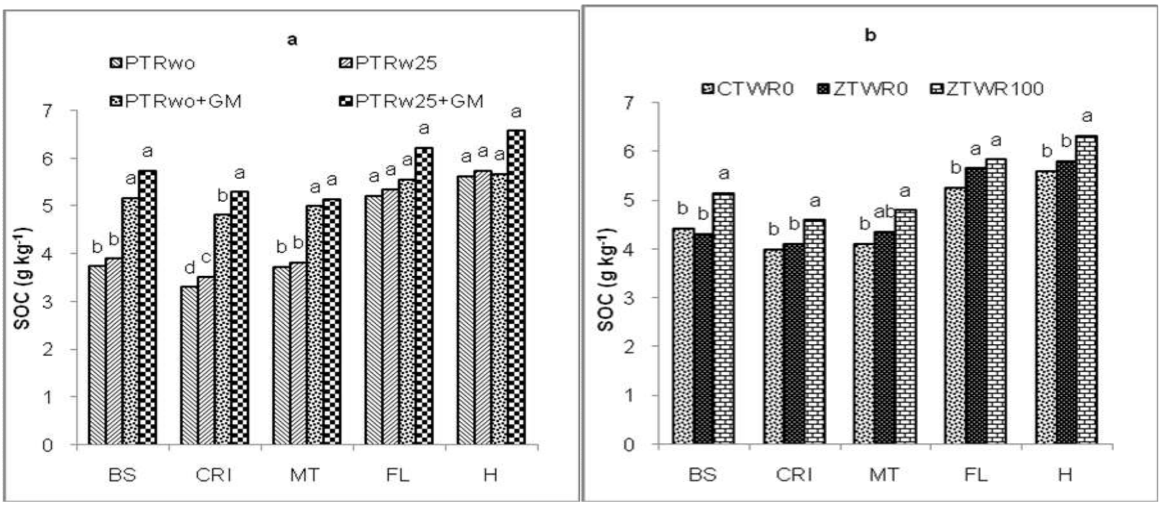

Fig. 1 Soil organic carbon as affected by (a) Wheat straw and green manure practices in rice (b) Tillage and rice straw management practices in wheat in surface soil layer at different wheat growth stages

Table 2. Treatment means averaged across five wheat growth stages and mean of wheat growth stages at surface soil layer.

Treatments	pH	EC (dSm^{-1})	SOC ($g\ kg^{-1}$)	AVN ($kg\ ha^{-1}$)	AVP ($kg\ ha^{-1}$)	AVK ($kg\ ha^{-1}$)
PTR_{wo}/CTW_{Ro}	7.7	0.13	4.19	77.4	19.7	77.3
PTR_{wo}/ZTW_{Ro}	7.7	0.13	4.24	82.8	20.6	90.1
PTR_{wo}/ZTW_{100}	7.6	0.13	4.69	100.9	24.1	110.6
PTR_{w25}/CTW_{Ro}	7.6	0.14	4.13	77.4	21.1	86.0
PTR_{w25}/ZTW_{Ro}	7.7	0.15	4.40	94.6	21.7	92.7
PTR_{w25}/ZTW_{R100}	7.6	0.15	4.71	115.9	24.5	112.0
PTR_{wo}+GM/CTW_{Ro}	7.6	0.17	4.91	83.5	21.8	91.9
PTR_{wo}+GM/ZTW_{R0}	7.7	0.17	5.16	108.9	22.1	98.8
PTR_{wo}+GM/ZTW_{R100}	7.6	0.16	5.67	119.7	26.7	118.0
PTR_{w25}+GM/CTW_{R0}	7.7	0.16	5.48	104.1	26.3	97.4
PTR_{w25}+GM/ZTW_{R0}	7.7	0.16	5.62	117.1	27.5	109.3
PTR_{w25}+GM/ZTW_{R100}	7.6	0.15	6.29	131.0	34.0	129.9
LSD (*p<0.05*)	NS	NS	0.35	5.25	3.4	9.6
Wheat growth stages						
Before sowing	7.7	0.14	4.63	108.0	19.9	90.6
Crown root initiation	7.7	0.16	4.24	115.9	22.1	110.5
Maximum Tillering	7.6	0.16	4.43	94.5	29.6	86.9
Flowering	7.6	0.15	5.59	106.7	24.3	98.6
Harvesting	7.6	0.14	5.91	80.5	25.0	119.3
LSD (*p<0.05*)	NS	NS	0.22	3.4	2.2	6.2
LSD Interaction (*p<0.05*)	NS	NS	0.79	11.8	NS	21.4

Table 3. Treatment means averaged across five wheat growth stages and mean of wheat growth stages at sub-surface soil layer.

Treatments	pH	EC (dSm^{-1})	SOC ($g\ kg^{-1}$)	AVN ($kg\ ha^{-1}$)	AVP ($kg\ ha^{-1}$)	AVK ($kg\ ha^{-1}$)
PTR_{wo}/CTW_{Ro}	7.8	0.16	3.17	55.5	15.9	75.2
PTR_{wo}/ZTW_{Ro}	7.8	0.16	3.25	61.2	16.8	80.1
PTR_{wo}/ZTW_{100}	7.8	0.15	3.48	81.0	17.7	92.3
PTR_{w25}/CTW_{Ro}	7.8	0.15	3.25	62.2	18.7	80.6
PTR_{w25}/ZTW_{Ro}	7.6	0.16	3.43	69.4	18.4	88.9
PTR_{w25}/ZTW_{R100}	7.6	0.16	3.76	86.3	19.9	114.2
PTR_{wo}+GM/CTW_{Ro}	7.7	0.16	3.57	65.7	21.2	75.4
PTR_{wo}+GM/ZTW_{R0}	7.7	0.16	3.89	77.4	22.0	95.2
PTR_{wo}+GM/ZTW_{R100}	7.6	0.17	4.35	88.8	25.0	100.6
PTR_{w25}+GM/CTW_{R0}	7.6	0.17	4.05	76.8	24.1	84.0
PTR_{w25}+GM/ZTW_{R0}	7.8	0.16	4.28	84.6	25.5	99.3
PTR_{w25}+GM/ZTW_{R100}	7.7	0.16	4.82	99.9	28.1	114.9
LSD (*p<0.05*)	NS	NS	0.5	5.83	2.21	6.6
Wheat growth stages						
Before sowing	7.8	0.15	2.81	77.8	19.3	93.9
Crown root initiation	7.7	0.16	2.97	84.9	19.2	85.4
Maximum Tillering	7.7	0.15	3.33	78.1	13.8	95.7
Flowering	7.7	0.17	4.32	77.8	24.8	88.5
Harvesting	7.7	0.17	5.45	60.2	19.0	95.0
LSD (*p<0.05*)	NS	NS	0.3	3.8	1.4	4.2
LSD Interaction (*p<0.05*)	NS	NS	NS	13.0	4.9	14.7

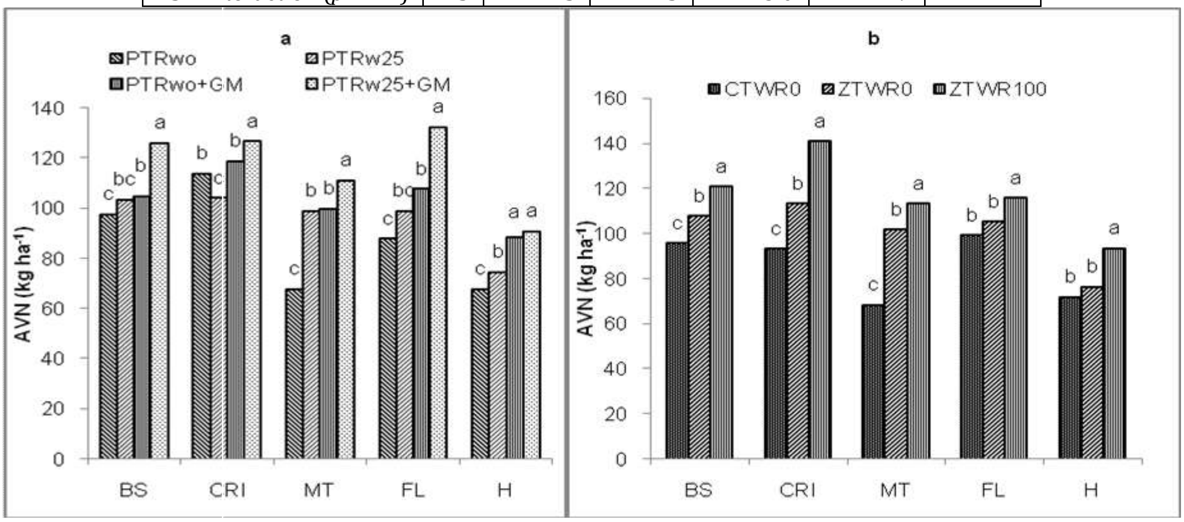

Fig. 2 Available nitrogen in soil as affected by (a) Wheat straw and green manure practices in rice (b) Tillage and rice straw management practices in wheat in surface soil layer at different wheat growth stages

Principal component analysis

The principal component analysis clearly separated the treatments in the factorial space defined by two PCs (Fig. 5). In the surface soil layer PC1 explained 64.81% of the variation and separated PTR_{W25}+GM and ZTW_{R100} treatment from rest of the treatments, while PC2 explained 20.18% of the variability in the dataset. All the variables except pH significantly contributed (>50%) to the PC1. pH and EC significantly contributed to PC2. All the variables except pH and EC were related to PTR_{W25}+GM and ZTW_{R100} treatments. Similarly in the sub-surface soil layer, PC1 and PC2 explain 84.43% of the total variability in the dataset. All the variables significantly contributed to PC1. Variables (SOC, AVN, AVP and AVK) were related to PTR with residue retention or green manure and zero tillage with 100% residue retention.

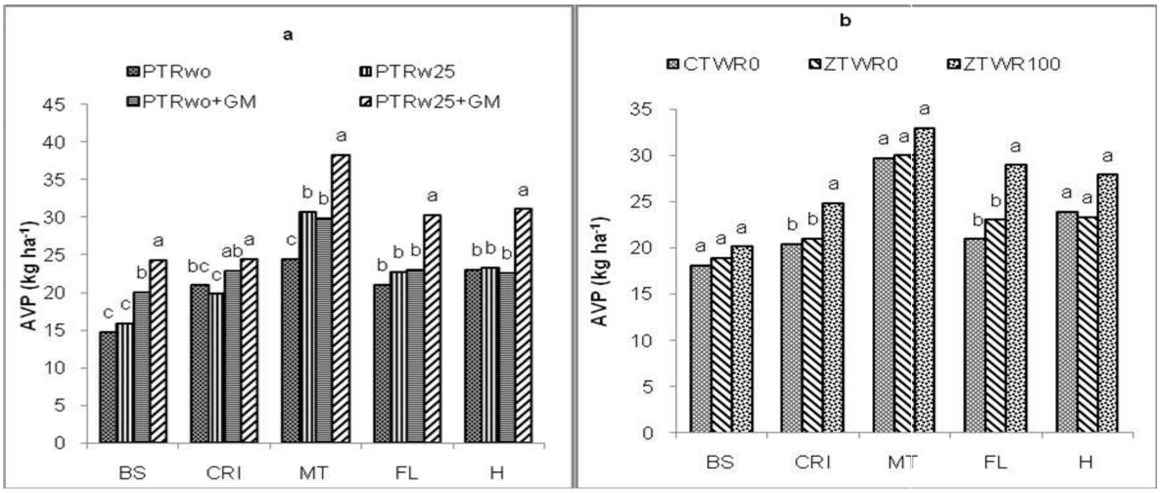

Fig. 3 Available phosphorus in soil as affected by (a) Wheat straw and green manure practices in rice (b) Tillage and rice straw management practices in wheat in surface soil layer at different wheat growth stages

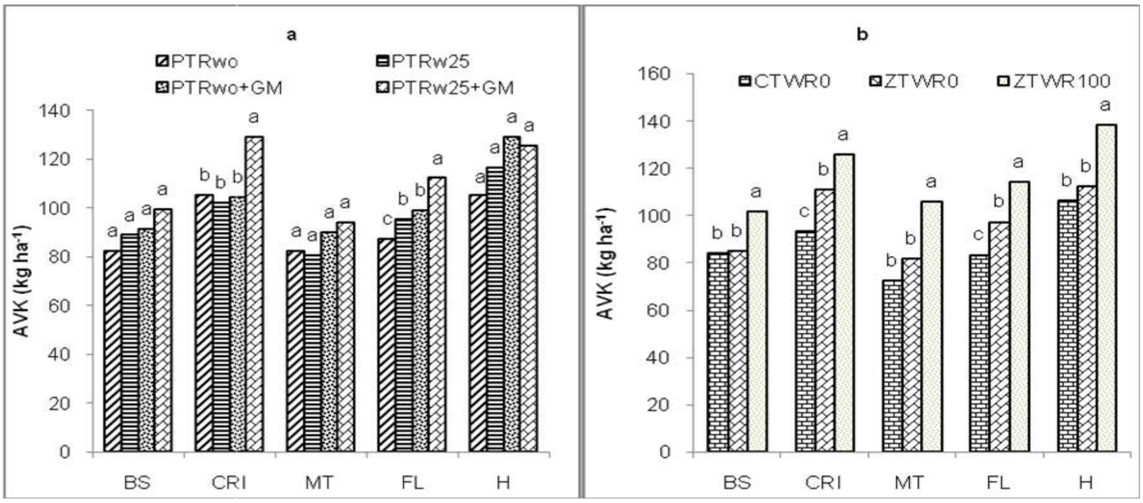

Fig. 4 Available potassium in soil as affected by (a) wheat straw and green manure practices in rice (b) tillage and rice straw management practices in wheat in surface soil layer at different wheat growth stages

BS-Before sowing, CRI-Crown root initiation, MT-Maximum tillering, FL-Flowering, H-Harvesting

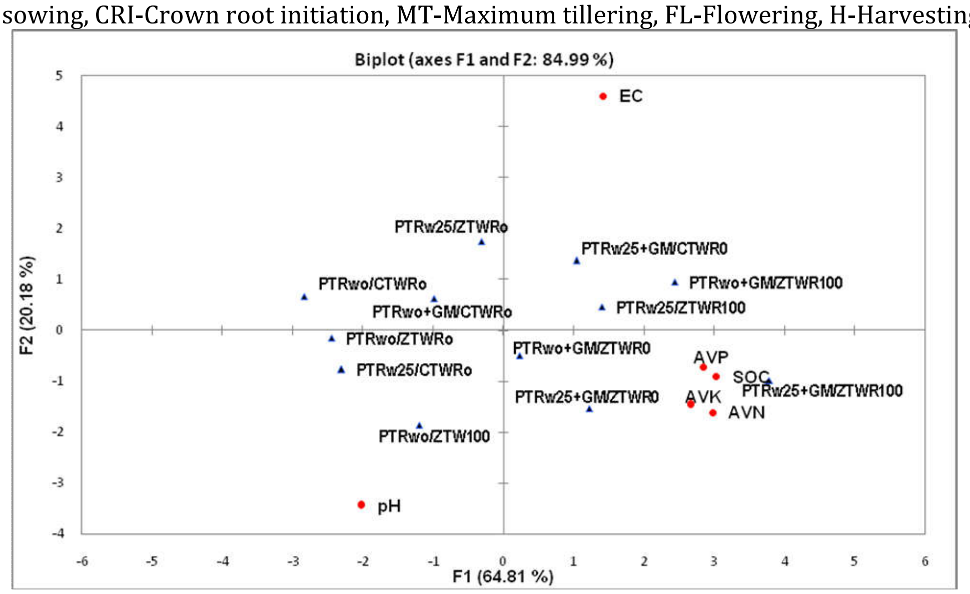

Fig. 5 Principal component analysis of assayed variables at surface soil layer.

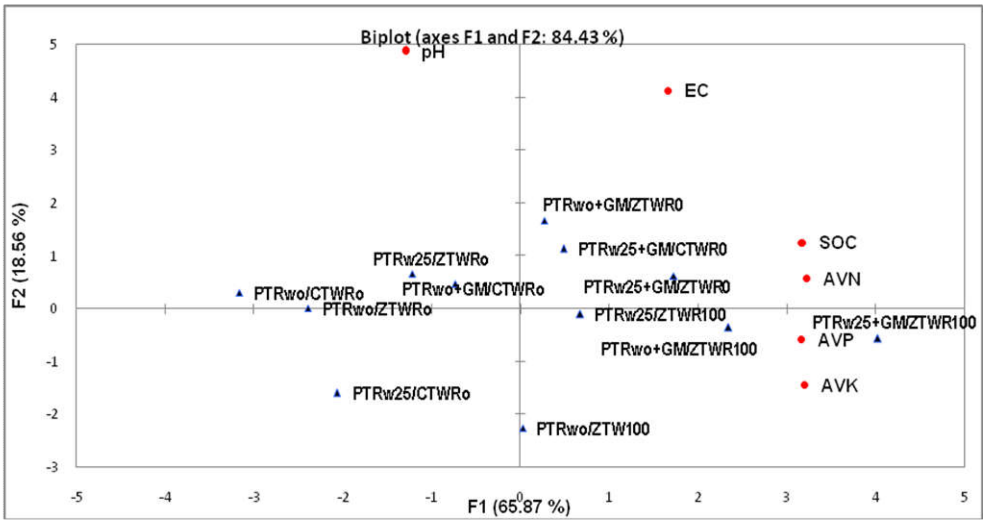

Fig. 6 Principal component analysis of assayed variables at sub-surface soil layer
EC-Electrical conductivity, SOC-Soil organic carbon, AVN-Available nitrogen, AVP-Available phosphorus, AVK-Available potassium

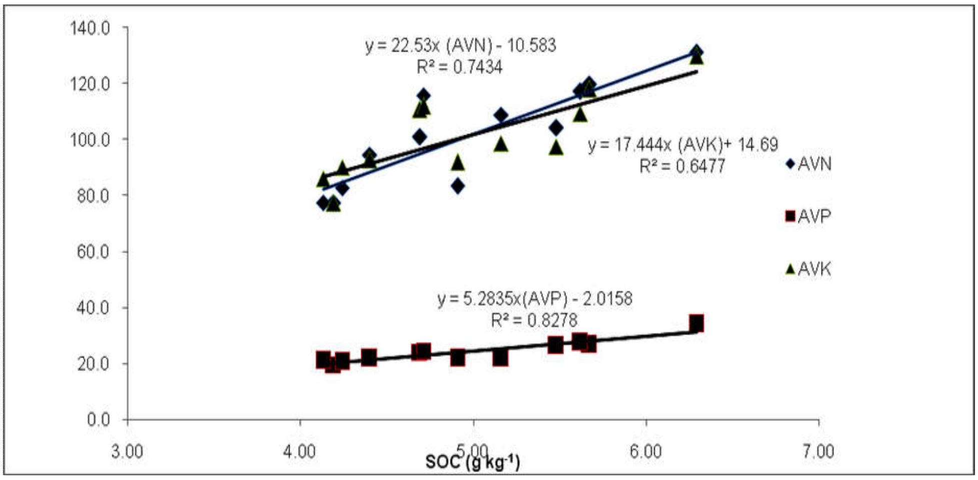

Fig. 7 Regression analysis of assayed variables at surface soil layer
SOC-Soil organic carbon, AVN-Available nitrogen, AVP-Available phosphorus, AVK-Available potassium

CONCLUSIONS

Results from this 5-year study showed that integration of GM and partial retention of wheat straw in conventional puddled transplanted rice (PTR_{W25}+GM) followed by zero till wheat seeded into rice residue (ZTW_{R100}) increased organic carbon , N , P and K content in surface soil layer by 50.1%, 69.3%, 75.2% and 67.9%, respectively. Principal component analysis clearly distinguished PTR_{w25}+GM amended treatment and ZTW from PTR_{w0}-non GM treatment and CTW. It suggest that soil variables *viz*. SOC, AVN, AVP and AVK can clearly distinguish sustainable management practices from unsustainable practices in rice-wheat system. The results of the present study will hopefully support the scientific evidence that, rice-wheat system can be more sustainable when using conservation management techniques than the conventional practices. Besides above benefits of tillage, residue retention and green manuring on gradual improvement in soil chemical properties, it would overcome the ill effects of residue burning on soil and environment.

ACKNOWLEDGMENTS

Thanks are due to the Head, Department of Soil Science, Punjab Agricultural University for providing necessary laboratory and field facilities.

REFERENCES

1. Chauhan, B.S., Mahajan, G., Sardana, V., Timsina, J., Jat, M.L., (2012). Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, opportunities, and strategies. Advances in Agronomy 117, 316-355.

2. Das, A., Ghosh, P.K., Lal, R., Saha, R., Ngachan, S., (2014). Soil quality effect of conservation practices in maize-rapeseed cropping system in eastern Himalaya. Land Degradation and Development DOI: 10.1002/ldr.2325.
3. DeBusk, W.F., White, J.R., Reddy, K.R., (2001). Carbon and nitrogen dynamics in wetland soils. In: Shaffer, M, J., Ma, L., Hansen, S. (Eds) Modeling Carbon and Nitrogen Dynamics for Soil Management, CRC Press, Boca Raton, 27–53.
4. Dikgwatlhe, S.B., Chen, Z.D., Lal, R., Zhang, H., Chen, F., (2014). Changes in soil organic carbon and nitrogen as affected by tillage and residue management under wheat-maize cropping system in the North China Plain. Soil and Tillage Research 144, 110-118.
5. Dobermann, A., Fairhurst, T.H., (2002). Rice Straw Management. Better Crops International 16, 7-11.
6. Follett, R.F., 2001. Soil management concepts and carbon sequestration in cropland soils. Soil and Tillage Research 61, 77–92.
7. Gathala M.K., Kumar, V., Sharma, P.C., Saharawat, Y.S., Jat, H.S., Singh, M., Kumar, A., Jat, M.L., Humphreys, E., Sharma, D.K., Sharma, S., Ladha, J.K., (2013). Optimizing intensive cereal- based cropping systems addressing current and future drivers of agricultural change in the north western Indo-Gangetic Plains of India. Agriculture, Ecosystems and Environment 177, 85-97.
8. Gupta R, Seth A (2007) A review of resource conserving technologies for sustainable management of the rice-wheat cropping systems of the Indo-Gangetic plains (IGP). Crop Protection 26, 436-447.
9. Habtegebrial, K., Singh, B.R., Haile, M., (2007). Impact of tillage and nitrogen fertilization on yield, nitrogen use efficiency of tef (*Eragrostis tef (Zucc.) Trotter*) and soil properties. Soil and Tillage Research 94, 55-63.
10. Heidari, G., Mohammadi, K., Sohrabi, Y., (2016). Responses of soil microbial biomass and enzyme activities to tillage and fertilization systems in soybean (*Glycine max L.*) production. Frontiers in Plant Science 7, doi: 10.3389/fpls.2016.01730.
11. Henriksen, T., Breland, T., (2002). Carbon mineralization, fungal and bacterial growth, and enzyme activities as affected by contact between crop residues and soil. Biology and Fertility of Soils 35, 41-48.
12. International Rice Research Institute (IRRI), (2000). IRRISTAT for window (CD-ROM) version 4.02b. IRRI, Los Ban˜os.
13. Jackson, M.L., (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd, New Delhi.
14. Jat, M.L, Dagar, J.C, Sapkota, T.B., Yadvinder-Singh., Govaerts, B., Ridaura, S,L., Saharawat, Y.S., Sharma, R.K., Tetarwal, J.P., Jat, R.K., Hobbs, H., Stirling, C., (2016). Climate change and agriculture: adaptation strategies and mitigation opportunities for food security in south Asia and Latin America. Advances in Agronomy, DOI: 10.1016/bs.agron.2015.12.005.
15. Kaur M, Aggarwal NK, Kumar V, Dhiman R (2014) Effects and management of *Parthenium hysterophorus*: A weed of global significance. International Scholarly Research Notices, doi: 10.1155/2014/368647.
16. Kumar, S., Patra, A.K., Singh, D., Purakayastha, T.J., (2014). Long-term chemical fertilization along with farmyard manure enhances resistance and resilience of soil microbial activity against heat stress. Journal of Agronomy and Crop Science 200, 156-162.
17. Kushwah, S.S., Reddy, D.D., Somasundaram, J., Srivastava, S., Khamparia, R.S., (2016). Crop residue retention and nutrient management practices on stratification of phosphorus and soil organic carbon in the soybean-wheat system in Vertisols of Central India. Communication in Soil Science and Plant Analysis 47, 2387-2395.
18. Martinez, E., Fuentes, J.P., Pino, V., Silva, P., Acevedo, E., (2013). Chemical and biological properties as affected by no tillage and conventional tillage systems in an irrigated Haploxeroll of Central Chile. Soil and Tillage Research 126, 238-245.
19. Monsefi, A., Sharma, A.R., Zan, N.R., Behera, U.K., Das, T.K., (2014). Effect of tillage and residue management on productivity of soybean and physico-chemical properties of soil in soybean-wheat cropping system. International Journal of Plant Production 8, 429-440.
20. Nagar, R.K., Goud, V.V., Kumar, R., Kumar, R., (2016). Effect of organic manures and crop residue management on physical, chemical and biological properties of soil under pigeon pea based intercropping system. International Journal of Farm Science 6, 101-113.
21. Nivelle, E., Verzeaux, J., Habbib, H., Kuzyakov, Y., Decocq, G., Roger, D., Lacoux, J., Duclercq, J., Spicher, F., Nava-Saucedo, J., Catterou, M., Dubois, F., Tetu, T., (2016). Functional response of soil microbial communities to tillage, cover crops and nitrogen fertilization. Applied Soil Ecology 108, 147-155.
22. Olsen, S.R., Cole, C.V., Waternabe, F.S., Dean, L.A., (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. United State Department of Agriculture Circular, 939.
23. Roldan, A., Caravaca, F., Hernandez, M.T., Garcia, C., Sánchez-Brito, C., Velasquez, M., Tiscareno, M., (2003). No-tillage, crop residue additions, and legume cover cropping effects on soil quality characteristics under maize in Patzcuaro watershed (Mexico). Soil and Tillage Research 72, 65-73.
24. Salinas-Garcia, J.R., Velazquez-Garcia, J.J., Gallardo-Valdez, M., Diaz-Mederos, P., Caballero-Hernandez, F., Tapia-Vargas, L.M., Rosales-Robles, E., (2002). Tillage effects on microbial and nutrient distribution in soils under rain-fed corn production in central-western Mexico. Soil and Tillage Research 66, 143-152.
25. Sidhu, H.S., Manpreet-Singh., Humphreys, E., Yadvinder-Singh., Balwinder-Singh., Dhillon, S.S., Blackwell, J., Bector, V., Malkeet-Singh., Sarbjeet-Singh., (2007). The Happy Seeder enables direct drilling of wheat into rice stubble. Australian Journal of Experimental Agriculture 47, 844-854.
26. Singh, S.S., Singh, A.K, Sundaram, P.K., (2014). Agro technological options for up scaling agricultural productivity in eastern indo gangetic plains under impending climate change situations: A review. Journal of AgriSearch 1(2), 55-65.

27. Smith, J,L., Papendick, R.I., Bezdicek, D.F., Lynch, J.M., (1993). Soil organic dynamics and crop residue management. In: Metting, F.B. Jr. (Ed) Soil Microbial Ecology. Marcel Dekker Inc, New York, 65–94.
28. Srinivasan, V., Maheswarappa, H.P., Lal, R., (2012). Long term effects of topsoil depth and amendments on particulate and non particulate carbon fractions in a Miamian soil of Central Ohio. Soil and Tillage Research 121, 10-17.
29. Summerell, B.A., Burgess, L.W., (1989). Factors influencing survival of *Pyrenophora Tritici-repentis:* Stubble management. Mycological Research 93, 38-40.
30. Syswerda, S.P., Corbin, A.T., Mokma., D.L., Kravchenko, A.N., Robertson, G.P., (2011). Agricultural management and soil carbon storage in surface vs. deep layers. Soil Science Society of America Journal 75, 92-101.
31. Tamilselvi, S.M., Chinnadurai, C., Ilamurugua, K., Arulmozhiselvan, K., Balachandar, D., (2015). Effect of long-term nutrient managements on biological and biochemical properties of semi-arid tropical Alfisol during maize crop development stages. Ecological Indicators 48, 76-87.
32. Villamil, M.B., Nafziger, E.D., (2015). Corn residue, tillage and nitrogen rate effects on soil carbon and nutrient stocks in Illinois. Geoderma 253, 61-66.
33. Walkley, A., Black, C.A., (1934). An examination of the Degtjareff method for determination of soil organic matter and a proposed modification of chromic acid titration method. Soil Science 37, 29-39.
34. Wei, T., Zhang, P., Wang, K., Ding, R., Yang, B., Nie, J., Han, Q., (2015). Effects of wheat straw on the availability of soil nutrients and enzyme activities in semiarid areas. Plos One 10, doi:10.1371/journal.prone.0120994.
35. Wold, A., Esbensen, K., Gelada, P., (1987). Principal Component Analysis. Chemometrics and Intelligent Laboratory Systems 2, 37-52.
36. Yadvinder-Singh., Bijay-Singh., Ladha, J.K., Khind, C.S., Khera, T.S., Bueno, C.S., (2004). Effect of residue decomposition on productivity and soil fertility in rice-wheat rotation. Soil Science Society of America Journal 68, 854-864.
37. Yadvinder-Singh., Sidhu, H.S., (2014). Management of cereal crop residues for sustainable rice- wheat production system in the Indo-Gangetic plains of India. Proceedings of the Indian National Science Academy 80, 95-114.
38. Yadvinder-Singh., Thind, H.S., Sidhu, H.S., (2014). Management options for rice residues for sustainable productivity of rice-wheat cropping system. Journal of Research Punjab Agricultural University 51, 209-220.
39. Zhang, Y., Zang, G.Q., Tang, Z.H., Chen, X.H., Yu, Y.S., (2014). Burning straw, air pollution, and respiratory infections in China. American Journal of Infection Control 42, 81-87.

CITATION OF THIS ARTICLE

Rituparna Saikia. Sandeep Sharma . H S Thind. Neemisha. Periodic Soil Chemical Changes in Wheat under Tillage, Residue Management and Green Manure in Rice-Wheat System in North-West India . Bull. Env. Pharmacol. Life Sci., Vol 6[10] September 2017: 93-101