Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.5657

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (4):** 1337-1344 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Influence of Long-Term Application of Different Organics on Soil Physico-Chemical Properties

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Received: 2.07.2017 | Revised: 11.07.2017 | Accepted: 12.07.2017

ABSTRACT

Studying the dynamics of soil organic carbon (SOC) is important for understanding the C stabilization into different pools. Carbon sequestration in soils has the potential to curb global warming besides maintaining sustainability of agricultural system under tropical and subtropical climate. Thus, a 28-year old experiment was used to assess the impact of rice-wheat cropping system with manuring and grades of fertilization on some soil properties and crop yield sustainability in an Inceptisol in India. There was significant decrease ($p<0.05$) in bulk density with increasing using organics over control. The oxidizable organic C content varied from 2.7 to 9.9 g kg^{-1} among the treatments with a decreasing trend with 50% RDF+FYM (9.9 g kg^{-1}) > 75% RDF+FYM (8.8 g kg^{-1}) > 50% RDF+GM (8.6 g kg^{-1}) > 50%RDF+PS (8.3 g kg^{-1}) > 75%RDF+FYM (8.1 g kg^{-1}) > 75% RDF+PS (7.9 g kg^{-1}) > RDF (7.5 g kg^{-1}) > Control (6.8 g kg^{-1}) treatments at 0-15 cm soil depth. Organic carbon was significantly correlated with yields of rice (r=0.74) and wheat (r=0.71*). On the other hand organic carbon showed significant correlation with SYI of rice (r=0.77*) and wheat (=0.71*). Hence we can conclude that soil organic carbon can maintain sustainable yields by maintaining good soil structure and health.*

Key words: *Organic carbon, pH, Critical carbon Input, Yield*

INTRODUCTION

Soil organic carbon (SOC) is one of the most important components in soil that contributes positively to soil fertility, soil tilth, crop production, and overall soil sustainability[1,2]. Since soil is the major reservoir of terrestrial C any attempt to enrich this reservoir through sequestration of atmospheric C will help to manage global warming and achieve global food security to a great extent. Crop cultivation is known to adversely affect the distribution and stability of soil aggregates and reduces SOC stock in soils[3]. The impacts of cultivation on C stock have commonly been observed to be restricted mostly to surface soils and/or to root zone depth[4].

Cite this article: Chaitanya, A.K., Mandal, B., Hazra, G.C., Bandyopadhyay, P.K. and Pramanik, M., Influence of Long-Term Application of Different Organics on Soil Physico-Chemical Properties, *Int. J. Pure App. Biosci.* **5(4):** 1337-1344 (2017). doi: http://dx.doi.org/10.18782/2320-7051.5657

Altering soil physico-chemical properties by management practices may increase one or more of the protective attributes which ultimately increases C in soils provided C inputs to soil do not decrease. Intensive cultivation of crops with inputs like fertilizers, organics and chemicals, water, tillage which are used to increase economic yield of crops, also may normally be expected to result in build up of C stock in soils[5]. Aboveground and belowground C may be a major source for SOC accumulation in soils. However, there is a lack of information on quantification of the mass of belowground residue C produced by plant roots from various crops under fallow and cultivated land management systems in the subtropical India. Crop species play important roles in C sequestration because their residues vary in quantity and quality (e.g. lignin, phenolic content, C/N), which affect their decomposition and turnover rates in soil[6]. In contrast, numerous reports show that C stock in soils has declined with intensive cultivation using modern inputs[7,8]. In fact, the magnitude of decline or enhancement of SOC due to continuous cultivation depends on the balance between the loss of C by oxidative forces of tillage operation and the quantity and quality of crop residues that are returned and organics added to the soils. The loss of C is enormous in tropical and sub-tropical regions because of high atmospheric temperature[8].

Therefore, the hypothesis set out for the study was to study the changes of physic chemical properties, carbon sequestration potential and economic aspects of different nutrient management practices.

MATERIALS AND METHODS

Site description

The long-term experiment was started in1986 with rice-wheat cropping system at the Mandouri Teaching Farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal (23° 40’ latitude, 89° 52’ longitude and 9.5 m above mean sea level). The climate is hot, humid subtropics with an average annual rainfall of approximately 1480 mm and mean annual minimum and maximum temperatures of 12.5 and 36.2ºC, respectively. The soil is hyperthermic (AericHaplaquept, US Soil Taxonomy, Soil Survey Staff, 2003).

Rice (*Oryza sativa* L) and wheat (*Triticum aestivum* L) are annually grown under irrigated conditions. The varieties IET 4094 (IET 1444 upto 1997) for rice and UP-262 (Sonalika up to 1994) for wheat were used for the experiment. The experiment was laid out in randomized block design (RBD) with three replications and consisted of the following treatments: (i) control (plots without NPK fertilizers and organics), (ii) RDF (recommended), (iii) 50% RDF + farmyard manure (FYM-7.5 t ha^{-1}), (iv) 75% RDF+ FYM (3.75 t ha^{-1}), (v) 50% RDF+ paddy straw (PS-10 t ha^{-1}), (vi) 75% RDF+ PS (5 t ha^{-1}), (vii) 50% RDF+ green manure (GM-8 t ha^{-1}) and (viii) 75% RDF+ GM (4 t ha^{-1}). Standard crop management practices were followed in both the crops. Requisite amount of well decomposed FYM (7.5 Mg ha^{-1}) were manually spread uniformly on the surface of the specified plots (size: 8 m×8 m) 7 days before puddling for rice crop.

Soil analysis

The pH of the soil was determined in 1: 2.5:: soil : water and soil : 0.02 M $CaCl_2$ suspension by using digital pH meter[9]. Electrical conductivity (EC) of soil-water suspension (1: 2.5) was estimated with the help of a direct reading conductivity meter (Model: systronics, 363) outlined by Jackson[9]. Bulk density was determined by core sampler (5.0 cm length and 5.0 cm diameter) method following the protocol of Blake and Hartge[10]. Soil organic carbon was determined by using rapid titration method (wet combustion method) as described by Walkley and Black[11].

Carbon Input

The cumulative C input values for the studied cropping systems were computed using harvested yield data for the last 28 years (1986–2013). Empirical equations were used to estimate crop residue-derived C inputs.Stubble biomass and rhizodeposition C of rice, was assumed to be 2.5 and 15% of total above ground biomass at maturity and root biomass assumed as 19 and 14 % of total above ground biomass for control and other fertilized treatments, respectively[12]. The total biomass yield of roots, stubble and rhizodeposition of wheat were computed as 22.0, 3.0 and 12.6%, respectively of the total above ground biomass harvested at maturity[12,13]. The extra C input through photosynthetic aquatic organism with rice was also accounted for following Saito and Watanabe[14].

The data were analysed using randomized block design (RBD). Statistical analysis was performed by DOS-based SPSS version 17.0. The SPSS procedure was used for analysis of variance (ANOVA) to determine the statistical significance of treatments. The 5.0% probability level is regarded as statistically significant.

RESULTS AND DISCUSSION

Soil physical and chemical properties

Depth-wise and treatment-wise changes in some important basic physical and chemical properties of the soils under different treatments are presented in Table 1. Soils under the present experiment were slightly alkaline in reaction with pH_w and pH_{ca} ranging from 7.5 to 7.9 and 6.8 to 7.3, respectively. Results showed that soil pH_w and pH_{Ca} increased insignificantly with depth in all the treatments excepting 75% RDF+GM which showed significant decrease both in pH_w and pH_{ca}, while RDF treatment showed significant decrease only in pH_w. The lowest (6.8) and highest (7.3) pH_{ca} were observed at surface soil under RDF and at 30-45 cm layer under 50% RDF+GM, respectively. The pH of the soils was lower in all the treatments, irrespective of depth, when measured in 0.02M $CaCl_2$ solution (pH_{Ca}). On an average, pH_{Ca} was about 0.69 units less than that of the pH_w irrespective of treatments and depths.

The bulk density values of the soils under different treatments varied from 1.19 to 1.41 Mg m^{-3} (Table 1), irrespective of soil depth. The 50% RDF+FYM treatment had the lowest bulk density value at all of the depths and the values were 1.19, 1.22 and 1.29 Mg m^{-3} at 0-15, 15-30 and 30-45 cm soil depth, respectively. With depth, bulk density increased significantly in the control and RDF treatments, in other treatments 30-45 cm layer showed significantly higher values than 0-15 and 15-30 cm layers.

The oxidizable organic C content varied from 2.7 to 9.9 g kg^{-1} among the treatments with a decreasing trend with 50% RDF+FYM (9.9 g kg^{-1}) > 75% RDF+FYM (8.8 g kg^{-1}) > 50% RDF+GM (8.6 g kg^{-1}) > 50%RDF+PS (8.3 g kg^{-1}) > 75%RDF+FYM (8.1 g kg^{-1}) > 75% RDF+PS (7.9 g kg^{-1}) > RDF (7.5 g kg^{-1}) > Control (6.8 g kg^{-1}) treatments at 0-15 cm soil depth (Table 1). The oxidizable organic C content decreased significantly with depth in all the treatments, excepting RDF, 75% RDF+FYM and 75% RDF+PS which showed significant higher values in surface soil compared to sub surface ones.

Yield and carbon inputs

Results from the yield data showed that the yields were significantly increased with the application of different inorganic and organic inputs (RDF+FYM) as compared to control. The crop productivity was calculated through sustainable yield index (SYI) using yield data of 28 years, to offset annual variation in the yield and to highlight treatment impact over the years (Table 3). The annual C input value was higher in 50% RDF+FYM treatment (3.64 Mg ha^{-1}) as compared to the others. Balanced fertilization with organics has improved crop yields, subsequently contributed the highest amount of C inputs into the soils. This was supported by the existence of a significant positive correlation between them (R^2=0.99; $P \leq 0.01$). Similar relationship between crop yield and associated annual C inputs added into soils have also been reported by others[12, 13, 15, 16, 17]. Cultivation with or without inorganics (RDF and control) produced 1.25 and 2.3 fold lower annual C inputs, respectively than 50% RDF+FYM treatment (Table 2). The quantity of rhizodeposition, root biomass and stubble biomass were higher in RDF+FYM than any other treatment (Fig 1).

Relationships:

Cumulative carbon input was negatively correlated (r= -0.69) with bulk density. Bulk density has negative correlation with all other parameters like amount of organic carbon (-0.89), grain yield of rice (-0.60), SYI (-0.60), grain yield of wheat (-0.59), SYI (-0.58). Grain yield of rice was significantly correlated with organic carbon (=0.74*) where as grain yield of wheat was positively correlated at r= 0.69. Organic carbon was significantly correlated with yields of rice (r=0.74*) and wheat (r=0.71*). On the other hand organic carbon showed significant correlation with SYI of rice (r=0.77*) and wheat (=0.71*). Hence we can conclude that soil organic carbon can maintain sustainable yields by maintaining good soil structure and health.

Table 1: Some important physical and chemical properties of the experimental soils

Treatment	Depth (cm)	pH_w	pH_{ca}	ΔpH	BD ($Mg\ m^{-3}$)	OC ($g\ kg^{-1}$)
Control	0-15	$7.74^{a\ A}$	$6.87^{b\ B}$	$0.87^{a\ A}$	$1.28^{c\ A}$	$6.75^{a\ E}$
	15-30	$7.78^{a\ A}$	$6.96^{b\ B}$	$0.82^{ab\ A}$	$1.35^{b\ A}$	$3.60^{b\ C}$
	30-45	$7.82^{a\ AB}$	$7.11^{a\ C}$	$0.71^{b\ AB}$	$1.41^{a\ A}$	$2.70^{c\ D}$
RDF	0-15	$7.74^{c\ A}$	$6.83^{b\ B}$	$0.91^{a\ A}$	$1.26^{c\ AB}$	$7.50^{a\ DE}$
	15-30	$7.79^{b\ A}$	$6.97^{ab\ B}$	$0.82^{ab\ A}$	$1.33^{b\ A}$	$3.60^{b\ C}$
	30-45	$7.82^{a\ AB}$	$7.12^{a\ C}$	$0.70^{b\ AB}$	$1.37^{a\ B}$	$3.33^{b\ AB}$
50%RDF+FYM	0-15	$7.50^{a\ B}$	$7.13^{b\ A}$	$0.37^{a\ B}$	$1.19^{b\ D}$	$9.87^{a\ A}$
	15-30	$7.63^{a\ A}$	$7.21^{ab\ A}$	$0.42^{a\ B}$	$1.22^{b\ D}$	$5.00^{b\ A}$
	30-45	$7.77^{a\ B}$	$7.26^{a\ AB}$	$0.51^{a\ C}$	$1.29^{a\ E}$	$3.37^{c\ AB}$
75%RDF+FYM	0-15	$7.72^{b\ A}$	$6.97^{b\ B}$	$0.75^{a\ A}$	$1.24^{b\ BC}$	$8.77^{a\ B}$
	15-30	$7.83^{a\ A}$	$6.99^{b\ B}$	$0.84^{a\ A}$	$1.25^{b\ CD}$	$4.00^{b\ BC}$
	30-45	$7.88^{a\ AB}$	$7.08^{a\ C}$	$0.80^{a\ A}$	$1.32^{a\ DE}$	$3.60^{b\ A}$
50%RDF+PS	0-15	$7.81^{b\ A}$	$7.12^{a\ A}$	$0.69^{a\ A}$	$1.22^{b\ C}$	$8.30^{a\ BCD}$
	15-30	$7.83^{a\ A}$	$7.21^{a\ A}$	$0.62^{a\ AB}$	$1.25^{b\ BC}$	3.97^{bBC}
	30-45	$7.92^{a\ A}$	$7.27^{a\ AB}$	$0.64^{a\ ABC}$	$1.36^{a\ BC}$	$2.87^{c\ CD}$
75%RDF+PS	0-15	$7.74^{a\ A}$	$6.93^{b\ B}$	0.81^{aA}	$1.26^{b\ AB}$	$7.90^{a\ CD}$
	15-30	$7.75^{a\ A}$	$6.95^{b\ B}$	$0.80^{a\ A}$	$1.29^{b\ B}$	$3.73^{b\ C}$
	30-45	$7.77^{a\ B}$	$7.17^{a\ BC}$	$0.60^{b\ BC}$	$1.33^{a\ CD}$	$3.30^{b\ AB}$
50%RDF+GM	0-15	$7.77^{b\ A}$	$7.13^{b\ A}$	$0.64^{a\ A}$	$1.25^{b\ BC}$	$8.63^{a\ BC}$
	15-30	7.79^{abA}	$7.19^{ab\ A}$	$0.61^{a\ AB}$	$1.27^{b\ BC}$	$4.30^{b\ B}$
	30-45	$7.83^{a\ AB}$	$7.31^{a\ A}$	$0.52^{a\ C}$	$1.35^{a\ BCD}$	$2.83^{c\ CD}$
75%RDF+GM	0-15	$7.71^{c\ A}$	$6.90^{c\ B}$	$0.82^{a\ A}$	$1.26^{b\ AB}$	$8.10^{a\ BCD}$
	15-30	$7.77^{b\ A}$	$7.09^{b\ B}$	$0.68^{b\ A}$	$1.27^{b\ BC}$	$3.60^{b\ C}$
	30-45	$7.84^{a\ AB}$	$7.26^{a\ AB}$	$0.58^{c\ BC}$	$1.34^{a\ BCD}$	$3.17^{c\ BC}$

(BD=bulk density, OC= oxidizable organic carbon) Values with different upper case (A–C) and lower case (a–c) superscript letters are significantly different between treatments for each soil layer and between soil layers for each treatment, respectively, at $P < 0.05$ (Duncan multiple range tests for separation of mean).

Table 2: Annual C input (Mg ha^{-1}) returned to soil under rice-wheat cropping system

	Rice				Wheat				
Treatment	Stubble biomass C	Root biomass C	Rhizo-deposited C	Aquatic biomass C	Stubble biomass C	Root biomass C	Rhizo-deposited C	Organic amendment C	Annual C inputs
Control	0.03	0.27	0.22	0.70	0.03	0.21	0.12	-	1.58
RDF	0.07	0.49	0.53	0.70	0.08	0.66	0.38	-	2.91
50%RDF+FYM	0.07	0.52	0.56	0.70	0.09	0.70	0.40	0.60	3.64
75%RDF+FYM	0.07	0.52	0.56	0.70	0.07	0.61	0.35	0.30	3.18
50%RDF+PS	0.07	0.51	0.55	0.70	0.08	0.69	0.39	0.68	3.68
75%RDF+PS	0.07	0.50	0.54	0.70	0.08	0.63	0.36	0.34	3.23
50%RDF+GM	0.07	0.52	0.56	0.70	0.09	0.72	0.41	0.60	3.68
75%RDF+GM	0.07	0.52	0.56	0.70	0.08	0.62	0.35	0.30	3.20

Table 3: Mean seasonal grain yield (Mg ha^{-1}) and sustainable yield index (SYI) of the system under different treatments

Treatment	Rice	SYI	Wheat	SYI	Productivity	SYI
Control	1.35 ^{g}	0.52^{c}	0.86 ^{f}	0.33^{d}	2.2^{f}	0.58^{c}
100% RDF	3.56 ^{f}	0.68^{ab}	2.90 ^{e}	0.56^{ab}	6.4^{e}	0.65^{ab}
50 % RDF +FYM	3.94 ^{a}	0.72^{a}	3.12 ^{c}	0.58^{a}	7.0^{a}	0.68^{a}
75% RDF+FYM	3.70 ^{cd}	0.68^{ab}	2.91 ^{de}	0.54^{bc}	6.5^{d}	0.64^{ab}
50% RDF +PS	3.73 ^{bc}	0.67^{ab}	3.27 ^{a}	0.52^{bc}	6.9^{b}	0.61^{bc}
75% RDF+PS	3.62 ^{e}	0.63^{b}	2.95 ^{d}	0.55^{abc}	6.5^{d}	0.63^{b}
50% RDF +GM	3.75 ^{b}	0.70^{a}	3.17 ^{b}	0.55^{abc}	6.8^{c}	0.65ab
75% RDF +GM	3.69 ^{d}	0.71^{a}	2.91 ^{de}	0.51^{b}	6.5^{d}	0.62bc

Different small letters within the same column show the significant difference at p = 0.05 according to Duncan Multiple Range Test for separation of mean

Table 4: Correlation coefficients (r) values between Critical carbon input, organic carbon, yield, bulk density and SYI

	BD	OC	CCI	$Yield_{rice}$	SYI	$Yield_{wheat}$	SYI
BD	1.00	-0.89**	-0.69	-0.60	-0.61	-0.59	-0.58
OC	-0.89**	1.00	0.79*	0.74*	0.77*	0.69	0.71*
CCI	-0.69	0.79*	1.00	0.94**	0.87**	0.96**	0.88**
$Yield_{rice}$	-0.60	0.74*	0.94**	1.00	0.93**	0.99**	0.97**
SYI	-0.61	0.77*	0.87**	0.93**	1.00	0.90**	0.88**
$Yield_{wheat}$	-0.59	0.69	0.96**	0.99**	0.90**	1.00	0.95**
SYI	-0.58	0.71*	0.88**	0.96**	0.88**	0.95**	1.00

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

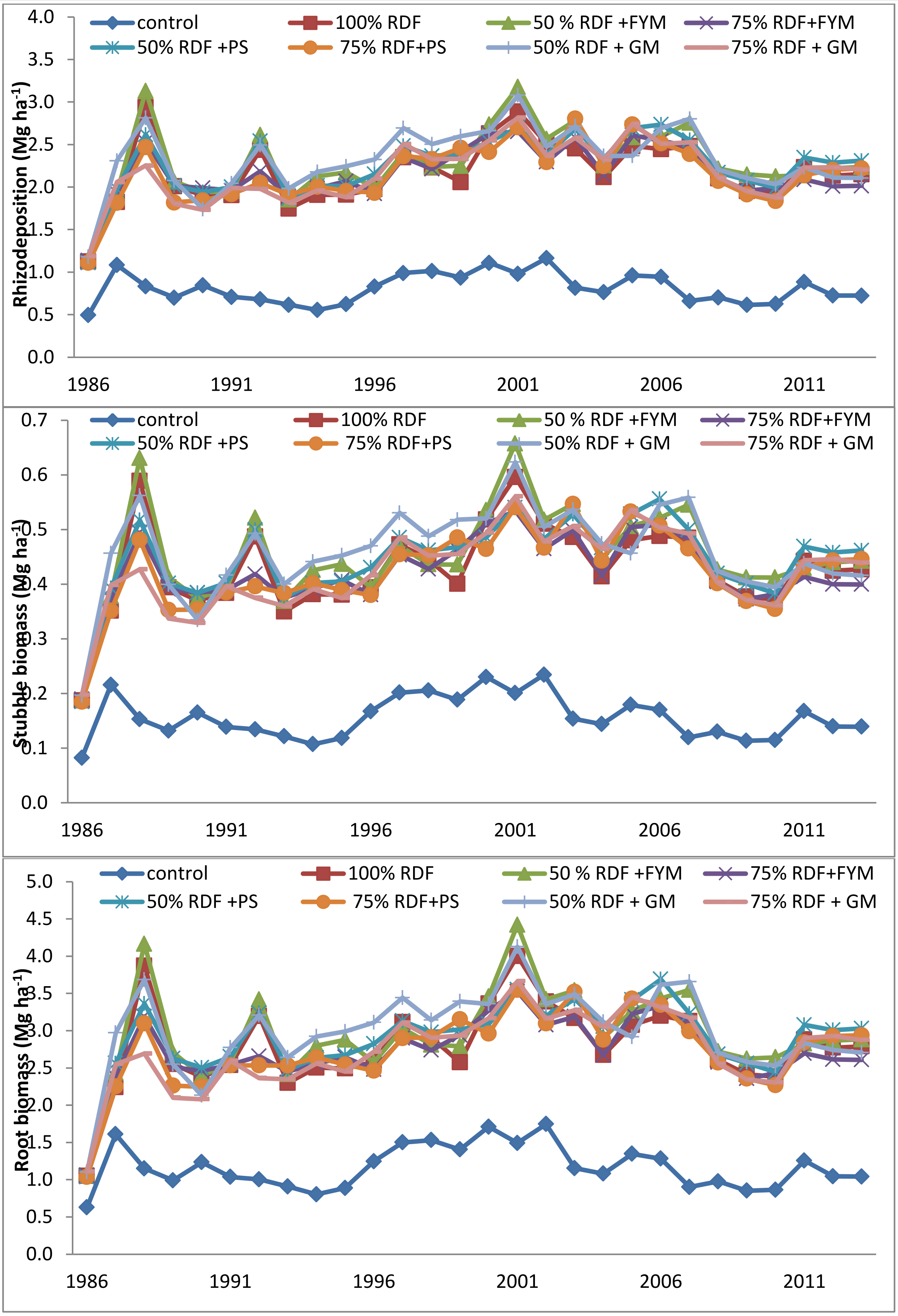

Fig. 1: Amount of crop residue (rhizodeposition, root and stubble) returned to the soil under different treatments

CONCLUSION

Soil pH_w and pH_{Ca} increased insignificantly with depth in all the treatments excepting 75% RDF+GM which showed significant decrease both in pH_w and pH_{ca}, while RDF treatment showed significant decrease only in pH_w. The lowest (6.8) and highest (7.3) pH_{ca} were observed at surface soil under RDF and at 30-45 cm layer under 50% RDF+GM, respectively. The 50% RDF+FYM treatment had the lowest bulk density value at all of the depths and the values were 1.19, 1.22 and 1.29 Mg m^{-3} at 0-15, 15-30 and 30-45 cm soil depth, respectively. Organic carbon was significantly correlated with yields of rice (r=0.74*) and wheat (r=0.71*). On the other hand organic carbon showed significant correlation with SYI of rice (r=0.77*) and wheat (=0.71*). Hence we can conclude that soil organic carbon can maintain sustainable yields by maintaining good soil structure and health.

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