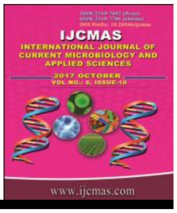
Int.J.Curr.Microbiol.App.Sci (2017) *6*(10): 349-357

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 6 Number 10 (2017) pp. 349-357**
Journal homepage: http://www.ijcmas.com



Original Research Article

https://doi.org/10.20546/ijcmas.2017.610.043

Soil Aggregation, Carbon and Nitrogen Stabilization in Relation to Application of Different Soil Organic Amendments in Aerobically Grown Basmati Rice and their Residual Effect on the Productivity of Wheat in Rice–Wheat System under Shiwalik Foothills of Jammu and Kashmir, India

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ABSTRACT

Keywords

Aerobic rice, Organic amendments, Productivity, Rice–wheat cropping, Water stable aggregates.

Article Info

Accepted:
04 September 2017
Available Online:
10 October 2017

Sustainability of the rice–wheat rotation is important to Asia's food security. Intensive cropping with no return of organic materials results in loss of soil organic matter and is not sustainable. We studied the impact of application of green manure crop like *dhaincha* (*Sesbania aculeata*), vermicompost and farmyard manure (FYM) in conjunction with inorganic fertilizers on aggregate stability, distribution of organic carbon (C), available nitrogen (N) and productivity of succeeding wheat in aerobically grown basmati rice in rice–wheat cropping on a sandy loam soil. Macroaggregates (0.25 mm) constituted 20–30% of total water stable aggregates (WSA) and were linearly related (R2 = 0.69) to soil organic carbon content. The incorporation of *dhaincha* and FYM significantly improved the formation of macroaggregates with a simultaneous decrease in the proportion of microaggregates at all the sampling depths (0–5, 5-10 and 10–15 cm). Macroaggregates had higher C and N density as compared to microaggregates and the improvement was greatest in plots that received both *dhaincha* and FYM each year this will help in sustainable rice – wheat productivity in the region.

Introduction

Rice–wheat cropping system occupies around 13.5 Mha in the Indo-Gangetic Plains (IGP) of Bangladesh, India, Nepal and Pakistan. The cropping system has contributed substantially towards food-grain production and its sustainability is of utmost importance for ensuring regional food security. In the Indian state of Jammu & Kashmir, rice–wheat is a major cropping system occupying an area of 2.56 lakh ha. In rice–wheat cropping system, puddling the soil for rice growing damages the soil structure and affects the physical and hydraulic properties of the soil (Meelu *et al.*, 1979). Yaduvanshi (2001) and Khan *et al.*, (1986) have reported that continuous cropping of rice–wheat with inorganic fertilizers has decreased the organic carbon content of the soil. Aggregate stability is a keystone factor in questions of soil physical fertility and can be enhanced by means of an appropriate management of organic amendments, which can maintain an appropriate soil structure. This agronomic procedure could improve pore space suitable for gas exchange, water retention, root growth and microbial activity (Van-Camp *et al.,* 2004). Satisfying soil organic carbon (SOC) is of primary importance in terms of cycling plant nutrients and improving the soils in long-term soil conservation and/or restoration by sustaining its fertility, and hence in sustainable agricultural production, due to the improvement of physical, chemical and biological properties of soils (Sequi, 1989).

The stagnating or declining crop yields has been attributed to depletion of soil C and N and decreased soil fertility (Bhandari *et al.*, 2002; Ladha *et al.*, 2003; Regmi *et al.*, 2002). For maintaining the productive potential of the rice–wheat cropping systems it is imperative to improve soil C and N storage and the structural status of soil that is crucial for controlling microbial activity (Ladd *et al.*, 1977). One of the options is the input of C through addition of organic manures like green manuring (*dhaincha*), mulching with leguminous plant material (*dhaincha*), vermicompost and farm yard manure besides improving the water holding capacity as well as its retention for longer duration in the soil. Incorporation of green manures in the soil besides bringing the essential organic C and N back to the field could favourably impact soil structural status. It is known that addition of organic manure improves soil aggregation and aggregate stability (Aoyama *et al.*, 1999; Benbi *et al.*, 1998; Christensen 1986; Smith and Elliott 1990; Yang *et al.,* 2005). However, the effect of different organic amendments incorporation on aggregate formation depends on soil texture. While the number of macroaggregates and SOM increased with residue input in a loamy sand soil. The present study was undertaken to assess the magnitudes of change in organic carbon content, soil aggregation, available nitrogen and productivity of wheat with the applications of green manure (*dhaincha*), vermicompost and farmyard manure in rice–wheat cropping system.

Materials and Methods

The experiment was conducted at the Research Farm, Main Campus, Chatha of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during *kharif* 2012 to *rabi* 2013-14 on a sandy loam soil (60.2 % sand and 17.5% clay; Typic Ustorthents) with an annual rice–wheat cropping rotation. At the start of the experiment, the field soil (0–15 cm) tested 7.27 in pH (1:2.5 soil: water suspension), 0.10 dS m^{-1} in electrical conductivity (1:2.5 soil water supernatant) and 4.8 g kg^{-1} in soil organic C. The treatments included four basmati cultivars namely Basmati-370, Basmati-564,Saanwal basmati and Ranbir basmati in main plots and soil organic amendments including control *viz.*T_1 : Control (recommended fertilizer dose), T_2 : *In-situ* green manuring of *dhaincha* (*Sesbania aculeata*) on N-basis, T_3 : *In-situ* green manuring of *dhaincha* followed by application of vermicompost on N-basis (1:1), T_4 : *In-situ* green manuring of *dhaincha* followed by application of vermicompost and mulching with *dhaincha* on N-basis (1:1:1), T_5: *In-situ* green manuring of *dhaincha* followed by application of FYM on N-basis (1:1) and T_6 : *In-situ* green manuring of *dhaincha* followed by application of FYM and mulching with *dhaincha* on N-basis (1:1:1) as sub-plot treatments. A seed rate of 60 kg/ha was used for sowing of *dhaincha*. For *in-situ dhaincha*, seed rate was worked out keeping in view the size of the plots of experimental treatments and the seed was sown by broadcasting. Besides this an additional *ex-situ* crop of *dhaincha* was also grown by using similar quantity of seed 10 days prior to the normal sown *in-situ*. This *ex-situ dhaincha* crop was used to assess nitrogen content to be taken as reference for working out the quantity of *dhaincha* to meet out the different nitrogen requirement as per of the experimental treatments. Application of organic amendments *viz*. FYM with 45% moisture, vermicompost with 50% moisture and fresh biomass of *dhaincha* with 80 % moisture used as sources of nitrogen were analysed for determine their N content (oven dry weight basis) to decide the total quantity of these organic amendments to be used to supplement 30 kg N/ha. The quantity of FYM, vermicompost and fresh biomass of *dhaincha* to fulfil the recommended dose of nitrogen on their respective N contents was 10.88, 5.00 and 8.30 tonnes/ha were applied 2 weeks before direct seeded rice each year. Farmyard manure, vermicompost and *dhaincha* had an average composition of 36.6% C, 0.60% N, 1.3% P and 1.5% K, 1.56% N, 1.6% P, 1.8% K and 1.85% N, 1.7% P, 1.4 K, respectively.

The *ex-situ* raised *dhaincha* crop was cut near the ground surface and 10 kg's (8.33 tonnes/ha) of its fresh biomass was spread in the inter row spaces of each plot of mulching treatments at 20 days after sowing. Recommended doses of N P K (30:20:10 kg/ha) were applied. Total P, K and ½ doses of N were broadcasted before sowing and rest was top dressed at tillering and flowering stages in equal doses. Sowing of direct seeded basmati rice was done in lines giving row-row spacing of 20 cm using a seed rate of 40 kg/ha. Pre-sowing irrigation was avoided due to receipt of sufficient rainfall of 130.40 mm before the sowing. To maintain aerobic conditions during crop growing period of rice, the depth of water for irrigation was fixed to 4 cm and irrigation was applied when 50% depletion of soil moisture from field capacity was observed. This was ascertained by following the procedure underlined for feel and appearance method for determination of moisture status of soil. Irrigation water was given when soil was slightly moist, forms a weak ball with defined finger marks, darkened color, no water staining on fingers, grains break away (USDA-2007). Since the objective of this study was to quantify the residual effects of different soil organic amendments applied to preceding basmati rice on succeeding bread wheat, therefore, a blanket crop of wheat 'RSP-561' was taken with its recommended package of cultivation during *rabi* in all the treatments using 100:50:25: N: P: K kg/ha to assess the impact of *kharif* treatments on the performance of succeeding wheat in rice-wheat system. Ten spikes were randomly selected from each plot for recording the data on yield attributes. One thousand grains were counted randomly from each subplot, and their weight was recorded at 12% moisture and expressed. Harvesting of the bread wheat was undertaken as soon as it attained the harvest maturity. Wheat was adequately irrigated with ground water and an irrigation of about 5 cm was applied as and when required depending on the visual inspection of the field.

The soil organic carbon was determined by Walkley and Black's titration method (Olsen and Sommers, 1982). Available N in straw and grain samples of both rice and wheat was analyzed by distillation and subsequent titration with standard acid (Richards, 1993). The available N content of surface (0–15 cm) soil sample was determined using the method given by Subbiah and Asija (1956). Available P in straw and grain samples of rice and wheat was estimated by Vandomolybedo phosphoric yellow color (Richards, 1993). The available P content of surface (0–15 cm) soil sample was determined using the method given by Kuo (1996). Available K in straw and grain samples at the harvest of rice and wheat was estimated by flame photometer method (Richards, 1993). The available K content of surface (0–15 cm) soil sample was determined using the method given by Brown and Warencke (1998). The respective concentrations of N, P and K in straw and grain of rice and wheat were multiplied by the straw and grain yields to obtain the total uptake of these nutrients. Aggregation status of soil was determined by wet sieving method (Yoder, 1936). Water-stable aggregates Soil samples at three locations per treatment were collected by pushing a metal core, 0.15 m long and 0.103 m internal diameter, to 0.15 m depth and pooled. The moist soil samples were air-dried, gently broken into aggregates and passed through 8- and 2-mm sieves retained on a 2-mm sieve (i.e., 2–8 mm diameter) were wet-sieved for 30 min using Yoders apparatus as mentioned by Singh (1980). The water-stable aggregates were expressed as WSA > 0.25 mm diameter (%) and mean weight diameter (MWD, mm). The aggregates Mean weight diameter (MWD) of the aggregates was calculated as follow

$$MWD = \sum_{i=1}^{n} <d>i \; wi$$

Where,

MWD = Mean weight diameter (mm)

d = Mean diameter of each size fraction size i (mm)

w = Proportion of total sample weight (g) – sand and coarse fragments weight (g) occurring in the size fraction i

n = Number of size fractions

The statistical analysis was carried out following the procedure given by Cochran and Cox (1957).

Results and Discussion

Organic carbon

Organic carbon content in surface 0–15 cm soil layer was significantly greater in all organically amended treatments compared to control –(RFD) at both the cropping years i,e after basmati rice and succeeding wheat crop. After basmati rice, organic carbon content in the T_2 (0.53%), T_5 (0.52%), T_6 (0.51%), T_4 (0.51%) and T_3 (0.49%) treatments was significantly greater compared to that in T_1 (0.42%). Significantly more organic carbon with T_2, T_5, T_6, T_4 and T_3 treatments than that of T_1 is attributed to the slower rate of decomposition and wider C:N ratio of farmyard manure, vermicompost and green manure crop like *dhaincha* (*Sesbania esculata*), which leaves more carbon in the soil (Table 1). With depth, organic carbon content decreased significantly. Beneficial effect of organically amended treatments in increasing organic carbon content over control (T_1) was significant in 0–5, 5–10 and 10-15 cm soil layers indicating that green manure individually increase the organic carbon content in all the soil depths and when it is in combination with farmyard manure and vermicompost treatments. After wheat, the mean effects of organic manure treatments and depth although remained similar to that after rice but their magnitudes were greater possibly because of two reasons, firstly all the organic manures were added before rice crop and secondly there is decomposition of organic materials with passage of time.

Aggregation

After rice, mean weight diameter (MWD) of the aggregates in organically amended treatments was significantly greater than that in control (T_1). The decrease in aggregation because of fertilizer application with N alone could be attributed to the dispersive action of ammonium ions (Table 2). Among different organically amended treatments the order of MWD was in accordance with that of the soil organic carbon content (Sharma and Bhushan 2001) showing that improvement in aggregation status of the soil was through improved organic carbon content in soil resulted from organic manures, which acted as binding agents. However, the size of aggregates was smaller after rice than after wheat harvest in the 0–15 cm soil layer.

Table.1 Application of recommended fertilizer dose, incorporation of dhaincha, vermicompost and farmyard manure (FYM) in a rice–wheat cropping rotation in Shiwalik foot hills of Jammu, India

S. No	Treatment acronym	Basmati-Rice	Wheat (RSP-561)
1	T_1	30:20:10 Kg/ha::N:P:K	100:50:25 kg/ha::N:P:K
2	T_2	*In-situ* green manuring of *dhaincha* on N-basis	Nil
3	T_3	*In-situ* green manuring of *dhaincha* + vermicompost on N-basis (1:1)	Nil
4	T_4	*In-situ* green manuring of *dhaincha* + vermicompost + mulching with *dhaincha* on N-basis (1:1:1)	Nil
5	T_5	*In-situ* green manuring of *dhaincha* + FYM on N-basis (1:1)	Nil
6	T_6	*In-situ* green manuring of *dhaincha* + FYM + mulching with *dhaincha* on N-basis (1:1:1)	Nil

Table.2 Effect of basmati rice cultivars and soil organic amendments on organic carbon and mean weight diameter

Treatments (T)	**Soil depth (D) after rice harvest**				**Soil depth (D) after wheat harvest**			
	0–5 cm	**5–10 cm**	**10–15 cm**	**Mean**	**0–5 cm**	**5–10 cm**	**10–15 cm**	**Mean**
***Organic carbon content* (%)**								
T_1	0.42	0.40	0.36	0.39	0.42	0.41	0.37	0.40
T_2	0.53	0.47	0.44	0.48	0.56	0.49	0.45	0.50
T_3	0.49	0.43	0.40	0.44	0.51	0.44	0.41	0.45
T_4	0.51	0.45	0.43	0.46	0.53	0.47	0.44	0.48
T_5	0.52	0.46	0.43	0.47	0.55	0.48	0.44	0.49
T_6	0.51	0.46	0.42	0.46	0.54	0.48	0.43	0.48
CD (P=0.05)	**0.04**	**0.02**	**0.03**		**0.05**	**0.03**	**0.04**	
***Mean weight diameter* (mm)**								
T_1	0.45	0.29	0.27	0.34	0.45	0.33	0.30	0.36
T_2	0.69	0.35	0.33	0.46	0.70	0.40	0.38	0.49
T_3	0.60	0.30	0.28	0.39	0.65	0.35	0.32	0.44
T_4	0.63	0.31	0.30	0.41	0.67	0.37	0.35	0.46
T_5	0.66	0.33	0.32	0.44	0.69	0.39	0.37	0.48
T_6	0.64	0.32	0.30	0.42	0.68	0.38	0.36	0.47
CD (P=0.05)	**0.15**	**0.01**	**0.01**		**0.19**	**0.02**	**0.01**	

Initial values of soil pH = 7.27, OC = 0.43% and Available N = 260 kg/ha

Table.3 Effect of basmati rice cultivars and soil organic amendments on yield attributes of succeeding crop of wheat (pooled data of 2 years)

	Plants/m^2	**Effective ears/ m^2**	**Grains/ear**	**1000-grain weight(g)**
Treatments				
Wheat following V_1	300.3	287.3	41.4	39.2
Wheat following V_2	290.5	279.6	39.5	38.6
Wheat following V_3	299.3	285.6	40.8	39.1
Wheat following V_4	302.5	289.9	41.9	39.3
SEm±	4.89	5.99	3.81	5.27
CD (P=0.05)	N.S.	N.S.	N.S.	N.S.
T_1	287.1	274.5	40	38.7
T_2	291.6	280	40.5	38.8
T_3	297.4	287.5	41.1	39.2
T_4	304.6	296.4	41.4	39.5
T_5	294.3	283.7	40.5	38.8
T_6	303.1	292.4	41.2	39.3
SEm±	5.77	6.79	6.05	7.13
CD (P=0.05)	N.S.	N.S.	N.S.	N.S.

V_1, 'Basmati 370'; V_2, 'Basmati 564'; V_3, 'Saanwal Basmati' and V_4, 'Ranbir Basmati' were sown in preceding year in rice–wheat system

Table.4 Effect of basmati cultivars and soil organic amendments on grain yield, straw yield (t/ha) and harvest index (%) of succeeding crop of wheat (pooled data of 2 years)

	Grain yield (t/ha)	**Straw yield (t/ha)**	**Harvest index (%)**
Treatment			
Wheat following V_1	4.2	4.7	4.8
Wheat following V_2	3.9	4.4	4.7
Wheat following V_3	4.0	4.4	4.7
Wheat following V_4	4.2	4.7	4.9
SEm±	1.00	2.16	0.33
CD (P=0.05)	N.S.	N.S.	N.S.
T_1	3.8	4.0	4.8
T_2	4.0	4.4	4.9
T_3	4.0	4.4	4.9
T_4	4.4	4.9	4.9
T_5	4.0	4.4	4.8
T_6	4.3	4.8	4.9
SEm±	1.1	1.2	1.3
CD (P=0.05)	N.S.	3.6	3.7

Table.5 Effect of cultivars and soil organic amendments on uptake of N, P and K in wheat (Kg/ha) (pooled data for 2 years)

Treatments	Grain			Straw		
	N	P	K	N	P	K
Wheat following V_1	40.3	9.1	21.0	33.4	8.5	59.4
Wheat following V_2	40.1	9.0	20.0	32.0	7.3	59.2
Wheat following V_3	40.2	9.0	20.0	33.0	8.4	59.3
Wheat following V_4	41.0	9.5	21.0	34.0	8.7	60.0
SEm±	0.58	0.61	0.34	0.45	0.96	0.99
CD (P=0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
T_1	50.0	10.0	20.0	32.1	8.3	58.0
T_2	49.4	11.1	22.5	33.0	8.9	58.6
T_3	49.5	11.5	23.0	33.0	9.2	58.9
T_4	57.1	13.4	26.3	34.4	11.3	64.3
T_5	49.5	11.5	23.0	33.1	9.0	58.8
T_6	56.0	13.3	26.1	34.1	11.1	64.0
SEm±	1.62	0.20	0.50	0.30	0.67	1.07
CD (P=0.05)	4.87	1.20	1.5	0.90	2.15	3.22

Yield and harvest index of wheat

The grain yield of succeeding wheat after rice recorded significant effect by the application of treatment T_4: *in-situ* green manuring of *dhaincha* + vermicompost + mulching with *dhaincha* on N-basis (1:1:1) during second year of crop- growing season of *rabi* 2013-14 and straw yield during both the cropping seasons (Table 3). It was followed by treatment $T_{6:}$ *in-situ* green manuring of *dhaincha* + FYM + mulching with *dhaincha* on N-basis (1:1:1), these treatments in turn were significantly superior to the other treatments. Similar trend was also recorded for harvest index. This could be attributed to the higher supply of N and other micronutrient cations through the incorporation of organic amendments into soil (Bisht *et al.*, 2006; Pooniya and Shivay, 2011) (Table 4).

Nutrient uptake

Residuals of organic applied treatments had a significant effect on N, P and K uptake in grain and straw by succeeding wheat. The increase in N,P,K uptake by succeeding wheat with the residual of T_4 and T_6 recorded significantly higher as compared to rest of the treatments which lead to 25.25, 17.57,17.43 and 17.33% increase over the treatments T_1,T_2,T_5 and T_3 (Table 5).

From the results it can be conclusively stated that in rice–wheat cropping system, use of green manure (*dhaincha*), farmyard manure and vermicompost restore the damaged soil structure (due to puddling in rice) by increasing its organic carbon content, size and stability of aggregates, available nitrogen and productivity of succeeding wheat.

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How to cite this article:

Shah, I.A., B.C. Sharma, A. Samanta, Brij Nandan, Akhil Verma, Monika Banotra and Rakesh Kumar. 2017. Soil Aggregation, Carbon and Nitrogen Stabilization in Relation to Application of Different Soil Organic Amendments in Aerobically Grown Basmati Rice and their Residual Effect on the Productivity of Wheat in Rice–Wheat System under Shiwalik Foothills of Jammu and Kashmir, India. *Int.J.Curr.Microbiol.App.Sci.* 6(10): 349-357.
doi: https://doi.org/10.20546/ijcmas.2017.610.043