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Effect of different organic and inorganic sources on physico-chemical properties of paddy soils in Kerala

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Abstract
Appropriate fertilizer application is an important management practice in agriculture to improve soil fertility. In the present study, we examined the effects of four organic sources (OS) in an integrated approach on soil bulk density (BD), water holding capacity (WHC), pH and soil organic carbon (SOC) contents in the surface layer (0–15 cm) of paddy soil in Kerala. The treatments consisted of one control [no organic source (CT), Farm yard manure (FYM), artocarpus (jack tree) leaves (JCK), daincha (DNC) and rice husk biochar (RHB)] along with inorganic fertilizers (NPK) involving different levels of N. Results showed that the soil BD was considerably reduced (1.06 Mg m^{-3}) with the use of organic source, RHB. The WHC was also found to be maximum in this treatment with the highest being 54.66 percent. Soil pH was the lowest in CT with a value of 4.58 and was significantly higher in RHB treated plots (5.10 and 5.28). The application of manures have remarkably improved SOC value compared with the CT and specifically, the OS treatment, RHB resulted in the highest SOC (2.05%). During the experimental period, the increase in OC content was double the value over CT. These results indicated that organic sources/manure should be recommended to improve soil physico-chemical fertility. Considering the longterm use efficiency, rice husk biochar can be suggested to improve the soil acidity in the region thereby enhancing soil fertility.

Keywords: Green manure; fertilizer; organic sources; soil physico-chemical property; rice husk biochar

Introduction
Rice (*Oryza sativa* L.) is the main cereal crop, contributing 19 percent and 29 percent of the world rice area and rice production, respectively. In recent years, due to the rapid population growth and a continuous decline in the cultivated land area, the rate of fertilizer application keeps on rising in order to obtain high crop production in agriculture. Nevertheless, instead of improving the soil structure and fertility, the long-term unbalanced fertilization has caused severe degradation of rice soils, characterized by high acidity, low available nutrients and a disturbed ecosystem. Therefore, it has become necessary to ameliorate degraded paddy soils and maintain the region’s sustainable development of agricultural production. Recently, soil quality has gained attention as a result of environmental issues related to soil degradation and production sustainability under different farming systems. It has been considered that the physico-chemical properties such as bulk density (BD), water holding capacity (WHC), pH, organic carbon (OC) content of soil are good indicators of soil quality and productivity because of their favourable effects on the physical, chemical, and biological properties of soil. Soil pH affects the chemical reactions in soil. Extremes of pH in soils, for example, will lead to a rapid increase in net negative surface charge and thus increase the soil’s affinity for metal ions (Yang *et al*., 2006) [13]. The organic component of soil, organic carbon (OC) is the most critical index of paddy soil fertility (Liu *et al.*, 2011) [7].
Some studies had revealed that continuous fertilizer application increased the concentration of SOC and other nutrients in plough layers compared with the initial value (Benbi, 2013) [2]. Manure amendments markedly increased the contents of SOC and soil structure, water retention capacity and decreased bulk density (Liu *et al.*, 2011) [7]. Combined application of organic and inorganic fertilizers is often found to be effective in increasing SOC stock by enhancing biomass production and decreasing decomposition of soil organic matter. A regular application of biomass-C with chemical fertilizer is essential to enhance SOC sequestration in Central India by improving soil quality and minimizing the depletion of SOC stock under continuous cropping (Shirani *et al*., 2002) [10].

A thorough understanding of how these fertilizers and varying management practices affect the soil fertility of conventional cropping systems is still lacking in rice soils of Kerala. In this study, fertilization treatments with four organic sources (no organic manure, farmyard manure, green manure, *artocarpus* leaves and rice husk biochar) in combination with inorganic nitrogen at various levels were applied. The objectives of the study were to (i) assess the changes of soil physical parameters in paddy soil (ii) evaluate the effects of different fertilization treatments on soil chemical fertility parameters, and (iii) put forward suggestions to improve soil health in paddy growing acid soils.

Materials and Methods

A. Experimental site

A farmer's field (10^0 31' 49" N latitude and $76^0$12' 53" E longitude) cultivating paddy situated on the typical lateritic lowland region in the tropical monsoon land scape zone of Kerala, India was selected for the study. The experimental field was located in the flat floodplain with the sandy clay loam soil of village, Varadium in Thrissur district. The data on preliminary analysis of soil is given in table 1.

Table 1: Initial physico- chemical characteristics of soil

Bulk density (Mg m^{-3})	Water holding capacity (%)	pH	Organic carbon (%)
1.36	48.47	4.68	1.05

B. Experimental design

A short-term fertilization experiment was conducted in 2015-16 under a double rice cropping system (rice-rice-fallow) which is one of the most common cropping systems in the region. Summer rice, commonly known as 'virippu' season was sown in the middle of May- June and harvested in August- September. Winter rice, known as 'mundakan' season was sown in the middle of September -October and harvested in December-January. There were five treatments using organic sources (OS) along with control, viz., no organic manure (CT), farm yard manure (FYM), *artocarpus* leaves (JCK), daincha (DNC) and rice husk biochar (RHB) amended with four levels of nitrogen such as no inorganic nitrogen, 35 kg N ha^{-1}, 70 kg N ha^{-1} and 105 kg N ha^{-1}. All treatments were arranged in a randomized block design with three replications totalling 60 plots. The plot size was 20 m^2 (5m x 4m) and was isolated by bunds (30 cm width and 15 cm above the soil surface). In NPK treatments, inorganic fertilizers were applied at the rates of N-P_2O_5-K_2O at 90-45-45 kg ha^{-1} using urea, super phosphate and muriate of potash. Before sowing, 100 percent of P, 50 percent of N and 50 percent of K fertilizer were applied as basal dose. Remaining 50 percent of N and 50 percent of K fertilizer were applied as top-dressing. In OS treatments, organic sources such as *artocarpus* leaves, FYM, daincha (DNC), rice husk biochar (RHB) were applied @ 5t ha^{-1} and they were incorporated in the field 15 days prior to transplanting. During the growing season, hand weeding was done to control weeds.

C. Soil sampling and analysis

Soil samples were collected seasonally for two cropping seasons after the harvest of the rice crop during 2015-16 from the experimental plots. From each plot, soil samples were taken in the plough layer (0–15 cm). All fresh soil samples were air-dried and sieved through a 2.0 mm sieve and tested for analysis. Bulk density and water holding capacity were also estimated for the soil samples taken. Soil pH was measured with glass electrode in a 1:2.5 soil - water suspension and SOC by Walkely and Black method [12].

D. Statistical analyses

Three-way of variance (ANOVA) and Duncan's multiple comparisons were performed to determine the differences among various organic-inorganic combination of treatments. All statistical analyses were performed using the OP Stat software package. A difference at P, 0.05 level was considered as statistically significant.

Results

A. Effects of different fertilizer treatments on bulk density and water holding capacity

The impact of organic amendments on bulk density of soil is given in table 2. Bulk density in virippu season was significantly minimum for the treatment, RHB without N (1.10 Mg m^{-3}). The treatment *artocarpus* without N and RHB with 35 kg N ha^{-1} showed a value of 1.12 Mg m^{-3}. It was the highest in the treatment where 105 kg N ha^{-1} alone was applied with a value 1.38 Mg m^{-3}. In mundakan season also, RHB without N as well as with 35 kg N ha^{-1} recorded the minimum value of 1.06 Mg m^{-3}.

Table 2: Effect of different organic sources on BD (Mg m^{-3}) of soil

	Virippu					Mundakan				
	NOM	FYM	JCK	DNC	RHB	NOM	FYM	JCK	DNC	RHB
N_0	1.33	1.25	1.12	1.23	1.10	1.34	1.22	1.12	1.15	1.06
N_1	1.35	1.27	1.16	1.26	1.12	1.37	1.26	1.14	1.18	1.06
N_2	1.36	1.29	1.17	1.28	1.14	1.37	1.28	1.12	1.19	1.08
N_3	1.38	1.30	1.19	1.29	1.15	1.39	1.29	1.15	1.20	1.08
CD - A x B – 0.007 ; B x C - 0.006 ; A x B x C - 0.014										

A- cropping season, B - organic sources, C - nitrogen level

Table 3: Effect of different organic sources on WHC (%) of soil

	Virippu					Mundakan				
	NOM	FYM	JCK	DNC	RHB	NOM	FYM	JCK	DNC	RHB
N_0	48.65	51.47	50.51	52.54	54.54	49.03	52.77	51.23	53.30	54.66
N_1	48.29	51.40	50.44	52.44	53.44	48.76	53.05	50.78	52.53	54.23
N_2	48.39	50.47	50.31	50.51	53.43	48.36	52.33	51.20	51.11	54.14
N_3	47.76	49.43	49.60	49.40	53.26	48.07	50.54	50.46	50.65	53.94
CD - A x B – 0.498; B x C -0.705 ; A x B x C – NS										

A- cropping season, B - organic sources, C - nitrogen level

The maximum WHC (table 3) of 54.54 percent was attained in the treatment RHB with no added nitrogen. The same organic source with higher dose of nitrogen also received value more than 53.00 percent. The lowest values of 47.76 and 48.07 percent were obtained in the treatment with inorganic fertilizers alone in both the seasons. The results showed that the same trend was observed during mundakan season also showing the highest value (54.66%).

B. Effects of different fertilizer treatments on soil pH

The average soil pH of soil is shown in table 4. Statistical analysis revealed that combination of organic and inorganic fertilization treatments led to a significant increase in soil pH compared with the CT treatment (P, 0.05). The soil pH was the lowest in the CT treatment with a value of 4.58. In OS treatments, the soil pH was relatively higher than CT and maximum significant pH of 5.10 was recorded in virippu season in the treatment, RHB without N source. During mundakan season also, the highest pH value of 5.28 which was also significant was recorded for the same treatment. In both seasons treatment with 105 kg nitrogen source showed the minimum pH value of 4.58.

Table 4: Effect of different organic sources on pH of soil

	Virippu					Mundakan				
	NOM	**FYM**	**JCK**	**DNC**	**RHB**	**NOM**	**FYM**	**JCK**	**DNC**	**RHB**
N_0	4.64	4.67	4.65	4.78	5.10	4.60	4.65	4.64	4.76	5.28
N_1	4.63	4.65	4.64	4.75	5.02	4.60	4.63	4.63	4.73	5.15
N_2	4.58	4.64	4.63	4.76	4.98	4.59	4.62	4.61	4.70	5.01
N_3	4.58	4.62	4.61	4.75	4.96	4.58	4.62	4.61	4.70	5.00
CD - A x B - 0.008 ; B x C – 0.012 ; A x B x C – 0.016										

A- cropping season, B - organic sources, C - nitrogen level

C. Effects of different fertilizer treatments on soil organic C

The OC content showed statistically significant differences among the treatments (table 5). It was observed that the application of fertilizers (especially OS and NPK fertilizers) had remarkably improved OC values compared with that of CT. Specifically, the OS treatment with RHB resulted in the highest OC values of 1.67 and 2.01 percent in virippu and mundakan seasons respectively. Farm yard manure with 35/70 kg N ha^{-1} recorded the same value of 1.38 percent. The control treatment showed minimum value of 1.13 percent. The OC values had a decreasing trend as a whole in the second season while higher values were observed in the RHB treatment. It was also noticed that the SOC content in OS was obviously higher than the control treatment during the experiment period.

Table 5: Effect of different organic sources on OC (%) of soil

	Virippu					Mundakan				
	NOM	**FYM**	**JCK**	**DNC**	**RHB**	**NOM**	**FYM**	**JCK**	**DNC**	**RHB**
N_0	1.13	1.34	1.27	1.23	1.67	0.94	1.15	0.91	1.03	2.05
N_1	1.17	1.38	1.28	1.26	1.58	0.64	1.16	1.20	1.06	1.94
N_2	1.19	1.38	1.26	1.35	1.30	0.94	1.14	1.01	1.14	1.23
N_3	1.14	1.13	1.24	1.28	1.27	0.82	1.11	1.01	1.12	1.05
CD - A x B – 0.014 ; B x C – 0.020 ; A x B x C - 0.028										

A- cropping season, B - organic sources, C - nitrogen level

Discussion

In our study, soil pH tended to increase in different treatments with OS and the rate was relatively lower (Fig.1), which suggested that chemical fertilizer and organic manure could alleviate soil acidification to some extent. It was reported that the application of alkaline manure (e.g. rice husk biochar) with a pH of 9.1 would return some alkaline substance to soils and thus increase the soil pH. In addition, the application of organic manure could ameliorate soil acidity by increasing the soil organic matter, promoting the soil maturation, improving the soil structure, and enhancing the soil base saturation percentage (Li *et al*., 2010) [6]. The preferable variation in pH due to the application of biochar was generally attributed to the presence of ash residues that contain carbonates of alkali and alkaline earth metals, amounts of silica, heavy metals, sesquioxides, phosphates and small amounts of organic and inorganic N (Raison, 1979) [8]. Moreover, studies showed that the soil pH in the treatment CT was lower than the initial value. Since a too high or too low pH is harmful to the crop growth, it might be a practicable measure to establish the proper range of soil pH through integrated approach. Soil organic matter is a key contributor to soil quality and fertility due to its capacity to affect plant growth indirectly and directly (Lee *et al*., 2009) [5].

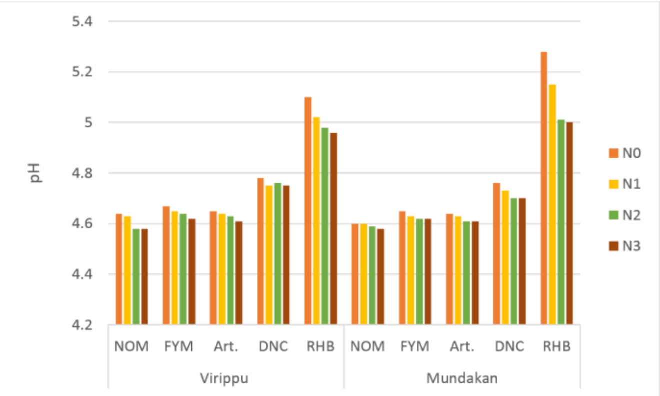

Fig 1: Effect of different organic sources on pH of soil in virippu and mundakan seasons

Bulk density of soil decreased from 1.39 Mg m^{-3} to 1.06 Mg m^{-3} in the surface layer (table 1). Among the different treatments, bulk density was found to be comparatively lower in the treatments amended with rice husk biochar or *artocarpus* leaves which may be due to increased soil organic matter and pore space. A significant decrease in surface layer bulk density of the manured fields was also reported (Arocena and Opio, 2003) [1]. Application of organic amendments such as composts, manures, crop residues and bio-solids has often been shown to decrease soil bulk density which is attributed to the increase in pore space (Tian *et al*., 2009) [11]. The results revealed that treatments which received addition of organic sources either alone or in combination with inorganic fertilizers had higher WHC, while treatments in which inorganic fertilizers alone were applied recorded the lowest values. The values ranged from 47.76 percent to 54.66 percent. Manures contained high amount of organic matter which increased the moisture retention of the soil and improved dissolution of nutrients particularly, phosphorus (Choudhary *et al*., 2013) [3]. The highest WHC in the RHB amended plot showed the formation of macroaggregates in the rice soil as a result of biochar treatment which increased total porosity and soil water retention (Sharma and Uehara, 1986) [9].

In our experiments, SOC content increased considerably in the fertilization treatments compared with CT, especially in OS and NPK treatments (Fig.2), suggesting that organic and chemical fertilizers are beneficial to the accumulation of soil organic matter and thus improved soil fertility and water holding capacity. This might be due to the fact that both the application of

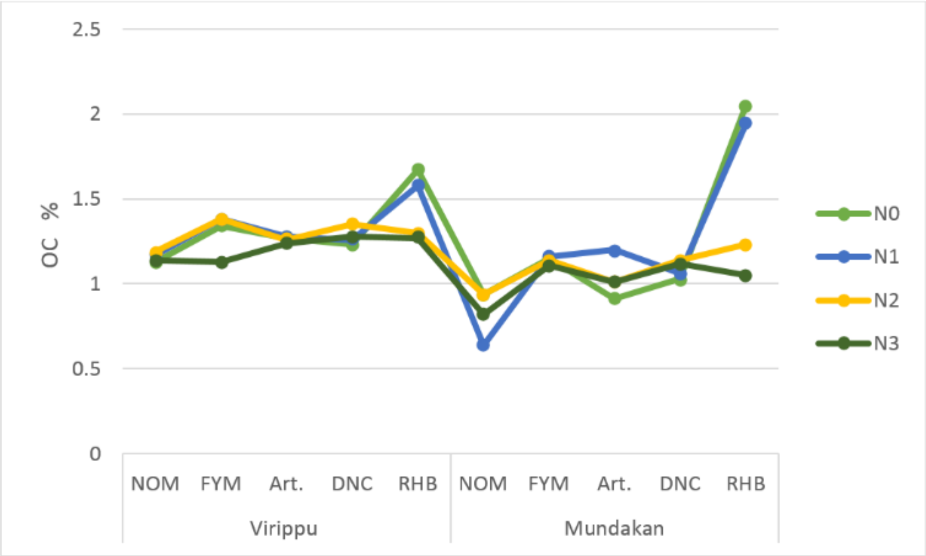

Fig 2: Effect of different organic sources on OC (%) of soil in virippu and mundakan seasons

organic manure and chemical fertilizer can improve soil aggregation, soil water retention, and reduce bulk density of the soil in the plough layer, promoting crop growth and return of more root residues to the soil (Hyvonen *et al*., 2008) [4]. The highest values of organic carbon in biochar treated soils indicated the presence of recalcitrant organic carbon in biochar. The OC values decreased after virippu season and it ranged between 0.64 and 2.05 percent. The inability of organic manures to enhance the organic carbon content of soil considerably in spite of their application at same doses in the second cropping season is mainly due to the effect of continuous cropping and tropical conditions of high rainfall and temperature prevailing in the region leading to higher rate of decomposition of organic matter.

Conclusion

Significant differences in soil physico-chemical properties such as bulk density, WHC, pH and organic carbon content of paddy soils in the wetland region of Kerala receiving different fertilization treatments in an integrated approach were found in the present study. Application of OS and NPK resulted in a substantial increase of SOC content relative to the other fertilization treatments. Thus, it is clear that the organic manure and NPK application could improve soil quality. Hence the organic sources, particularly rice husk biochar (RHB) which improved the soil pH substantially in acidic soil condition is found to be a cheap and effective alternative to lime and its use by farmers must be encouraged. Also suitable methods have to be adopted for ensuing minimum loss of biochar during application to increase use efficiency.

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