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EFFECT OF PUDDLING AND ORGANIC SOURCES OF NUTRIENTS ON PRODUCTIVITY OF RICE – WHEAT CROPPING SYSTEM IN LOWLANDS

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ABSTRACT

A field experiment was conducted during kharif and rabi seasons of 2008 to 2010 at Crop Research Station, Ghaghraghat, Bahraich to evaluate the effect of soil manipulation (puddling) and organic sources of nutrients along with inorganic fertilizer on rice and its residual effect on wheat productivity in rice-wheat cropping system. Puddling treatments did not influence the rice and wheat yield significantly. Slightly higher grain yield of rice (1.7%) and wheat (2.3%) was recorded under non-puddled treatment over puddled one. However, application of organic sources caused significant increase in grain yield of rice (5.7-17.5%) and residual effect of organics on wheat (5.3-13.0%) over inorganic fertilizer alone. Among the organics, significantly higher grain yield of rice (17.5%) and residual wheat yield (13.0%) was obtained with dhaincha (insitu) + wheat residue (5 t ha^{-1}) over inorganic fertilizer alone. Organic sources increased the N P and K uptake by rice and wheat crop and also improved the bulk density, porosity, pH, SOC and available N P and K as compared to inorganic fertilizer alone. The above results indicated that the application of dhaincha (insitu) + wheat residue (5 t ha^{-1}) along with inorganic fertilizer was found the best treatment for getting higher yield of rice and wheat crop by mitigating the adverse effect of puddling on soil health in rice – wheat system.
Keywords: Puddling, organic source, nutrients, productivity, rice-wheat system lowlands

INTRODUCTION

Rice-wheat is one of the major and important cropping systems of the Indo-Gangetic alluvial plains. However, this system has been performing way below to its potential (Timsina and Connor 2001) due to highly contrasting nature of cultivation of both rice and wheat crops leading to deterioration in soil quality, with stagnation in yield levels in most of the area (Rattan and Singh 1997). In lowlands, mostly rice crop was transplanted after puddling. Soil puddling is done to assist the transplanting of seedlings, control of weeds and decrease water loss. On long-term basis puddling has led to deterioration in soil physical properties through structural break down of soil aggregates, capillary pores, clay dispersion and reduction in soil organic matter. Puddling forms a compacted layer (plough pan) that restricts the percolation of water, causing temporary water logging and restricts root growth for succeeding crops after rice (Gill *et al*. 2006). Rice-wheat system is an intensive and most exhaustive cropping system requires huge quantity of nutrients for getting higher production of the system while farmers of the lowland ecosystem are not capable to use sufficient amount of fertilizer nutrients and in balance form due to their poor economic condition resulting lower production and poor soil health. This needs the proper understanding of the cropping system and its demands with respect to judicious resource management for sustainable production. Rice and wheat crops grown in sequence are likely to exert large influences on soil structure, organic carbon and nutrient availability. As these parameters are related to soil quality, it becomes necessary to study how they can be manipulated by soil management practices. Application of organic sources of nutrients as supplement to inorganic fertilizers has positive effect on soil quality parameters and sustainability of the system. Organic sources of nutrients applied to preceding crop benefits the succeeding crop to a great extent and system becomes sustainable. So far, meagre studies have been carried out on this aspect particularly in lowlands. Hence, present investigation was undertaken to study the combined effect of puddling and organic sources on soil quality and sustained productivity of rice-wheat system.

MATERIALS AND METHODS

A field experiment was conducted during Crop Research station, Ghaghraghat, Bahraich (UP). *kharif* and *rabi* seasons of 2008, 2009 and 2010 at the reaction (8.2) having SOC 4.2g kg^{-1} and available N 228, P 14.6 and K 203 kg ha^{-1} and bulk density 1.44 Mgm^{-3}. The treatments consisting of two (2) levels of puddling (puddled and non-puddled) in main plots and seven (7) nutrient sources (T_1 - Control, T_2 - inorganic fertilisers alone, T_3 - FYM (10 t ha^{-1}), T_4 - *dhaincha* (*Sesbania rostrata*) in situ, T_5 – wheat residue (5 t ha^{-1}), T_6 - *dhaincha* insitu + wheat residue (5 t ha^{-1}) and T_7 - blue green algae (BGA)) in sub plots were laid out in split plot design replicated three

times. After accounting N added through organics, the remaining N dose of recommended N (120 kg ha^{-1}) was added through urea in three splits (at basal, tillering and panicle initiation stages) to the treatments T_3 to T_7. For treatment T_2, only inorganic N @ 120 kg N ha^{-1} was added through urea in three equal splits. Phosphorus and potassium were given @ 60 and 40 kg ha^{-1} as basal dose through diammonium phosphate and muriate of potash, respectively to the entire treatments. Twenty four days old seedlings of rice variety NDR-359 using 2-3 seedlings $hill^{-1}$ were transplanted at a spacing of 20 cm x 10 cm. During rabi season, wheat variety PBW-373 was sown to measure the residual effect of preceding treatments applied to rice, in terms of wheat productivity by applying inorganic fertilisers (120 N + 60 P_2O_5 + 40 K_2O kg ha^{-1}) only. Nitrogen in grain and straw of both the crops was determined by modified Kjeldahl method. Phosphorus and K were determined in di acid extract (HNO_3 and $HClO_4$) by vanadomolybdate yellow colour method and flamephotometer, respectively. Bulk density (core method), soil pH in 1:2 soil water suspension using glass electrode, SOC (Jackson, 1973), available N (Subbiah and Asija, 1956), P (Olsen et al.,1954) and K (1N NH_4OAc) were determined at the end of 3 years. The average rainfall received by rice during *Kharif* season was 1340.1 mm in 2008, 834.2 mm in 2009 and 859.8 mm in 2010 while in *rabi* season by wheat crop was 30.60 mm, 202.0 mm, and 49.8 mm in respective years.

RESULTS AND DISCUSSION

Rice

Puddled and non-puddled treatments did not influence the grain and straw yield of rice and wheat crop probably owing to almost equal crop stand under both the treatments. Slightly higher grain (1.75%) and straw (2.98%) yield of rice was recorded under non-puddled treatment as compared to puddled one which was on account of higher panicle m^{-2} (Table1). The crop supplemented with organics (T_3-T_7) gave significantly higher grain and straw yield of rice as compared to inorganic fertilizer alone (T_2). Among the organic sources (T_3-T_7), *dhaincha* (insitu) + wheat residue (5 t ha^{-1}) -T_6 gave significantly higher grain yield (53.6 q ha^{-1}) of rice as compared to T_4, T_5 and T_7. Increase in rice yields by incorporating green manure (narrow C/N) along with wheat residue (wide C/N) may be due to mitigating the adverse effect of N immobilization and improving the N use efficiency as reported by Yadvinder Singh et al. (2004a). Grain yield obtained with *dhaincha* (insitu) (T_4) was significantly superior to blue green algae (T_7). All the organic treatments (T_3-T_7) proved significantly superior to control (T_1) in respect of grain yield of rice. The magnitude of yield increase with organic treatments (T_3-T_7) was 13.8, 11.6, 7.4, 17.5 and 5.7%, respectively, as compared to inorganic fertiliser alone (T_2) and corresponding increase in straw yield was 10.2, 6.6, 1.4, 15.4 and 0.35%. Increase in rice grain yield owing to incorporation of organic sources of nutrients (T_3-T_7) may be attributed to increased and prolonged availability of nutrients and improved soil physical condition on account of increased density of soil organic carbon, supply of other nutrients that are not supplied by inorganic fertilizer and less losses of nutrients from soil (Yadav *et al*., 2000). Significantly higher panicles m^{-2} was recorded with application of organics (T_3-T_7) to inorganic fertilizer alone (T_2). However, the highest panicles m^{-2} was recorded with T_6 significantly superior over T_4, T_5 and T_7. Panicles m^{-2} recorded under all the treatments significantly superior over control (T_1). Interaction effect was not significant.

Wheat

Puddling treatments applied during the *kharif* rice did not have any significant residual effect on grain and straw yield of succeeding wheat crop. However, slightly higher grain (2.3%) and straw (1.9%) yield of wheat was recorded with non-puddled treatment over puddled one. Increase in yield under non-puddled treatment may be due to increased soil organic carbon resulting improved soil physical properties (soil aggregation, pore space and bulk density) and available nutrients status of soil. Higher yield of wheat under non-puddled rice was also reported by Rath *et al*. (2000). Effective tillers m^{-2}were also higher under non- puddled treatment than puddled one (Table 1). Organics (T_3, T_4 and T_6) applied to preceding rice crop had significant residual effect on grain and straw yield of succeeding wheat as compared to inorganic fertilizer alone (Table 1). The entire treatments (T_2 - T_7) were significantly superior to control with respect to grain and straw yield of wheat. Among the organics, *dhaincha* (insitu) + wheat residue (5 t ha^{-1}) (T_6) gave significantly higher residual effect in terms of grain (4.4 q ha^{-1}) and straw(5.0 q ha^{-1}) yield of wheat to wheat residue alone and blue green algae and at par with FYM(10t ha^{-1}) and *dhaincha* (insitu). Residual effect of crop residues to subsequent crop was also reported by Gaur and Mathur (1990) and residual effect of green manure in rice-rice system was reported by Ladha *et al*. (2000). The magnitude of increase in yield with organic sources (T_3 - T_7) was 7.7, 11.5, 3.3, 13.0 and 5.3%, respectively as compared to inorganic fertilizer alone and corresponding increases in straw yield were 5.9, 10.8, 3.2, 9.5 and 3.6%. Significant residual effect of organics (T_3-T_7) was also observed on

Table 1: Effect of different treatments on yield attributes, yield and NPK uptake by rice and wheat crops in rice –wheat cropping system (mean of 3 years)

Treatments	Yield attributes		Yield (q ha^{-1})						Total NPK uptake(Kgha^{-1})					
	Panicle m^{-2} (Rice)	Effective tillers m^{-2} (Wheat)	Rice			Wheat			N		P		K	
			Grain	Straw	Direct effect (qha^{-1})	Grain	Straw	Residual effect (qha^{-1})	Rice	Wheat	Rice	Wheat	Rice	Wheat
Soil Manipulation														
Puddling	289	304	45.7	53.6	-	35.1	53.1	-	89.2	88.8	19.2	17.2	102.2	112.2
Non-Puddling	292	307	46.5	55.2	0.80	35.9	54.1	0.8	91.0	89.8	19.7	17.7	105.1	114.9
CD (P=0.05)	04	05	1.1	1.9	-	1.02	1.26	-	1.92	1.21	0.47	0.72	3.23	2.87
Organic Sources														
T_1 - Control	147	272	23.8	29.5	-	31.7	50.1	-	38.5	76.6	9.2	14.6	53.8	102.7
T_2 - Inorganic fertilizer alone	293	290	45.6	55.8	-	33.8	52.4	2.1	90.6	86.2	18.0	16.0	104.5	111.3
T_3– FYM (10t ha^{-1})	323	320	51.9	61.5	6.3	36.4	55.5	2.6	106.7	92.5	22.6	18.9	117.9	116.7
T_4 – *Dhaincha* (insitu)	319	326	50.9	59.5	5.3	37.7	58.1	3.9	104.1	95.8	23.0	18.6	115.9	122.6
T_5–wheat residue (WR) (5 t ha^{-1})	313	306	49.0	56.6	3.4	34.9	54.1	1.1	96.8	90.0	21.9	17.9	111.3	115.3
T_6 – *Dhaincha* insitu + WR (5 t ha^{-1})	330	335	53.6	64.4	8.0	38.2	57.4	4.4	110.1	98.6	24.7	20.0	125.2	124.9
T_7– Blue green Algae (BGA)	310	309	48.2	56.0	2.6	35.6	54.3	1.8	95.9	87.6	18.9	16.8	106.3	113.0
CD (P=0.05)	08	16	2.43	2.7	-	1.92	2.31	-	4.28	2.73	1.12	1.08	5.37	3.63

effective tillers as compared to inorganic fertilizer alone.The highest effective tillers m^{-2} was recorded under plots receiving T_6 significantly superior to T_5 and T_7. All the treatments (T_2 -T_7) were significantly superior to control with respect to panicle m^{-2}.

Uptake of nutrients

Rice

The uptake of N, P and K by rice and wheat crop did not influence significantly with puddling treatments. However, significant increase in N, P and K uptake by rice was recorded with organics as compared to inorganic fertilizer alone and control. Among the organics, crop receiving *dhaincha* (insitu) + wheat residue (5t ha^{-1}) (T_6) removed significantly higher amount of N (110 kg ha^{-1}), P (24.7 kg ha^{-1}) and K (125.2 kg ha^{-1}) and minimum under blue green algae (T_7). The percent increases in N uptake due to T_3, T_4, T_5 T_6 and T_7 were 17.8, 14.9, 6.8, 21.5 and 5.8% respectively over inorganic fertilizer alone. The corresponding increases in P uptake were 25.3, 27.3, 21.6, 36.7 & 5.0 percent. Similarly K uptake increased by 12.8, 10.9, 6.5, 19.8 and 1.8 percent. The increased N uptake in T_6 by rice was observed might be due to combined application of *dhaincha* and wheat residue along with inorganic fertilizer resulting regulated release of N from *dhaincha* for longer period to the crop (Yadvinder Singh *et al*. 2004a).

Wheat

Incorporation of organic sources of nutrients to the preceding rice crop had a significant residual effect on nutrient uptake by succeeding wheat crop. Significantly highest uptake of N (98.6 kg ha^{-1}), P (20.1 kg ha^{-1}) and K (124.9 kg ha^{-1}) by wheat was recorded with *dhaincha* (insitu) + wheat residue (5t ha^{-1}) comparable with T_4 in case of K only. The uptake values of N P and K by wheat with blue green algae were at par with inorganic fertilizer alone. The magnitude of increase in N uptake with T_3, T_4, T_5 T_6 and T_7 treatments was 7.3, 11.0, 4.5, 14.3 and 1.6% over inorganic fertilizer alone. The corresponding values for P uptake were 17.6, 16.1, 11.7, 24.8 and 4.7%. The K uptake by wheat increased by 4.9, 10.1, 3.6, 12.2 and 1.5% with organics (T_3 - T_7), respectively, over inorganic fertilizer alone. Higher uptake of N P and K by wheat with *dhaincha* (insitu) + wheat residue (5t ha^{-1}) was might be due to decomposition of wheat residue (wide C/N) with green manure which provides higher SOC contents resulting improved soil physical properties and increased available nutrients status of soil. Significant residual effect of incorporating wheat residue with green manure applied to rice on the uptake of N, P and K by succeeding wheat crop was also reported by Yaduvanshi and Sharma (2007).

Properties of soil

Puddling caused significant increase in bulk density of the soil (Table 2) and highest bulk density (1.4 Mgm^{-3}) in 0-15 cm layer was recorded under puddled plot as against 1.3 Mgm^{-3} in the non-puddled plots. This may be due to settling of soil particle which increased bulk density to great extent under puddled condition (Gangwar *et al*. 2006). The decrease in bulk density (7.14%) under non-puddled plots was might be due to increased soil aggregation

and porosity on account of increased SOC contents. Application of organic sources except T_7 had significant effect on bulk density over inorganic fertilizer alone (T_2). The significantly lowest bulk density was recorded with *dhaincha* (insitu) + wheat residue (5t ha^{-1}) (1.28 Mgm^{-3}) as compared to (T_2) (1.43 Mgm^{-3}) and control (1.48 Mgm^{-3}). The bulk density under T_3, T_4, T_5 and T_7 treatments were 1.29, 1.32, 1.30 and 1.35 Mgm^{-3} respectively. The magnitude of decrease in bulk density with organic sources (T_3 – T_7) was 9.8, 7.7, 9.1, 10.5 and 5.6%, respectively as compared to inorganic fertilizer alone. Soil porosity was recorded higher (7.3%) under non-puddled treatment as compared to puddled one. Application of organics improved the porosity appreciably and the highest improvement was 12.8% under the treatment T_6. The corresponding improvement in porosity with T_3, T_5 T_4, and T_7 was 11.3, 10.6, 8.9 and 6.5%.

Soil pH, SOC and available N P K

Puddling treatments did not influence significantly the soil pH, SOC and available N P K while unpuddled plots performed comparatively better in terms of maintaining the SOC, available N, P and K level (Table 2). Incorporation of organic sources (T_3 – T_7) decreased the soil pH from 7.8-7.6 as against inorganic fertilizer alone (pH 8.0) and control (pH 8.2). The lowest soil pH was recorded with T_3 (7.6) and T_7 (7.6).

Table2: Effect of different treatments on physico-chemical properties of soil after three years

Treatments	Bulk Density (Mg m^{-3})	Porosity (%)	pH	SOC (g kg^{-1})	Available nutrients (Kg ha^{-1})		
					N	P	K
Soil Manipulation							
Puddling	1.40	46.8	7.8	5.2	241	15.8	239
Non-Puddling	1.30	50.2	7.8	5.4	245	16.4	242
CD (P=0.05)	0.08	-	-	0.3	4.3	NS	NS
Organic Sources							
T_1 - Control	1.48	42.6	8.2	3.7	213	13.8	194
T_2 - Inorganic fertilizer alone	1.43	46.1	8.0	4.4	237	15.1	221
T_3 – FYM (10t ha^{-1})	1.29	51.3	7.6	6.1	253	17.3	255
T_4 – *Dhaincha* (insitu)	1.32	50.2	7.7	5.6	247	16.3	245
T_5 – wheat residue (WR)(5 t ha^{-1})	1.30	51.0	7.8	5.8	251	16.6	261
T_6 – *Dhaincha* insitu + WR (5 t ha^{-1})	1.28	52.0	7.7	6.3	257	17.8	265
T_7 – Blue green Algae (BGA)	1.35	49.1	7.6	5.2	244	15.9	232
CD (P=0.05)	0.1	-	-	1.0	6.3	0.7	16
Initial Soil Status	1.44	-	8.2	4.2	228	14.6	203

Organic sources (T_3 – T_7) influenced significantly the SOC, available N, P and K except T_7 with respect to available K in soil (Table 2). The soil organic carbon contents (5.2- 6.3 g kg^{-1}) increased significantly with organics (T_3 – T_7) over inorganic fertilizer alone (4.4g kg^{-1}). The magnitude of increase in SOC contents with organics was 18.2 - 43.2% over inorganic fertilizer alone in a period of three years. Among the organics, plots receiving *dhaincha* (insitu) + wheat residue (5tha^{-1}) (T6) recorded higher SOC contents being at par with T_3 and T_5 over other treatments. Increase in SOC contents could be attributed to combined application of *dhaincha* and wheat residue containing higher organic carbon contents. Similar findings were also reported by Yadvinder-Singh *et al*. (2004a). Application of organics (T_3 – T_7) significantly increased the available N contents (244 -257 kg ha^{-1}) over inorganic fertilizer alone (237 kg ha^{-1}) (Table 2). A higher amount of available N (257 kg ha^{-1}) in soil was obtained with *dhaincha* (insitu) + wheat residue (5tha^{-1}), on par with T_3 and T_5 and significantly superior to T_4 and T_7. The increase in available N contents with incorporation of *dhaincha* (insitu) + wheat residue (5tha^{-1}) might be attributed to enhanced N mineralization. The favourable soil conditions under green manuring might have helped the mineralization

of soil N leading to higher available N (Sharma *et al*. 2000).

Available P contents (15.9-17.8 kg ha^{-1}) were significantly increased with organics (T_3 – T_7) as compared to inorganic fertilizer alone (15.1 kg ha^{-1}). The available P status was highest under *dhaincha* (insitu) + wheat residue (5tha^{-1}) (T_6), on par with T_3 and significantly superior to T_4, T_5, and T_7. The enhanced availability of soil P might be due to direct addition and production of organic acids during microbial decomposition of the wheat residue and green manure in soil and decrease in soil pH which results in increase in available soil P contents. Recycling of crop residues along with application of green manure increased available P contents of soil compared with chemical fertilizer alone also reported by Kumar *et al*. (2008). The incorporation of organics (T_3 – T_6) significantly increased the available K contents (245-265 kg ha^{-1}) of soil except T_7 (232 kg ha^{-1}) as compared to inorganic fertilizer alone (221 kg ha^{-1}) (Table 2). The highest increase in available K contents (265 kg ha^{-1}) was under the treatment receiving *dhaincha* (insitu) + wheat residue (5tha^{-1}), on par with T_3 and T_5 and significantly superior to T_4 and T_7. Increase in available K contents due to green manuring and wheat residue application may be attributed to the direct addition of potassium to the available pool of the soil (Yadvinder Singh *et al*. 2004a). Beneficial effect of green manuring on available K may also be attributed to reduction of fixation and release of K due to interaction of organic matter with clay besides the direct K addition to the available K pool of the soil (Pannu *et al*. 2003) Available N P and K contents in all the treatments (T_2 – T_7) were significantly superior over control.

Thus, it may be concluded from the above results that the application of *dhaincha* (insitu) + wheat residue (5t ha^{-1}) along with inorganic fertilizer to rice and inorganic fertilizer alone to wheat was found the best treatment for good soil health and highest productivity of rice and wheat crops by mitigating the ill effect of puddling on soil health in rice-wheat cropping system in lowlands.

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