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Use of Inorganic Fertilizers and FYM for Twenty-Nine Years in Rice-Wheat Cropping System Improves Physical Soil Quality Indices after Rice

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ABSTRACT

In order to assess the effect of balanced and imbalanced use of inorganic fertilizers and FYM in rice-wheat cropping system for twenty-nine years on physical soil quality indices after rice the observations were recorded from the continuing long-term fertility experiment initiated in 1984 at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar. Combined use of inorganic fertilizer along with FYM significantly improved the bulk density (BD), water holding capacity (WHC), hydraulic conductivity (HC), mean weight diameter (MWD) and water stable aggregate (WSA) after rice in both the surface and sub-surface soil layer. Lowest bulk density (1.28 and 1.35 g cm⁻³) in surface and sub-surface soil, respectively was achieved due to N₁₂₀+P₄₀ +K₄₀+FYM and N₁₂₀+P₄₀+K₄₀+Zn(F)+FYM, while application of N₁₈₀+P₈₀+K₄₀+Zn(F)+FYM resulted in highest WHC (69.32 and 57.94%), HC (0.273 and 0.192 cm hr⁻¹), MWD (0.610 and 0.506 mm) and WSA (24.15 and 20.27%) at surface and sub-soil surface layers, respectively. The positive significant correlations were observed between various soils physical quality indices whereas BD and PD were negatively correlated with MWD, WSA, porosity, WHC and HC. The present investigation clearly points out the significance of balanced use of nutrients including FYM in rice-wheat cropping system for improving the various physical soil quality indices over a long period.

Keywords

Long term fertilizer experiment, Rice, FYM, Physical indices, Soil quality.

Article Info

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Introduction

India produces about 20 percent of the total production of rice globally ranking second. In India, Rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.) cropping system covers about 12 million hectares (Tripathi *et al.*, 2011) and it is the backbone of country's food security with a yield potential of 8-12 t/ha/year (Ladha *et al.*, 2012). Rice and wheat together plays a pivotal role in livelihood sustenance across the India.

The contribution of rice-wheat production was 101.05 million tonnes out of 264 million tonnes of food grain production in 2014-2015 (Economic Survey, 2015) accounting to about 38 percent of total production. In northern India rice-wheat cropping system covers about 60% of the total area. The nutrient requirement of rice and wheat crops is of great concern in order to feed the over growing population of the country both being

an exhaustive feeder. The nutrient requirement of these crops is generally met through application of imbalance use of N, P and K through inorganic chemical fertilizers. However, prolonged imbalanced use of fertilizers in the absence/meager application of organic manure hampers the soil quality as well as sustainability of crop production.

For the development of sustainable food production system maintenance and management of soil fertility is pivotal (Doran *et al.*, 1988). Thus, the logical way emerging to manage long-term fertility and productivity of soil is integrated use of organic and inorganic sources of plant nutrients to address the concern of excess and/ or depletion of nutrients (Aulakh and Grant, 2008). The use of organic manures and/ crop residue is gaining recognition for the maintenance of the soil quality (Chander *et al.*, 1997).

Physical soil quality indices have a vital role in soil productivity and un-disposable components of soil quality assessment (Karlen and Cambredella, 1996). Physical parameters of soil such as bulk density, hydraulic conductivity, porosity, soil strength and particle size distribution dictates the varying soil functions (Wagenet and Hutson, 1997). An application of both inorganic and organic fertilizers improves water holding capacity, porosity, and water stable aggregates and decreasing bulk density and surface crusting *vis-à-vis* soil fertility and productivity. As the application of organic manures brings about structural improvement, it increases the air capacity, may cause the roots to extend into and exploit a larger volume of soil in addition to increasing water retention in the soil profile (Pernes-Debuyser and Tessier, 2004). Improvement in structure, water retention characteristics, water holding capacity saturated hydraulic conductivity, mean weight diameter, aggregate stability and also

lowering the bulk density for sandy clay loam soil were observed under permanent manurial trial (Bishwas and Khosla, 1971). Application of continuous addition of inorganic fertilizer along with organic manures resulted in improvement in soil physical properties as well as productivity of crops on soil as compared to inorganic alone (Belaki *et al.*, 1998). Long-term fertilizer experiments are very pivotal asset to understand the impact of various nutrient management practices on soil quality, sustainability and productivity over a period of time. The present investigation was targeted to study the impact of continuous use of inorganic fertilizers at varying levels alone and with FYM for twenty-nine years in rice-wheat crop rotation on physical soil quality indices after rice in Mollisols.

Materials and Methods

The present investigation was carried out in an ongoing long term experiment, after twenty nine years, located at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, U. S. Nagar, Uttarakhand which was initiated in 1984. The experimental site lies in *Tarai* plains about 30 km southward of foothill of shivalik range of Himalayas at 29⁰ N latitude, 79⁰ 29' E longitude and at an altitude of 243.8 m above the mean sea level. The chemical analysis of top 15 cm soil showed that it was rich in organic matter and medium in phosphorus and potassium and neutral to slightly alkaline in reaction. The field experiment has been laid in Randomized Block Design (RBD) in four replications with fourteen treatments comprising control, N, NP, NPK at varying doses alone and with FYM. The N, P and K were provided as per treatment details through urea, single super phosphate and muriate of potash, respectively. In one treatment N and P was provided using Di-ammonium phosphate. The FYM was applied @5 tonne ha¹ only in rice crop.

Collection of soil samples and processing

Individual soil samples from each plot were collected from two depths (0-15 and 15-30 cm) after harvesting of rice crop in the year 2013-14. These individual soil samples were pooled to get one representative composite sample each for every depth from all the plots.

The soil bulk density at desired depths (0-15 and 15-30 cm) was determined by core sampler method (Blake, 1965). Water holding capacity of soil was determined by the method enlisted by Piper (1950). The undisturbed soil samples of desired depths (0-15 and 15-30 cm) were taken by core, and used for determination of hydraulic conductivity by constant head method (Klute, 1965). Air dried solid clods were used for aggregate analysis employing modified Yoder's wet sieving method (Van-Bavel, 1953)

Statistical analysis

The experimental data were analysed using the statistical program STPR of G. B. Pant University of Agriculture and Technology, Pantnagar in a Randomized Block Design. Analysis of Variance and critical difference (CD) between treatments was calculated at 5% level of significance. Correlation coefficients were computed using SPSS version 16.

Results and Discussion

The long term fertilization and manuring in rice-wheat cropping system significantly influenced the bulk density of surface as well as sub-surface soil (Table 1). The combined use of inorganic fertilizers along with FYM significantly improved the bulk density of soil. The highest bulk density of surface and sub-surface soil layers (1.39 and 1.46 g cm^{-3})

was recorded in control, while the lowest (1.28 and 1.35 g cm^{-3}) due to application of $\text{N}_{120}+\text{P}_{40}+\text{K}_{40}+\text{FYM}$ and $\text{N}_{120}+\text{P}_{40}+\text{K}_{40}+\text{Zn(F)}+\text{FYM}$ in surface and subsurface soil layer, respectively. Combined application of inorganic fertilizer and FYM reduced the bulk density of surface and sub-surface layer by 7.75-8.59 and 7.35-8.15 percent, respectively over the control. An application of inorganic fertilizer along with FYM significantly improved soil aggregation (Singh *et al.*, 2000), organic carbon content and more pore space (Selvi *et al.*, 2005) favoring lower bulk density. Similarly, reduction of bulk density due to application of FYM along with inorganic fertilizer were also observed by Bellaki *et al.*, (1998) and Bhattacharya *et al.*, (2004). The bulk density of soil increased slightly with increasing soil depth. This could be attributed to greater soil organic carbon content in the surface soil and more compaction in the sub-surface layer. An application of compost, mycorrhiza, organic manure and fertilizer reduced the bulk density and improved other some physical properties of soil (Celik *et al.*, 2004). Reduced bulk density can be explained with the significant inverse correlation of BD with porosity ($r = -0.939^{**}$), MWD ($r = -0.852^{**}$) and WSA ($r = -0.739^{**}$).

The particle density (PD) and porosity did not vary significantly from control over a period of twenty-nine years due to continuous application of inorganic fertilizers alone and along with organic manure. However, in the surface layer particle density reduced marginally by 3.49-3.89 percent while the porosity enhanced by 5.76-6.54 percent due to combined application of chemical fertilizers and FYM (Table 1). The reduced particle density can be explained as PD was inversely correlated with mean weight diameter ($r = -0.798^{**}$), water stable aggregates ($r = -0.803^{**}$) indicating reduction in mean weight diameter and water stable aggregates will result in the

increase in PD. The porosity was also inversely correlated with MWD ($r = -0.816^{**}$), WSA ($r = -0.698^{**}$) and PD ($r = -0.851^{**}$). Increase in mean weight diameter, water stable aggregates and decrease in PD results in increase in volume *vis-à-vis* porosity. This might be due to increase soil organic carbon content of higher root biomass with application of fertilizer and more aggregate formation with the presence of FYM (Nandapure *et al.*, 2014; Dhaliwal *et al.*, 2015).

The significant influence of nutrient application through fertilizer alone and with FYM for twenty-nine years on water holding capacity and hydraulic conductivity of surface and sub-surface soil after harvest of rice crop was observed (Table 2). Highest water holding capacity and hydraulic conductivity in surface and sub-surface soil layers was recorded with application of $N_{180}+P_{80}+K_{40}+Zn(F)+FYM$, whereas, the lowest was observed under control. The

increase in water holding capacity and hydraulic conductivity due to the $N_{180}+P_{80}+K_{40}+Zn(F)+FYM$ after twenty nine years was to the tune of 27.45 & 22.73; and 88.28 & 42.22 percent in surface and sub-surface soil layers, respectively. The higher water holding capacity in the surface layer could be due to surface application of FYM. Application of NPK + FYM increased the WHC of soil largely due to its beneficial impact on soil aggregation (Prasad and Singh, 1980). In the present investigation WHC and WSA were correlated significantly ($r = 0.833^{**}$) supporting the observation of Prasad and Singh (1980). The WHC was 11% higher with FYM and $N_{120}P_{30}K_{30}$ application as compared to control (Rehana *et al.*, 2007). Selvi *et al.*, (2005) also found that in long term fertilizer experiment WHC was highest in the plots receiving 100% NPK+FYM. They suggested that addition of organic matter helped in increasing the water holding capacity of the soil.

Table.1 Effect of long-term fertilizer application at varying levels on bulk density, particle density and porosity after twenty-ninth cycle of rice crop at different depths under rice-wheat cropping system

Treatments		Bulk density ($g\ cm^{-3}$)		Particle density ($g\ cm^{-3}$)		Porosity (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Control	1.39	1.46	2.67	2.75	46.31	45.12
T ₂	N ₁₂₀	1.37	1.43	2.65	2.73	46.57	45.88
T ₃	N ₁₂₀ +P ₄₀	1.37	1.43	2.65	2.73	46.79	45.87
T ₄	P ₄₀ +K ₄₀	1.36	1.40	2.64	2.72	47.92	47.00
T ₅	N ₁₂₀ +K ₄₀	1.37	1.41	2.65	2.73	47.05	46.90
T ₆	N ₁₂₀ +P ₄₀ +K ₄₀	1.36	1.40	2.64	2.72	47.16	46.74
T ₇	N ₁₂₀ +P ₄₀ +K ₄₀ +Zn(F)	1.33	1.38	2.63	2.71	47.43	46.83
T ₈	N ₁₂₀ +P ₄₀ +K ₄₀ +FYM	1.28	1.35	2.57	2.65	49.10	48.00
T ₉	N ₁₂₀ +P ₄₀ +K ₄₀ +Zn(F)+FYM	1.28	1.35	2.57	2.65	49.34	48.04
T ₁₀	N ₁₈₀ +P ₈₀ +K ₄₀ +Zn(F)+FYM	1.29	1.36	2.58	2.66	48.98	47.86
T ₁₁	N ₁₅₀ +P ₄₀ +K ₄₀	1.36	1.40	2.63	2.71	46.91	45.65
T ₁₂	N ₁₈₀ +P ₈₀ +K ₄₀ +Zn(F)	1.32	1.36	2.64	2.72	48.77	46.95
T ₁₃	N ₁₈₀ +P ₈₀ +Zn(F)	1.33	1.39	2.64	2.72	47.62	46.42
T ₁₄	N ₁₂₀ +P ₄₀ +K ₄₀ (DAP)	1.35	1.39	2.63	2.71	47.12	46.25
S.Em+		0.02	0.02	0.06	0.08	1.69	1.39
C.D. (5%)		0.06	0.06	NS	NS	NS	NS
C.V. (%)		3.54	3.26	4.72	5.61	7.11	5.79

Table.2 Effect of long-term fertilizer application at varying levels on water holding capacity and hydraulic conductivity after twenty-ninth cycle of rice crop at different depths under rice-wheat cropping system

Treatments		WHC (%)		Hydraulic conductivity (cm hr ⁻¹)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Control	54.39	47.21	0.145	0.135
T ₂	N ₁₂₀	56.05	51.10	0.181	0.149
T ₃	N ₁₂₀ +P ₄₀	57.42	55.75	0.237	0.154
T ₄	P ₄₀ +K ₄₀	55.22	52.59	0.207	0.151
T ₅	N ₁₂₀ +K ₄₀	57.02	53.55	0.227	0.152
T ₆	N ₁₂₀ +P ₄₀ +K ₄₀	60.02	54.05	0.241	0.155
T ₇	N ₁₂₀ +P ₄₀ +K ₄₀ +Zn(F)	60.91	54.84	0.251	0.168
T ₈	N ₁₂₀ +P ₄₀ +K ₄₀ +FYM	66.65	55.65	0.253	0.159
T ₉	N ₁₂₀ +P ₄₀ +K ₄₀ +Zn(F)+FYM	67.34	56.36	0.262	0.171
T ₁₀	N ₁₈₀ +P ₈₀ +K ₄₀ +Zn(F)+FYM	69.32	57.94	0.273	0.192
T ₁₁	N ₁₅₀ +P ₄₀ +K ₄₀	60.33	54.59	0.243	0.156
T ₁₂	N ₁₈₀ +P ₈₀ +K ₄₀ +Zn(F)	61.30	54.63	0.245	0.157
T ₁₃	N ₁₈₀ +P ₈₀ +Zn(F)	59.28	54.31	0.230	0.153
T ₁₄	N ₁₂₀ +P ₄₀ +K ₄₀ (DAP)	59.24	54.29	0.191	0.150
S.Em+		1.82	1.80	0.007	0.005
C.D. (5%)		5.23	5.15	0.021	0.015
C.V. (%)		6.04	6.64	6.36	6.688

Table.3 Effect of long-term fertilizer application at varying levels on mean weight diameter (MWD) and water Stable aggregate after twenty-ninth cycle of rice crop at different depths under rice-wheat cropping system

Treatments		MWD (mm)		Aggregate Stability (%)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁	Control	0.463	0.330	19.88	15.94
T ₂	N ₁₂₀	0.500	0.420	21.59	17.32
T ₃	N ₁₂₀ +P ₄₀	0.533	0.425	22.03	17.52
T ₄	P ₄₀ +K ₄₀	0.537	0.427	21.58	17.28
T ₅	N ₁₂₀ +K ₄₀	0.540	0.443	21.36	17.19
T ₆	N ₁₂₀ +P ₄₀ +K ₄₀	0.542	0.457	22.54	18.87
T ₇	N ₁₂₀ +P ₄₀ +K ₄₀ +Zn(F)	0.566	0.460	21.95	17.15
T ₈	N ₁₂₀ +P ₄₀ +K ₄₀ +FYM	0.586	0.473	22.77	19.57
T ₉	N ₁₂₀ +P ₄₀ +K ₄₀ +Zn(F)+FYM	0.590	0.490	23.57	19.70
T ₁₀	N ₁₈₀ +P ₈₀ +K ₄₀ +Zn(F)+FYM	0.610	0.506	24.15	20.27
T ₁₁	N ₁₅₀ +P ₄₀ +K ₄₀	0.569	0.470	21.88	18.38
T ₁₂	N ₁₈₀ +P ₈₀ +K ₄₀ +Zn(F)	0.571	0.480	21.42	17.44
T ₁₃	N ₁₈₀ +P ₈₀ +Zn(F)	0.564	0.460	21.59	17.49
T ₁₄	N ₁₂₀ +P ₄₀ +K ₄₀ (DAP)	0.528	0.421	20.45	17.14
S.Em+		0.017	0.018	0.79	0.69
C.D. (5%)		0.049	0.053	N/A	2.03
C.V. (%)		5.298	7.062	6.29	6.72

Enhanced hydraulic conductivity due to $N_{180}+P_{80}+K_{40}+Zn$ (F) + FYM can be attributed to soil aggregation and porosity. The hydraulic conductivity was inversely correlated with WSA ($r = -0.838^{**}$) and porosity ($r = -0.693^{**}$). Patnaik *et al.*, (1989) and Selvi *et al.*, (2005) recorded improved HC with application of FYM along with 100% NPK. Continuous addition of FYM and lime in combination with chemical fertilizers improved the HC of soil (Prasad and Singh, 1980). Increasing levels of NPK significantly increased the HC and highest HC was observed with 100% NPK + 10 t FYM ha⁻¹ and lowest in control (Nandapure *et al.*, 2014).

An application of fertilizers alone at varying levels and with FYM for twenty-nine years significantly influenced mean weight diameter of soil aggregates at surface (0-15cm) and sub-surface layer (15-30 cm) after harvest of rice crop (Table 3). Mean weight diameter of soil was decreased with increase in soil depth although the impact of treatment was pronounced in sub-surface layer. The use of $N_{180}+P_{80}+K_{40}+Zn(F)+FYM$ in rice crop in rice-wheat crop rotation increased the mean weight diameter by 31.74 and 53.33 percent in surface and sub-surface soil layers of soil over control, respectively. It may be due to the direct effect of FYM as a binding agent (Bhusan and Sharma, 2002). The balanced use of chemical fertilizers with FYM stimulates the root biomass production and root exudation resulting in enhanced addition of the organic matter in soil leading more microbial activity producing more polysaccharides and organic acids *vis-à-vis* improved mean weight diameter of soil through gluing effect. Similarly, the inorganic fertilizers helped in increasing the root biomass which ultimately increased the mean weight diameter (Haynes and Naidu, 1998).

In surface layer (0-15 cm) the percentage of water stable aggregates varied non-

significantly after twenty-ninth cycle of rice crop however, in sub-surface layer significant impact was observed with application of balanced application of inorganic fertilizers alone and with FYM (Table 3). The highest water stable aggregate formation (24.15 and 20.27%) in surface and sub-surface layer of soil was supported due to $N_{180}+P_{80}+K_{40}+Zn(F)+FYM$ which was higher by 21.48 and 27.16 percent over control, respectively. The enhanced root biomass production in the presence of balanced application of nutrients through inorganic and organic sources increases the microbial activity producing the polysaccharides. The microbial polysaccharides and root exudates bind the soil particles through their gluing action and improve the water stable aggregates. The improvement of aggregate stability in continuous use of chemical fertilizers along with organic manure may be due to the beneficial effect of certain polysaccharides formed during decomposition of organic manure by microbial activity (Mishra and Sharma, 1997; Subbian *et al.*, 2000). Organic matter is classified as an important binding agent for aggregation and is also responsible for the formation and stability of soil aggregates (Tisdall and Oades, 1982.) Increased percentage of aggregates with the application of 100% NPK along with FYM was observed (Roberson *et al.*, 1995; Selvi *et al.*, 2005).

The physical soil quality indices (bulk density, particle density, porosity, water holding capacity, saturated hydraulic conductivity, mean weight diameter and aggregate stability) of soil were improved after rice in rice-wheat crop rotation due to use of inorganic fertilizer along with FYM over a period of twenty-nine years. Hence, the balance and imbalanced use of nutrients through chemical fertilizers and organic manures should be followed for the improvement of physical soil quality for sustainability.

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