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Effect of inorganic fertilizers and FYM for twenty-nine years in rice-wheat cropping system improves physical soil quality indices after wheat

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Abstract
A study was conducted toassess the long-term effects of balanced and imbalanced use of inorganic fertilizers and FYM on physical soil quality indices after 29thcycle of wheat crop in rice and wheat cropping sequence. The observations were recorded from the continuing long-term fertility experiment initiated in 1984 at Norman. E. Borloug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar. Combined use of inorganic fertilizer along with FYMsignificantly improved the bulk density (BD), water holding capacity (WHC), and hydraulic conductivity (HC) after wheatin both the surface and sub-surfacesoil layer.Lowest bulk density (1.26 and 1.33 g cm^{-3}) in surface and sub-surface soil, respectively was recorded due to $N_{120}+P_{40}+K_{40}$+FYM and $N_{120}+P_{40}+K_{40}$+Zn(F)+FYM, whileapplication of $N_{180}+P_{80}+K_{40}$+Zn(F)+FYM resulted in highest WHC (69.95 and 58.61%), HC (0.278 and 0.198cm hr^{-1}), at surface and sub-soil surface layers, respectively. The positive significant correlations were observed between various soilsphysical quality indices whereasBD and PD were negatively correlated with 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, wheat, FYM, physical indices, soil quality

Introduction

Rice-wheat cropping system plays a significant role in food security, contributing 76% of total food grain production of India. 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) [7] accounting to about 38 percent of total production.Imbalance use of chemical fertilizers alone tends to decline soil quality and fertility over a period of years with given inputs. Therefore, the most logical way to manage long-term fertility and productivity of soil is integrated use of inorganic and organic sources of plant nutrients. For the development of sustainable food production system maintenance and management of soil fertility is pivotal (Doran *et al.*, 1988) [6] 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) [2]

In agriculture, soil quality refers to the soil's ability to sustain production (Lal, 1994) [10] High soil quality is associated with efficient use of water, nutrients and pesticide, improvement in water and air quality, mitigation of greenhouse gas emission, and increase in agronomic production. Soil quality cannot be measured directly, but it is inferred from static or dynamic soil quality indicators (SQIs) or measurable soil attributes generally influenced by land use and soil management practices (Sanchez-Maranon *et al*., 2002[16] Seybold *et al*., 1997 [18] and Shukla *et al* 2006) [19] Soil's physical properties can be used as indicators for making soil quality assessments and for determining the sustainability of farming system. The physical properties of soils such as bulk density, particle density, total porosity, saturated hydraulic conductivity, water holding capacity, mean weight diameter and aggregate size distribution were improved in plots amended with fertilizer and organic manure (Aggelides and Londra 2000).[1] The present study summarizes the long-term effect of chemical fertilizer and organic manure on the physical properties of soil. 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 wheat 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 29^0 N latitude, 79^0 29' E longitudeand atan 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 replicationswith fourteen treatments comprising control, N, NP, NPK, varying dosesalone and with FYM. The N, P and K were provided as per treatment details through urea, single super phosphate and potassium, respectively. In one treatment N and P was provided using Di-ammonium phosphate. The FYM was applied @5 tonne ha^1 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 wheat 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) [3] Water holding capacity of soil was determined by the method developed by Piper (1950) [13] 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) [9].

Statistical analysis

The experimental data were analyzed 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 application of inorganic fertilizers along with FYM significantly improved the bulk density of soil. The highest bulk density of surface and sub-surface soil layers (1.37 and 1.44g cm^{-3}) was recorded in control, while thelowest (1.26 and 1.33 g cm^{-3}) due to application of N_{120}+P_{40}+K_{40}+Zn(F)+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 7.71-8.55 and 7.31-8.12 percent, respectively over the control.An application of inorganic fertilizer along with FYM significantlyimproved soil aggregation (Singh *et al.*, 2000) [20] organic carbon content and more pore space (Selvi*et al.,* 2005) [17] favoring lower bulk density. Similarly, reduction of bulk density due to application of FYM along with inorganic fertilizers were also observed by Kaushal (2002) [8]. 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, mychorrhiza, organic manure and fertilizer reduced the bulk density and improved other some physical properties of soil (Celik*et al*., 2004) [4]. Reduced bulk density can be explained with the significant negative correlation of BD with porosity (r= -0.917**), WHC (r= -0.938**) and HC (r= -0.719**).

The particle density (PD) and porosity did not vary significantlyfrom control over a period of twenty-nine years due to continuous application of inorganic fertilizersalone and along with organic manure.The highest particle density of surface and sub-surface soil layers (2.57 and 2.64 g cm^{-3}) was recorded in control, while the lowest (2.49 and 2.57 g cm^{-3}) due to application of N_{120}+P_{40}+K_{40}+Zn(F)+FYM in surface and subsurface soil layer, respectively.The highest porosity of surface and sub-surface soil layers (50.22 and 48.06%) was recorded in N_{120}+P_{40}+K_{40}+Zn(F)+FYM , while the lowest porosity (46.70 and 45.21%) due to application of control in surface and subsurface soil layer, respectively(Table 1).The reduced particle density can be explained as significantly negative correlations were observed between PD and WHC (r= -0.896**), HC (r= -0.750**) indicating reduction in WHC and HC will result in the increase in PD. The porosity was significantly correlated with WHC (r= 0.820**) and HC (r= 0.662**) while it showed significantly negative correlation with PD (r= -0.819**). Increase in WHC, HC 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 [11] and Dhaliwal *et al.*, 2015) [5]

Table 1: Effect of long-term fertilizer application at varying levels on bulk density, particle density and porosity after twenty-ninth cycle of wheat 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	1.37	1.44	2.57	2.64	46.70	45.21
T_2	N_{120}	1.35	1.41	2.55	2.62	47.90	46.38
T_3	N_{120}+P_{40}	1.35	1.41	2.55	2.62	47.91	46.45
T_4	P_{40}+K_{40}	1.34	1.38	2.54	2.61	47.92	46.59
T_5	N_{120}+K_{40}	1.35	1.39	2.55	2.62	47.05	46.19
T_6	N_{120}+P_{40}+K_{40}	1.34	1.38	2.54	2.61	47.99	46.90
T_7	N_{120}+P_{40}+K_{40}+Zn(F)	1.33	1.36	2.53	2.60	48.84	47.30
T_8	N_{120}+P_{40}+K_{40}+FYM	1.27	1.33	2.49	2.57	49.96	47.72

T_9	$N_{120}+P_{40}+K_{40}$+Zn(F)+FYM	1.26	1.33	2.49	2.57	50.22	48.06
T_{10}	$N_{180}+P_{80}+K_{40}$+Zn(F)+FYM	1.27	1.34	2.50	2.58	49.10	47.62
T_{11}	$N_{150}+P_{40}+K_{40}$	1.34	1.38	2.53	2.61	47.29	46.00
T_{12}	$N_{180}+P_{80}+K_{40}$+Zn(F)	1.31	1.35	2.54	2.62	48.82	47.67
T_{13}	$N_{180}+P_{80}$+Zn(F)	1.33	1.37	2.54	2.62	47.83	47.23
T_{14}	$N_{120}+P_{40}+K_{40}$ (DAP)	1.34	1.38	2.52	2.61	47.32	47.10
S.Em±		0.02	0.02	0.07	0.06	1.63	1.96
C.D. (5%)		0.06	0.06	NS	NS	NS	NS
C.V. (%)		3.27	3.14	5.67	4.83	6.77	8.36

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 wheat 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 (69.32 and 57.94%) and (0.273 and 0.192) 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) [14]. In the present investigation WHC and HC were correlated significantly (r= 0.816**) supporting the observation of Prasad and Singh (1980) [14] The WHC was 11% higher with FYM and $N_{120}P_{30}K_{30}$ application as compared to control (Rehana*et al*., 2007) [15] and Selvi*et al.* (2005) [17] 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 2: Effect of long-term fertilizer application at varying levels on water holding capacity and hydraulic conductivity after twenty-ninth cycle of wheat 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	54.73	47.96	0.147	0.138
T_2	N_{120}	56.93	51.10	0.188	0.150
T_3	$N_{120}+P_{40}$	58.11	54.15	0.239	0.158
T_4	$P_{40}+K_{40}$	56.03	53.01	0.209	0.153
T_5	$N_{120}+K_{40}$	58.97	55.95	0.229	0.155
T_6	$N_{120}+P_{40}+K_{40}$	60.16	55.55	0.255	0.157
T_7	$N_{120}+P_{40}+K_{40}$+Zn(F)	62.33	56.75	0.258	0.169
T_8	$N_{120}+P_{40}+K_{40}$+FYM	66.95	57.12	0.266	0.175
T_9	$N_{120}+P_{40}+K_{40}$+Zn(F)+FYM	67.37	57.98	0.269	0.178
T_{10}	$N_{180}+P_{80}+K_{40}$+Zn(F)+FYM	69.95	58.61	0.278	0.198
T_{11}	$N_{150}+P_{40}+K_{40}$	61.28	55.74	0.248	0.156
T_{12}	$N_{180}+P_{80}+K_{40}$+Zn(F)	61.98	55.91	0.257	0.160
T_{13}	$N_{180}+P_{80}$+Zn(F)	60.12	55.57	0.249	0.158
T_{14}	$N_{120}+P_{40}+K_{40}$ (DAP)	59.27	55.49	0.243	0.155
S.Em±		2.21	1.39	0.008	0.004
C.D. (5%)		6.34	4.00	0.023	0.012
C.V. (%)		7.24	5.06	6.606	5.111

Enhanced hydraulic conductivity due to $N_{180}+P_{80}+K_{40}$+Zn (F) +FYM was due to the improved soil aggregation and porosity. The hydraulic conductivity was significantly correlated with porosity (r= 0.662**) and WHC (r= 0.816**). Patnaik*et al.* (1989) [12] and Selvi*et al.* (2005) [17] 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) [14] 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) [11].

Conclusion

The physical properties (bulk density, particle density, porosity, water holding capacity, and saturated hydraulic conductivity,) of soil were improved after wheat in rice-wheat crop rotation due to continuous long term application of inorganic fertilizer along with FYM over a period of twenty-nine years. Hence, the balance and imbalanced use nutrients through chemical fertilizers and organics manure should be followed for the improvement of physical soil quality for sustainability.

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