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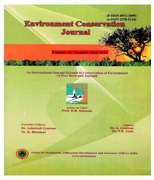

Continuous application of chemical fertilizers and organics influenced the soil chemical properties and zinc content of rice in the vertisols of the Chhattisgarh Plain

Chhaviraj Baghel✉
Department of Soil Science, CSK HPKV, Palampur, Himachal Pradesh
Alok Tiwari
College of Agriculture and Research Station, Saja, Bemetara, Chhattisgarh
Vinay Bachkaiya
Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh

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ABSTRACT

An experiment was carried out in rice crop on Vertisol (locally called as Kanhar) at research farm of College of Agriculture, IGKV, Raipur, during kharif 2019-20 entitled "Continuous application of chemical fertilizers and organics influenced the soil chemical properties and zinc content of rice in the vertisols of the Chhattisgarh Plain". This study comprised of ten treatments: control (no fertilizer), 50% NPK (suboptimal dose), 100% NPK (optimal dose), 150% NPK (super optimal dose) and 100% NPK along with $ZnSO_4$ @ 10 kg/ha, 100% NP, 100% N alone, 100% NPK along with farmyard manure @ 5t/ha, 50% NPK along with blue green algae @ 10 kg/ha and 50% NPK along with green manure @ 40 kg/ha. The experiment was laid out at randomized complete block design which was replicated four times. Long term effect of continuous application of chemical fertilizers and organic manures significantly influenced the physico-chemical properties viz. highest "organic carbon (0.67%) available N (252 kg/ha), P (29 kg/ha) and K (425 kg/ha) in 100% NPK + FYM and lowest was obtained under control treatment (0.45% OC), (177 N kg/ha), (10.1 P kg/ha) and (368 K kg/ha), respectively. The addition of farm yard manure and NPK also reduces soil acidity compared to NPK use alone. Among the treatment of 150% NPK accumulated more total soluble salts end of this treatment could be attributed to low residue will effect of fertilizers and nutrient removal by crop.

Introduction

Fertilizers are important for agricultural production, but growing large crops that require heavy doses of inorganic fertilizer over an extended period of time can be unsustainable in terms of output and environmentally hazardous (Smith *et al*. 1990, 2000; Harrison and Webb 2001). The development of multiple nutrient deficiencies and the degradation of the environment caused by fertilizers are the main causes of concern. Similarly, looking for organic waste as a substitute source to augment the nitrogen requirements of various crops is necessitated by rising fertilizer prices and restricted availability. A zinc (Zn) shortage is a global problem caused by the adoption of high-yield agricultural practices that have high Zn requirements and the increasing zinc demands of dense cropping systems. Additional causes for the increase in zinc-deficient areas include increased crop yields on low-zinc soil, increased zinc levels, reduced fertilizer use, reduced usage of animal dung, reduced use of manure, and reduced use of crop residue. In addition, human and natural factors can limit the availability of sufficient plant nutrients and result in nutritional imbalances (Fergeria *et al*., 2011). To maintain the highest possible level of soil fertility and achieve the required yield, fertilizer containing accessible amounts of manure is increasingly commonly used. The beneficial effect of using both inorganic

Corresponding author E-mail: chhaviraj.baghel007@gmail.com
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fertilizer and organic manure together can be perceived in this context through long-term fertilizer experiments. This effect is particularly prominent after a few years of continuous cropping with only nitrogen-phosphorus-potassium (NPK) applied, without any organic manure or micronutrient fertilizer (Swarup 2002; Katyal and Rattan 2003; Patel *et al*. 2003). Approximately 15% of the world's population depends on rice–wheat cropping systems (RWCSs) for their primary foods (Ray *et al*.,2012). The degradation of soil quality linked to resource shortages is the main problem facing the sustainability of conventional RWCSs in South Asia (Jat *et al*., 2018). Maintaining the health of the soil is essential for meeting the food and nutritional needs of India. Long-term soil health and crop productivity cannot be sustained by chemical fertilizers alone.

Materials and Methods

Study Site Description

A long–term field experiment was conducted at the research farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, during Kharif 2019-20. The site is in a subhumid zone, located at 22° 33’ N to 21° 14’ N latitude and 82° 6’ E to 81° 38’ E longitude at an altitude of 293 m above the mean sea level, which receives approximately 1200 – 1300 mm (51”) of rainfall, mostly in the monsoon season from late June to early October. The soil of the study area was classified as Vertisol, with fine Montmorillonite clay, also locally known as Kanhar, and identified as the Arang II series, with pH = 7.5, EC = 0.23 ds/m and OC = 0.60%, available nitrogen of 212.39, phosphorus of 21.31 kg/ha, potassium of 386.25 kg/ha, sulphur of 25.98 kg/ha and DTPA-extractable zinc of 1.2 mg/kg (Annual report LTFE, 2000).

Experimental details

The field experiment was carried out in a randomized block design with ten treatments that were replicated four times. The ten treatments included various inorganic and organic sources, namely, control (no fertilizer), 50% NPK (suboptimal dose), 100% NPK (optimal dose), 150% NPK (super optimal dose) and 100% NPK along with $ZnSO_4$ @ 10 kg/ha, 100% NP, 100% N alone, 100% NPK along with farmyard manure @ 5 t/ha, 50% NPK along with blue–green algae @ 10 kg/ha and 50% NPK along with green manure @ 40 kg/ha. The rice variety Rajeshwari R-1 was selected as a test crop, and various organic sources were applied in this experiment, *viz*., FYM, green manure (*Sesbania aculeta*) and blue–green algae. The recommended dose of NPK fertilizer for rice crops is 120:60:40 kg/ha. N, P and K were applied through urea, SSP and MOP, respectively, and nitrogen was applied in split doses. The in situ green-manure crop (Sunhemp) cultivated for a period of 45 days during the Kharif season was chopped into small pieces (5-7 cm) and incorporated into the soil with the help of a power-operated rotavator at the time of puddling before the transplantation of the rice crop.

Results and Discussion

Effect of chemical fertilizers and organics on the physicochemical properties of soil

pH is an important intrinsic property in soil that does not change, particularly in Vertisol soils, due to increased buffering capacity. The soil pH varied between 7.36 and 7.67 among the inorganic fertilizers and organic manures (Table 1). A significantly greater pH (7.67) was recorded in the 100% NPK+FYM treatment, whereas a lower pH (7.36) was obtained in the control plot. This result is in line with a similar observation, as explained by Shambhavi *et al.* (2017), that continuous fertilization over time reduces the pH. The addition of farmyard manure and NPK also reduced soil acidity compared to the addition of NPK alone. Similarly, Nagwanshi *et al*. (2018) reported that intensive cropping and continuous application of fertilizer in one or more combinations over 46 years resulted in little change in pH. The amount of soluble salts in the soil at a certain and specific temperature is determined by measuring the electrical conductivity (EC). The deposition of salts in soil is often known to be harmful to plant growth. The EC information shown in Table 2 included a range of treatments from 0.22 to 0.26 dS/m. The 150% NPK treatment had the highest (0.26 dS/m) EC, while the control and 100% N alone had the lowest (0.22 dS/m) EC. These findings, which are consistent with those of Bhavani *et al*. (2017), indicated that various treatments for long-term application of fertilizer and manure had an impact on the electrical conductivity of soil. Among the 150% NPK treatment, more total soluble salts accumulated at the end of this treatment, which could be attributed to low residue affecting fertilizer and nutrient removal by crops. The lowest EC occurred in the control plot, where the plot did not receive any fertilizer or manure, which was on par with the EC in the plots receiving organics alone or organic manure combined with NPK fertilizers.

Table 1: Effect of fertilization on pH before sowing of rice

S.No.	Treatment Name	pH
T_1	Control	7.36
T_2	50% NPK	7.43
T_3	100% NPK	7.50
T_4	150% NPK	7.60
T_5	100% NPK + $ZnSO_4$	7.37
T_6	100% NP	7.50
T_7	100% N	7.63
T_8	100% NPK + FYM	7.67
T_9	50% NPK + BGA	7.53
T_{10}	50% NPK + GM	7.57
	SEm (±)	0.06
	CD (p = 0.05)	0.19

Table 2: Effect of fertilization on the electrical conductivity of soil

S.No.	Treatment Name	EC (ds/m)
T_1	Control	0.22
T_2	50% NPK	0.24
T_3	100% NPK	0.25
T_4	150% NPK	0.26
T_5	100% NPK + $ZnSO_4$	0.23
T_6	100% NP	0.25
T_7	100% N	0.22
T_8	100% NPK + FYM	0.25
T_9	50% NPK + BGA	0.23
T_{10}	50% NPK + GM	0.25
	SEm (±)	0.01
	CD (p = 0.05)	0.02

Organic carbon (OC) helps to improve soil characteristics with the use of FYM, which increases crop productivity. Soil organic carbon (SOC) was greater in the rhizosphere than in the rhizosphere and decreased with increasing depth. The OC content at 0-15 cm increased with increasing levels of fertilizer application. The results indicated (Table 3) that the amount of OC in the soil gradually increased with nutrient application and ranged from 0.45 to 0.67. A significantly greater percentage of OC was recorded in the 100% NPK+FYM treatment (0.67%), followed by the 150% NPK treatment (0.65%). However, significantly lower (0.45%) OC was noted in the T1 control. This result is in line with a similar observation reported by Shambhavi *et al.* (2017) that the use of farmyard manure @ 10 t/ha to match crops increased the initial SOC content. The marked increase in LYM and NPK soils compared to all other treatments is attributed to improved crop production and was accompanied by greater recovery of composted material in the form of root rot, trash and crop residues. The constant increase in nitrogen availability in the soil encourages nitrogen fixation through biological processes and changes organically bound nitrogen into an inorganic form by way of atmospheric nitrogen. This could be the result of the soil bacteria multiplying more. The information in Table 4 shows that the application of organic manure to rice and inorganic fertilizer significantly enhanced the amount of nitrogen available in the soil. Regardless of the nutrient application technique, the application of fertilizers affects the soil's available N, which steadily declines with soil depth and ranges from 177 to 252 kg/ha. The treatments with 100% NPK and FYM @ 5 t/ha had significantly more available nitrogen (252 kg/ha) than did the treatment with the optimal dose (150% NPK). In contrast, the control plot had much less available nitrogen (177 kg/ha). Panwar *et al.* (2017) reported that the available nitrogen content increased successively and significantly, and the highest available nitrogen content was found in 100% NPK+FYM, while the lowest available nitrogen content was found in the control plot (no fertilizer). Katkar *et al.* (2011) revealed that the greatest amount of soil nitrogen was significantly greater when using FYM manure at 10 t/ha + 100% NPK. The soil N improved because of the long-term application of FYM at 10 t/ha + 100% NPK.

Nitrogen was obtained under NPK + farmyard manure rather than NPK alone through organic manure.

Table 3: Effect of fertilization on organic carbon before sowing of rice

S.No.	Treatment Name	OC (%)
T_1	Control	0.45
T_2	50% NPK	0.57
T_3	100% NPK	0.62
T_4	150% NPK	0.65
T_5	100% NPK + $ZnSO_4$	0.63
T_6	100% NP	0.61
T_7	100% N	0.59
T_8	100% NPK + FYM	0.67
T_9	50% NPK + BGA	0.58
T_{10}	50% NPK + GM	0.61
	SEm (±)	0.01
	CD (p = 0.05)	0.02

Table 4: Effect of fertilization on available nitrogen before sowing of rice

S.No.	Treatment Name	Available N (kg/ha)
T_1	Control	177
T_2	50% NPK	192
T_3	100% NPK	220
T_4	150% NPK	249
T_5	100% NPK + $ZnSO_4$	217
T_6	100% NP	213
T_7	100% N	206
T_8	100% NPK + FYM	252
T_9	50% NPK + BGA	192
T_{10}	50% NPK + GM	210
	SEm (±)	1.8
	CD (p = 0.05)	5.2

Table 5 shows that the available status of phosphorus in surface soil varied from 10.1-29.0 kg/ha, which considerably increased with nutrient application. A significantly greater P content (29.0 kg/ha) was recorded in the 100% NPK treatment than in the FYM treatment, followed by 27.3 and 26.3 kg/ha in the super optimal (150% NPK) and 100% NPK+Zn treatments, respectively. However, a significantly lower available P concentration of 10.13 kg/ha was detected in the control plot. The effect of the existing P content on the soil revealed that a high P content was associated with the highest subsequent application of fertilizer, and the lower P content was related to the control and N treatment only. This may be a result of the absence of P fertilization of the fertilizer, as proposed by Thakur *et al.* (2011). The available soil potassium data are presented in Table 6, which shows that the available K considerably increased with the effect of fertilization on rice. The soil available K, which gradually increased with the nutrient application treatments, ranged between 368 and 425 kg/ha. A significantly greater amount of available potassium (425 kg/ha) was detected in the 100% NPK treatment along with the FYM treatment at 5 t/ha, followed by the optimal NPK treatment at 150% NPK (414 kg/ha) and the optimal NPK treatment at 100% NPK (391 kg/ha). However, significantly lower available K (368 kg/ha) was detected in the control plot and 100% N-only plots.

Table 5: Effect of fertilization on available phosphorus before sowing of rice

S.No.	Treatment Name	Available P (kg/ha)
T_1	Control	10.1
T_2	50% NPK	14.6
T_3	100% NPK	26.0
T_4	150% NPK	27.3
T_5	100% NPK + $ZnSO_4$	26.3
T_6	100% NP	25.6
T_7	100% N	14.0
T_8	100% NPK + FYM	29.0
T_9	50% NPK + BGA	19.6
T_{10}	50% NPK + GM	20.6
	SEm (±)	0.3
	CD (p = 0.05)	1.1

Table 6: Effect of fertilization on available potassium before sowing of rice

S.No.	Treatment Name	Available K (kg/ha)
T_1	Control	368
T_2	50% NPK	381
T_3	100% NPK	391
T_4	150% NPK	414
T_5	100% NPK + $ZnSO_4$	385
T_6	100% NP	376
T_7	100% N	374
T_8	100% NPK + FYM	425
T_9	50% NPK + BGA	383
T_{10}	50% NPK + GM	386
	SEm (±)	3.0
	CD (p = 0.05)	8.0

Similarly, Parewa *et al.* (2014) reported that the available K content decreased in the control treatment. However, the availability of this nutrient in the rest of the treatments increased from its early level. A higher rate of available K was obtained because of two mixed applications of optimal doses of NPK and FYM @ 10 t/ha and bioinoculants. The lower values of these nutrients were controlled by the greater adsorption of nutrients by the wheat crop. The available K content in the soil considerably increased with increasing levels of fertilizer, but the K contents under the 75% and 100% NPK treatments were similar.

Zn content

The diverse applications of chemical fertilizer and organic manure had a substantial impact on the Zn concentration in the grain and straw. The Zn content of the rice is presented in Table 7. Higher Zn concentrations in grain and straw were recorded under the combined application of fertilizer and manure than under the application of inorganic fertilizer alone. The data presented in Table 7 indicate that the highest Zn content in grain (18.63 mg/kg) and straw (23.40 mg/kg) was recorded at the super optimal dose (150% NPK). The lowest (7.13 mg/kg) and (8.73 mg/kg) Zn contents in the grain and straw, respectively, were recorded in the control plot. On the other hand, the Zn content in both the grain and straw was 100%.

Table 7: Effect of various treatments on the Zn content in rice

S.No.	Treatment Name	Zn content (mg/kg)	
		Grain	Straw
T_1	Control	7.13	8.73
T_2	50% NPK	10.68	11.20
T_3	100% NPK	14.75	18.33
T_4	150% NPK	18.63	23.40
T_5	100% NPK + $ZnSO_4$	15.30	19.18
T_6	100% NP	14.03	16.23
T_7	100% N	8.83	9.60
T_8	100% NPK + FYM	16.45	20.63
T_9	50% NPK + BGA	11.23	14.00
T_{10}	50% NPK + GM	12.70	15.28
	SEm (±)	0.16	0.41
	CD (p = 0.05)	0.47	1.19

The NPK treatment had significantly less NPK than did the 100% NPK along with $ZnSO_4$ and 100% NPK along with FYM. The incorporation of FYM along with optimal NPK (100% NPK + FYM) maintained the availability of Zn in the soil comparable to that of Zn spray. This could be due to its direct impact on the nutrient pool and improved availability through either complexation (Nand Ram and Raman, 1984) or mobilization of native Zn (Nand Ram and Verloo, 1985). A greater collection of Zn grains stored using zinc in the rhizosphere and regular supply combined with a greater number of Zn grains on each hill and higher Zn concentrations are likely to increase grain yield, as observed by Jena *et al*. (2006).

Conclusion

The long-term application of organic residues and manure along with NPK increased the soil available nutrients and organic carbon content as well as the Zn content in rice crops. The addition of FYM along with an optimal dose (100% NPK) of inorganic fertilizer and a super optimal (150% NPK) dose of inorganic fertilizer significantly influenced the soil chemical properties, and the lowest value was recorded in the control. OM application enhanced the content of Zn in rice grain and straw in combination with chemical fertilizer application, whereas the control plot had the lowest Zn content.

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Conflict of interest
The authors declare that they have no conflicts of interest.

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