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Fertility status in wheat (*Triticum aestivum*) under long-term nutrient management practices in an Alfisol

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ABSTRACT

Soil samples were collected during 2018 from a long-term field experiment on soybean [*Glycine max* (L.) Merr.]-wheat (*Triticum aestivum* L.) system continuing since 1972 at Birsa Agriculture University, Jharkhand. The samples were analysed for available major and micro nutrient and biological properties at IARI, New Delhi. The treatments consisted of control, 100% N, 100% NP, 50% NPK, 100% NPK, 150% NPK, 100% NPK + FYM and 100% NPK + Lime. Highest grain yield of wheat was obtained with 100% NPK + FYM followed by 100% NPK + Lime. Whereas, in soybean, 100% NPK + Lime treatment recorded the highest yield, followed by 100% NPK + FYM. The highest available N (218 kg/ha) was found under 150% NPK, which was statistically similar to 100% NPK + FYM. Moreover, highest Bray-P (169 kg/ha) and available K (161 kg/ha) was observed in 100% NPK + FYM and 150% NPK treatment respectively. The DTPA extractable Fe, Mn, Zn and Cu were recorded in the range of 13.9-41.8 mg/kg, 31.1-60.6 mg/kg, 0.64-1.94 mg/kg and 0.71-1.28 mg/kg, respectively under different nutrient management practices. Treatment 100% NPK + FYM recorded the maximum contents of available micronutrients. Acid phospho-monoesterase (AMP) activity and microbial pools such as microbial biomass carbon (MBC) and microbial biomass phosphorus (MBP) were also found to be highest in 100% NPK + FYM treatment.

Keywords: Acid soil, LTFE, Major nutrients, Micro-nutrients, Microbial activity, Soybean, Wheat, Yield

In India, about 50 Mha area is acidic (Singh *et al.* 2017), mostly under the soil order Alfisol. Acidic soils of Jharkhand are inherently poor in available nutrient status due to low organic matter content, excessive leaching and fixation of phosphorus by iron (Fe) and aluminium (Al) oxides. The rice-wheat cropping system in Indo-Gangetic plain, being highly exhaustive and water demanding is not sustainable at long-run (Das *et al.* 2014). Substituting the kharif rice crop with a legume like soybean not only reduce water requirement, but also improve soil fertility and provide nutritional and livelihood security (Behera *et al.* 2007). Soybean [*Glycine max* (L.) Merr.]-wheat (*Triticum aestivum* L.) system is one of the most important legume-cereal cropping systems with wide adaptability to diverse agro-climatic conditions across the world as well as India (Chouhan *et al.* 2018). Considering the detrimental effects of continuous application of mineral fertilizers alone, integrated application of FYM, green manure and other organic sources are gradually gaining importance. Use of green manure and organic manure along with fertilizers have resulted significant accumulation of available nutrients (Prasad *et al.* 2010). Judicial management of different nutrients and integrating organic sources with inorganics are keys to maintain yield at desired level as well as to sustain soil quality and prevent land degradation. Correspondingly, addition of lime in acid soils not only minimize the deleterious effects of H^+ and Al^{+3} but also improve biological health of soil. Liming and inclusion of organic matter in nutrient management practices also boost microbial activities (Mandal *et al*. 2007). Long-term fertilizer experiments (LTFEs) ensure that a potential nutrient management practice will remain effective in the long-run. Long-term studies in acid soils of Eastern India are scarce, and mostly focussed on one or other nutrient in isolation like different K pools by Das *et al.* (2019); different C pools (Ghosh *et al.* 2019) rather than observing all the primary nutrients, micronutrients and biological properties. Therefore, the present study was undertaken to delineate the long-term effects of nutrient management practices on available major and micro-nutrients, and some important biological properties.

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MATERIALS AND METHODS

The LTFE at Birsa Agricultural University, Ranchi, India (23°17´N, 85°19´E) is continuing since 1972–73. The site has a hot sub-humid climate and receives an average

1450 mm of precipitation annually. Soil of the site is a red sandy clay loam. Among the 10 existing treatments at the study site, eight most relevant to our study, viz. control, 100% N, 100% NP, 50% NPK, 100% NPK, 150% NPK, 100% NPK + FYM and 100% NPK + Lime were chosen. Soil samples were collected after the harvest of wheat crop in 2017–18 from 0-30 cm depth and analysed at IARI, New Delhi for major and micro nutrient and biological properties (surface layer). The samples collected for analysing available nutrients were mixed to obtain a homogeneous sample and the samples for biological parameters were kept in a refrigerator. Available nitrogen (N) contents of soils were determined by steam distillation with alkaline $KMnO_4$ in a Kjeldahl apparatus (Subbiah and Asija 1956). For estimation of available phosphorus (Bray-P), soil was extracted with 0.03 N NH_4F + 0.025 N HCl (Bray and Kurtz 1945). Available K content was measured by extracting the soil with 1 N ammonium acetate (*p*H 7.0) as described by Hanway and Heidel (1952), followed by determination with a flame photometer. For estimation of available micronutrient contents in soil, 1:2 (soil: DTPA) at pH 7.3 (Lindsay and Norvell 1978) was used and micronutrient concentrations in the filtrates were determined in an Atomic Absorption Spectrophotometer. Phosphomonoesterase (Acid phosphatase) activities were estimated colorimetrically by the method suggested by Tabatabai and Bremner (1969). Microbial biomass carbon in the soil was estimated by fumigation extraction method (Vance *et al.* 1987). An extraction efficiency of 0.45 was taken for the calculation of MBC. For estimation of microbial biomass P, soils were extracted with 0.03 *N* NH_4F and 0.025 *N* HCl (Wu *et al.* 2000), an efficiency factor of 0.40 was used to transform the released P into MBP (Brookes *et al.* 1982). Crops were harvested at maturity and grain yields were recorded. The percent change in grain yield and microbial pools/activities over control were calculated using the following formula

% change in grain yield over control =

$$\frac{(\text{yield of treatment} - \text{yield of control})}{\text{value of control}} \times 100$$

% change of a microbial pool/activity over control =

$$\frac{(\text{value of treatment} - \text{value of control})}{\text{value of control}} \times 100$$

RESULTS AND DISCUSSION

Grain yield of soybean and wheat: For both the crops, only the treatment 100% N recorded slightly lower yield than control. All the other treatments increased yield to different extents. The increase in yield of soybean ranged from 17–331%. Application of lime and FYM with 100% NPK significantly increased the grain yield and these two treatments recorded the highest yield over rest treatments. Increasing fertilizer dose had shown a steady increase in grain yield. In wheat, the extent of increase in grain yield was higher than soybean and it ranged from 201–531%. Like soybean, here also treatments 100% NPK + FYM and 100% NPK + lime gave the highest yield. Although, in contrast to wheat the highest yield was recorded for the 100% NPK + FYM (5.3 times over control) treatment. The wheat grain yield for the treatments 100% NP, 100% NPK and 150% NPK were by and far similar. Our results are in line with the findings of Sharma *et al.* (2016), where they reported significantly higher yield of wheat with soil test based integrated fertilizer use in pearl millet-wheat cropping system.

Available major nutrients: Results showed that the highest available N in soil (218 kg/ha) was found under 150% NPK treatment which was statistically at par with 100% NPK + FYM treatment (Table 1). Treatment 100% N significantly increased the available N in soil over 50% NPK, 100% NP treatments and control, and it was statistically at par with the treatments 100% NPK, 100% NPK + FYM and 100% NPK + lime. The 100% NPK + FYM treatments recorded highest (169 kg/ha) Bray-P over the other treatments. However, 150% NPK significantly increased the Bray-P over rest of the treatments except 100% NPK + FYM, while 100% NPK + Lime, 100% NPK and 100% NP treatments were similar to each other in Bray-P content. Verma *et al.* (2012) also noticed build-up of available P with application of higher fertilizers doses with integration of FYM and lime. The average available (Bray) P content of the soil for 0-30 cm depth was 73 kg/ha. The available K content in ranged from 105 kg/ha (100% NP) to 161 kg/ha (150% NPK). The treatment 150% NPK gave significant higher available K content as compared to other nutrient management practices. Available K content in soil was significantly increased by the application of 100% NPK + FYM as compared to other treatments. Moreover, the treatments 100% NPK and 100% NPK + Lime were statistically similar with each other in respect of available K content and significantly higher over 100% N, 100% NP, 50% NPK and control. Application of soluble nutrient

Table 1 Percent change in grain yields of soybean and wheat over control and available major nutrients content (kg/ha) in 0-30 cm soil depth after wheat as affected by long term nutrient management practices

Treatment	Soybean	Wheat	N	P	K
Control			158^{F*}	11.3^{C}	114^{C}
100% N	-3.93	-2.50	198^{BC}	14.6^{C}	111^{CD}
100% NP	17.2	398	181^{DE}	78.4^{B}	105^{D}
50% NPK	151	201	172^{EF}	16.8^{C}	115^{C}
100% NPK	174	409	190^{BCD}	71.1^{B}	123^{B}
150% NPK	237	384	218^{A}	152^{A}	161^{A}
100% NPK +FYM	309	531	204^{AB}	169^{A}	155^{A}
100% NPK + Lime	331	483	184^{CDE}	70.1^{B}	128^{B}
Mean			189	72.8	126

*Values in each column with no common letters among them are significantly different from each other (P<0.05).

Table 2 DTPA-extractable micro nutrients content (kg/ha) in 0-30 cm soil depth after wheat as affected by long term nutrient management practices

Treatment	Fe	Mn	Zn	Cu
Control	14.2[D*]	28.3[C]	0.74[CD]	0.71[E]
100% N	20.9[C]	45.7[B]	1.08[B]	0.94[BC]
100% NP	22.1[C]	41.6[B]	0.88[BCD]	0.88[BCD]
50% NPK	16.3[D]	40.2[B]	0.84[BCD]	0.79[CDE]
100% NPK	23.9[C]	42.4[B]	0.98[BC]	0.85[BCDE]
150% NPK	29.0[B]	46.8[B]	1.06[B]	0.99[B]
100% NPK +FYM	41.8[A]	60.6[A]	1.94[A]	1.28[A]
100% NPK + Lime	13.9[D]	31.1[C]	0.64[D]	0.74[DE]
Mean	22.8	42.1	1.02	0.9

*Values in each column with no common letters among them are significantly different from each other ($P<0.05$).

source has increased the availability of these nutrients. More available primary nutrient in 100% NPK + FYM treated plots was not surprising as FYM could contribute substantial amount of N, P and K after its mineralization.

DTPA extractable micronutrients: DTPA extractable Fe, Mn, Zn and Cu were recorded in the range of 13.9-41.8 mg/kg, 31.1-60.6 mg/kg, 0.64-1.94 mg/kg and 0.71-1.28 mg/kg under different nutrient management practices, respectively (Table 2). Data revealed that highest amount of micronutrients Fe, Mn, Zn and Cu were found under 100% NPK + FYM treatment. DTPA extractable micronutrients were increased with increase in fertilizer dose, but this surge was only significant for Fe. Except 100% NPK + FYM, the DTPA-Fe was significantly increased in 150% NPK as compared to other treatments. The treatments 100% N, 100% NP and 100% NPK was statistically at par with each other with respect to DTPA-Fe. Except control, 100% NPK+ lime and 100% NPK + FYM, all the other treatments were statistically similar for DTPA-Mn and Zn. For DTPA-Zn, the treatments 100% NP, 50% NPK, 100% NPK and 100% NPK + lime did not show any difference compared to control. The DTPA-Cu in 150% NPK was increased over control and was comparable to 100% NPK, 100% NP and 100% N treatments. Inclusion of lime in nutrient management practice reduced all the four micronutrients over 100% recommended fertilizer application which is expected because liming elevates soil pH and reduce solubility of micronutrient cations. However, this reduction was not statistically significant for Cu. Owing to the acidic soil *p*H, all the DTPA-extractable micronutrients were above the critical deficiency level. Among the micronutrients, Mn had the largest share followed by Fe. DTPA-Zn and Cu content were by and far similar and much lower in abundance compared to Fe and Mn. High concentration of Mn might be due to higher solubility of Mn-minerals at low soil pH which over compensated the removal by plants. Increasing the fertilizer dose mostly increased the micronutrients, although the trend was not statistically significant. The possible reason might be soil acidification, generally observed with higher dose of chemical fertilizer. Application of FYM had noticeably increased the micronutrients and this was no exception as FYM contained significant amount of micronutrients, similar results were also observed by Sharma *et al.* (2015).

Microbial pool/activity: Microbial biomass carbon (MBC), microbial biomass phosphorus (MBP) and acid phospho-monoesterase (AMP) activity as influenced by nutrient managements are presented in Fig 1 which show percent increase/decrease over control. All the microbial pools and activity were maximum in 100% NPK + FYM. The increase in MBC, MBP and AMP activity over control were recorded in the range of 2.1–38.4%, 19.9–151% and -19.5–19%, respectively under different nutrient

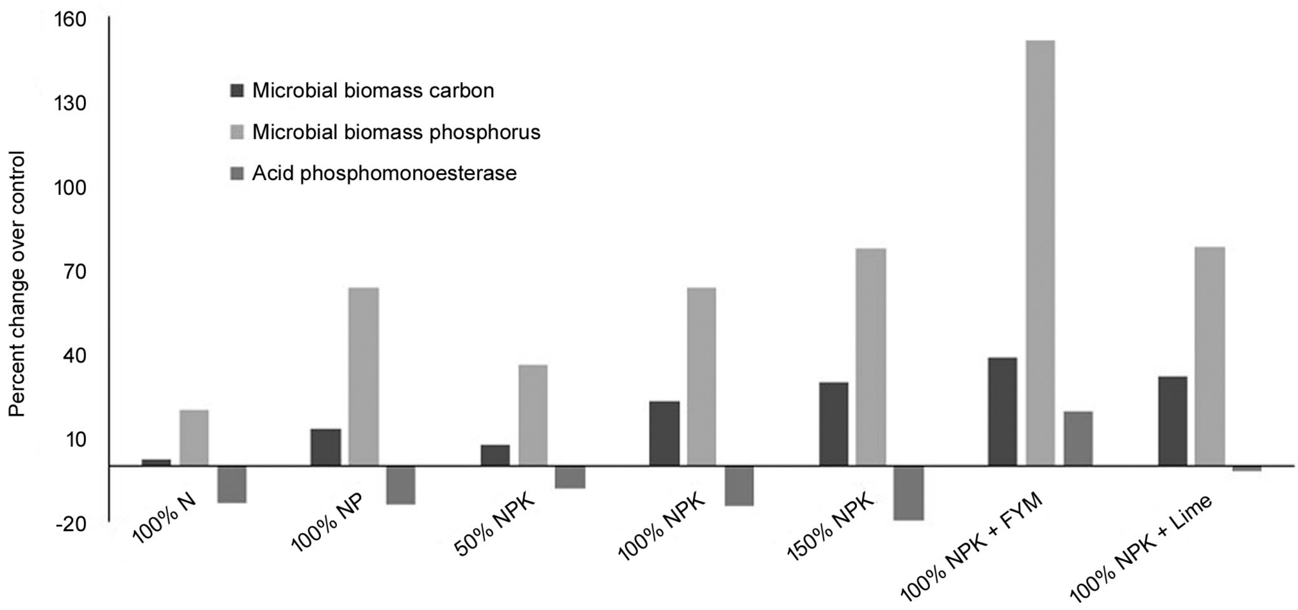

Fig 1 Percent change in selective microbiological properties over control after wheat as affected by long-term nutrient management practices.

management practices. All the treatments showed increase over control in respect to microbial biomass carbon and phosphorus. While, acid phosphomonoesterase (AMP) activity reduced in all but 100% NPK + FYM treatment compared to control. The microbial C and P were increased with increasing fertilizer dose. However, AMP activity showed some opposite trend and it progressively reduced with increasing fertilizer application rate. The MBC and MBP in soil were increased in 100% NPK + lime over other treatments except 100% NPK + FYM, whereas AMP was almost similar to control. Higher root growth in fertilized plots and higher rhizosphere microflora owing to supply of carbon through FYM could be responsible for the increase in activity (Bhattacharyya *et al*. 2005). Increasing fertilizer dose and balanced fertilizer application also contributed towards profuse vegetative growth. These were reflected in microbial biomass carbon (MBC) of soil which was higher in plots where balanced application of fertilizer and greater fertilizer doses were applied. Like MBC, microbial biomass phosphorus (MBP) also followed the same trend, which was expected due to large amount of root residue left in the soil, which on subsequent decomposition provided necessary C, N and P for cellular synthesis (Mandal *et al*. 2007). Similarly, long term addition of organic manure helps to maintain higher level of AMP in soil (Alvarez-Solis *et al.* 2010).

It may be concluded that the highest grain yield of crops was recorded with 100% NPK + FYM, and 100% NPK + lime, which signify that application of FYM and lime with recommended dose of fertilizer have a great potential to boost yield, probably due to augmenting microbial activity and reducing the negative impacts of Al^{+3} and H^+ ion in acid soil. On the other hand, 100% NPK + FYM also increased the available nutrients. Increasing the fertilizer dose to 150% of the recommended dose certainly improved the available N, P and K pool, but only slight effect on yield was observed. So, it would not be advisable to adopt this practice due to the huge cost of 50% extra fertilizers.

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