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Assessment of soil fertility status under long term balance fertilizer application on rice (*Oryza sativa* L.)

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Abstract
Long-term fertility experiments are good indicators for monitoring soil quality and crop productivity and is of vital importance in nutrient management as well as soil health. The present study "Assessment of soil fertility status under long term balance fertilizer application on rice (*Oryza sativa* L.)" was conducted at A2 block of N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) during *kharif* 2017. These treatments were a part of long-term fertility experiment since 1984. Nine treatments out of fourteen consisting different combination of N, P, K, Znf and FYM were tested in a Randomized Block Design with four replications. The variety sown was HKR 47. It was noticed that addition of FYM had a positive effect on soil fertility parameters. The value of soil pH and EC were higher compared to the initial value in the fertility treatments. Soil organic matter after harvesting of rice also increased due to continuous application of NPK+FYMr and NPK+Zn+FYMr. The highest value of available nitrogen was recorded with $N_{120}P_{40}K_{40}$+Znf+FYMr which was statistically at par with $N_{120}P_{40}K_{40}$ +FYMr but significantly higher than all other treatments. The value of available P and K after harvest and available micronutrients (Fe, Zn, Mn and Cu) too were higher due to the application of $N_{120}P_{40}K_{40}$+Znf+FYMr treatments. It has been observed that addition of FYM to fertilizer scheme has been found to increase microbial population in the soil which acts as a decomposer of crop. The experiment thus reported FYM as a complete source of nutrients for plant growth and development by supplying nutrients (macro and micro) through a process of recycling nutrients.

Keywords: HKR 47, Znf, FYMr, long-term fertility experiment, micronutrient, soil fertility

Introduction
The study of soil fertility and crop productivity under long-term cropping has long been the subject of immense importance. There are indications of declining productivity due to depletion in soil organic matter, over mining of nutrients reserves and losses of nutrients as clearly evolved through long-term fertilizer experiments being conducted in different parts of the country. Sustainable high yields of crops can support food security of the rapidly growing population (Palm *et al.,* 2014) [7]. Rice consumption is increasing and demand for rice will outstrip supply if production does not increase faster than its current rate. This means there is a need to produce even more rice for food security. Improved fertility status of soil health and could support sustainable crop production. Long-term fertility experiments have significantly contributed to our understanding of soil fertility management and sustainable crop production in different agroecosystems (Rawal *et al.*, 2017) [8]. The general recommendation of NPK fertilizers resulted in soil fatigue, proving their diseased efficiency and thus requires upward refinement and a proper balance among the macro and micronutrient (Yadav and Kumar, 2009) [12].
Physical properties of a soil greatly influenced its use and behavior towards plant growth. The plant supporting root penetration, drainage, aeration, retention of moisture and nutrient are linked with the physical condition of the soil. Physical properties also, influence the chemical and biological behavior of soils. Gupta *et al*. (2006) [4] reported that the different fertilizer treatment in continuous rice-wheat cropping system over years (1887-2003) did not show significant variation in pH and electrical conductivity of the soil. Similar results were observed by Singh and Nand Ram (2000) [6] at Pantnagar. The pH varied from 7.1 to 7.9 and electrical conductivity from 0.30 to 0.35 dSm^{-1} had no significant difference due to fertilizer application

after 25 years of continuous cropping of rice-wheat. On an evaluation of long-term fertility trials, Nambiar (1985) noted that continuous cropping without application of organic manures causes a fast decrease in organic carbon. This was also reported by other workers (Nand Ram, 2000 and Bhatt 2012) [6, 2]. Sharma and Behera (2004) [9] reviewed the results of 19 years of continuous cropping and manuring in the rice-wheat rotation and found that available N was improved from an initial value of 65 mg kg^{-1} to 68 and 70 mg kg^{-1} with $N_{120}P_{35}K_{33}$ and $N_{120}P_{35}$, respectively. Humne *et al*. (2008) [5] reported that available N in soil increased significantly with 100% NPK+FYM 5 t ha^{-1} compared to control, 100% N and 100% NPK after 7 years of continuous cropping at Raipur. Bhandari *et al*. (2002) [1] analyzed the soil P and observed that there were no significant treatment differences in terms of total and available P in 1988, but after a decade (1997), the data revealed that 50% NPK+FYM @ 6 t ha^{-1} applied in rice followed by 100% NPK in wheat resulted in significantly higher values of P compared to control plots. A field experiment was conducted at Pantnagar for a period of 10 years during 1998 to 2008 which indicates significantly higher available K in the soil as compared to the control. The treatment FYM+ *Sesbania rostrata* being at par with $N_{120}P_{60}K_{40}$ and *Sesbania aculeate*, alone caused significantly more available K status in soil than other treatments (Bisht *et al*., 2010) [3]. The higher amount of available micronutrients in the soil profile was recovered in NP and NPK treated plots (Setia *et al*., 2004) [10]. Reported that there was the reduction in the content of DTPA-Zn after ten years of continuous cropping where the plots did not receive these nutrients either directly or through FYM in a rice-wheat cropping system. However, there was the overall increase in the DTPA extractable Cu, Mn and Fe during the period in the plots treated with single super phosphate and/or FYM.

Under intensive cropping system, high use of fertilizer can cause a deficiency of primary, secondary and micronutrients which have a negative effect on rice growth while addition of FYM has a positive effect on soil fertility status. Presently farmer is using only NPK, that too in imbalance ratio and there is no attention paid for secondary and micronutrients. The present study was thus carried out to reinvestigate the effect of long term balance fertilizer application on soil fertility status in rice.

Material and Methods

In *Kharif*, 1984, the long-term fertility experiment on rice-wheat cropping system was initiated under the flagship of International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFER) programme of Indian Council of Agricultural Research (ICAR) and International Rice Research Institute (IRRI) and the same rice-wheat cropping system with same sets of treatments is practiced on the same piece of experimental site.

Field experiment was conducted in *kharif* season 2017 at A2 Block of Norman E. Borlaug Crop Research Center (NEBCRC) of G.B.P.U.A&T. Pantnagar, Udham Singh Nagar, (Uttarakhand). This center is situated at an altitude of 243.84 m above mean sea level, 29°N Latitude and 79.3° E longitude. It falls under foot hills of Shivalik range of Himalayas as a narrow belt called "*Tarai*". The *Tarai* belt falls under the sub-humid and sub-tropical climate zone with hot dry summers and cool winters. The soils are originated from alluvial sediments. 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. In the long term fertility experiment, fourteen treatments were tested in a Randomized Block Design 4 replications, however only nine important treatments (Control, N_{120}, $N_{120}P_{40}$, $P_{40}K_{40}$, $N_{120}K_{40}$ $N_{120}P_{60}K_{40}$, $N_{120}P_{40}K_{40}$ + Znf, $N_{120}P_{40}K_{40}$ + FYMr and $N_{120}P_{40}K_{40}$+Znf + FYMr) considered in the present study. The above mentioned symbols represent : N_{120}-120 kg N ha^{-1}, P_{40}-40 kg P_2O_5 ha^{-1}, K_{40}-40 kg K_2O ha^{-1}, Znf- Foliar Zinc (0.5% $ZnSO_4$+0.25% Slaked lime), FYMr- Farm Yard Manure applied @ 5 t ha^{-1} on the dry weight basis in rice crop only.

Results and Discussion

Soil pH and EC

The data pertaining to soil pH and EC are tabulated in Table 1. Treatment differences were non- significant with respect to both soil pH and EC. However, the soil pH ranged from 8.06 with N_{120} to 8.16 with $N_{120}P_{40}K_{40}$ + FYMr, while soil EC varied from 0.318 with $N_{120}K_{40}$ to maximum 0.349 in $N_{120}P_{40}K_{40}$ +Znf + FYMr. All the nitrogen consisting treatments resulted in higher soil pH as compared to control and comparing with an initial value, the EC increased with time approximately three times irrespective of treatments.

Soil organic matter content

The data pertaining to organic matter content in a soil are summarized in Table 1. The highest organic matter content was recorded with $N_{120}P_{40}K_{40}$+Znf+FYMr (2.16%) and $N_{120}P_{40}K_{40}$+FYMr (2.16%) which was at par with each other but found significantly higher than all the treatments. Comparing with $N_{120}P_{40}K_{40}$+ Znf indicated that organic matter percent was at par with $N_{120}P_{40}$, $N_{120}K_{40}$ and $N_{120}P_{40}K_{40}$ but significantly more than other inorganic treatments and significantly less than FYM enriched treatments. Comparing with initial values continuous use of $N_{120}P_{40}K_{40}$+FYMr and $N_{120}P_{40}K_{40}$+Znf+FYMr treatment increased up to 3% organic matter after 33 years, while FYM omitted fertilizer treatments led to a reduction in organic matter in the range of 8 to 32%. The decrease of organic matter from its initial 1984 value of 2.1% was found in imbalance and balance inorganic fertilizer treatments. The decrease of organic matter was more with $P_{40}K_{40}$ (32%) followed by control (30%), $N_{120}K_{40}$ (26%), $N_{120}P_{40}K_{40}$ (20%), $N_{120}P_{40}$ (12%) and $N_{120}P_{40}K_{40}$+Znf (8%).

Available nitrogen, phosphorus and potassium

The data pertaining to available nitrogen, phosphorus and potassium in soil are summarized in Table 2. Among the fertility treatments, the highest available nitrogen (233.80 kg N ha^{-1}), phosphorus (25.35 kg P ha^{-1}) and potassium (218. 13 kg K ha^{-1}) was recorded with treatment $N_{120}P_{40}K_{40}$ +Znf + FYMr followed by $N_{120}P_{40}K_{40}$ + FYMr having 231.93 kg N ha^{-1} available nitrogen, 24.75 kg P ha^{-1} available phosphorus and 216. 25 kg K ha^{-1} available potassium under which were at par with each other caused significantly more than all other treatments.

Continuous combined use of inorganic and organic treatments build up of available nitrogen than the other treatment. On the other hand, all other treatments were not able to maintain soil organic matter which dropped in other of 8 to 36% which might have resulted from the decrease in available soil nitrogen from its initial value of 220 kg N ha^{-1} in all the FYM omitted fertilizer treatments. Continuous application of imbalance or balance inorganic fertilizer treatment dropped available soil nitrogen in a range of 7 to 22%. The treatment consisting of FYM continuously buildup available phosphorus than the other treatments.On the other hand, phosphorus omitted treatments i.e. control, $N_{120}$and $N_{120}K_{40}$ had dropped available soil phosphorus to below critical level. The decrease of available soil phosphorus from its initial (1984) value of 20 kg ha^{-1} was found in all the treatments. Continuous application of Phosphorus omitted fertilizer treatments dropped of available Phosphorus status of soil by 50 %. fertilizer deficient in phosphorus if applied results in reduced in soil available phosphorus. Continuous cropping of rice with or without potassium fertilizer decrease available soil potassium which was in a range of 7- 22%. The maximum depletion was found in N_{120} (22%) and $N_{120}P_{40}$ (20%). Significantly higher content of available K was noticed in the treatments where organic manure was incorporated along with N and P_2O_5 as compared to the treatments where no organic manure was applied. The lowest value of available N, P and K in control may be due to mining of nutrients with continuous cropping without fertilization over the years.

DTPA-extractable micronutrients in soil

The data pertaining to available zinc, iron, manganese and copper in the soil are summarized in figure 1. Application of $N_{120}P_{40}K_{40}$ + FYMr significantly enhanced the available zinc (2.71 mg kg^{-1}), iron (34.85 mg kg^{-1}), manganese (7.14 mg kg^{-1}) and copper (5.42 mg kg^{-1}) compared to remaining treatments. Recommended dose of fertilizer, $N_{120}P_{40}K_{40}$ + Znf, was found to have 1.73 mg kg^{-1}, 29.23 mg kg^{-1}, 5.9 mg kg^{-1} and 2.53 mg kg^{-1} available zinc, iron, manganese and copper, respectively. While compared to the recommended dose of fertilizer, $N_{120}P_{40}K_{40}$ + Znf, there was a significant reduction in available micronutrients due to the omission of any nutrients form recommended dose of fertilizer, however, enriching recommended dose of fertilizer with FYM caused a significant increase in available micronutrients.

Higher micronutrients availability in soil was due to FYM enriched recommended dose of fertilizer. FYM is considered as a complete source of nutrients for plant growth and development through a process of recycling nutrient. It has been observed that addition of FYM to fertilizer scheme has been found to increase microbial population in the soil which acts as a decomposer of crop residue liberating a significant amount of nutrient including micronutrient thereby enhancement in available micronutrient in soil. The decline in available micronutrient in soil has been observed under control as well as the application of inorganic nutrient. This might be due to imbalance as well as nutrient sources resulting in reduced availability of micronutrient in the soil.

Conclusion

Based on the result obtained, it can conclude that continuous application of FYM enriched balanced fertilizer i.e. $N_{120}P_{40}K_{40}$+Znf+FYMr or $N_{120}P_{40}K_{40}$ +FYMr sustained the organic matter content, available N, P, K and micronutrients and maintained higher soil fertility in the soil after 33 years of cropping which is directly responsible for higher yield of the crop. Thus it is recommended to use $N_{120}P_{40}K_{40}$+Znf (0.5%$ZnSO_4$) +FYM (5t/ha) or $N_{120}P_{40}K_{40}$ +FYM (5t/ha) to sustained yield and soil health under *tarai* condition of Uttarakhand.

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Table 1: Effect of treatments on soil pH, EC and organic matter content at rice harvest.

Treatment		Soil pH	Soil EC (dSm^{-1})	Organic matter %
T_1	Control	7.98	1.46	0.328
T_2	N_{120}	8.06	1.51	0.322
T_3	$N_{120}P_{40}$	8.11	1.63	0.319
T_4	$P_{40}K_{40}$	8.11	1.42	0.332
T_5	$N_{120}K_{40}$	8.08	1.56	0.318
T_6	$N_{120}P_{40}K_{40}$	8.15	1.68	0.329
T_7	$N_{120}P_{40}K_{40}$ + Znf	8.13	1.73	0.332
T_8	$N_{120}P_{40}K_{40}$ + FYMr	8.16	2.16	0.322
T_9	$N_{120}P_{40}K_{40}$ +Znf + FYMr	8.13	2.16	0.349
	Initial values	8.0	2.10	0.120
	S.Em ±	0.046	0.06	0.008
	C.D. (5%)	N/S	0.17	N/S
	C.V. (%)	1.13	7.11	5.02

Table 2: Effect treatments on available nitrogen, phosphorus and potassium soil at rice harvest.

Treatment		Available Nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
T_1	Control	144.00	10.25	176.43
T_2	N_{120}	176.93	9.95	173.35
T_3	$N_{120}P_{40}$	174.15	17.19	177.88
T_4	$P_{40}K_{40}$	141.08	17.65	202.88
T_5	$N_{120}K_{40}$	186.43	10.00	200.38
T_6	$N_{120}P_{40}K_{40}$	201.63	18.28	207.35
T_7	$N_{120}P_{40}K_{40}$ + Znf	202.58	18.13	204.20
T_8	$N_{120}P_{40}K_{40}$ + FYMr	231.93	24.75	218.13
T_9	$N_{120}P_{40}K_{40}$ +Znf + FYMr	233.80	25.35	216.25
	Initial values	220	20	222
	S.Em ±	4.23	0.42	3.50
	C.D. (5%)	12.4	1.24	10.27
	C.V. (%)	4.50	5.02	3.54

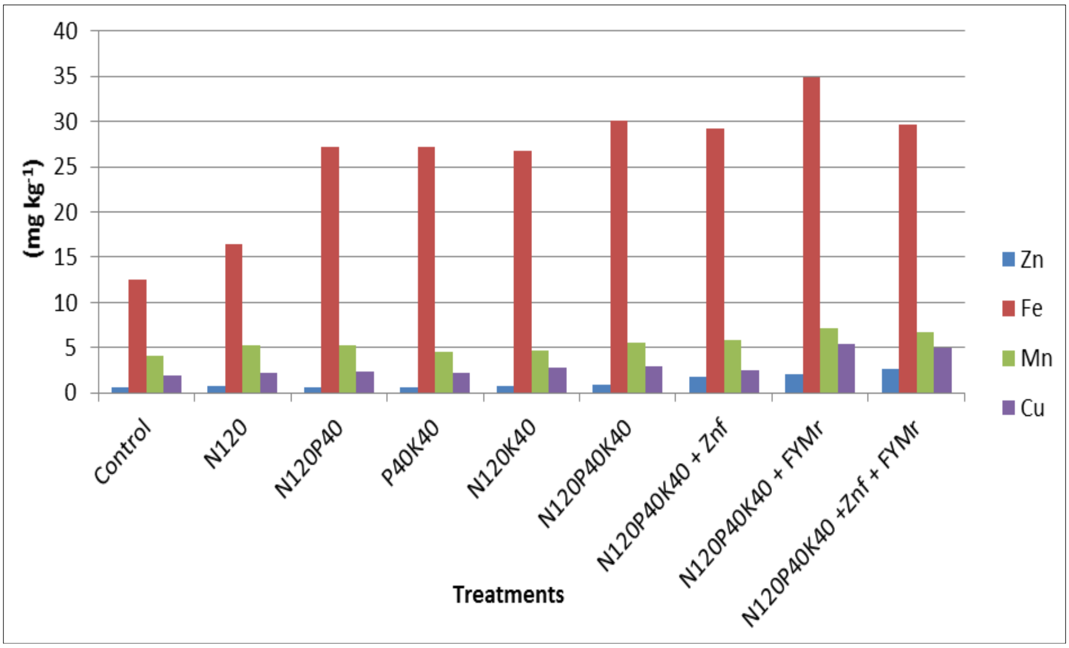

Fig 1: Effect of treatments on available micronutrients on soil at rice harvest.

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