Indian Journal of Agronomy **58** (4): 495–499 (December 2013)

Research Paper

Rice productivity and soil fertility as influenced by nutrient management in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

T. PAUL[1], P.S. BISHT[2], P.C. PANDEY[3], D.K. SINGH[4] AND S. ROY[5]

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145

Received : June 2013; Revised accepted : December 2013

ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2010 and 2011 at Pantnagar, Uttarakhand, to evaluate the effect of nutrient management on rice (*Oryza sativa* L.) productivity, nutrient uptake and soil fertility under long–term rice–wheat (*Triticum aestivum* (L.) emend Fiori & Paol] cropping system. Twelve treatments, viz. control, N_{120}, $N_{120}P_{40}$, $N_{120}K_{40}$, $P_{40}K_{40}$, $N_{120}P_{40}K_{40}$, $N_{120}P_{40}K_{40}$ + Znf (@ 0.5%), $N_{120}P_{40}K_{40}$ + FYM (@ 5 tonnes/ha), $N_{120}P_{40}K_{40}$ + Znf + FYM, $N_{180}P_{80}$ + Znf, $N_{180}P_{80}K_{40}$ + Znf and $N_{180}P_{80}K_{40}$ + Znf + FYM, were maintained in a fixed layout right from the beginning of the experiment (1984-85) in a randomized block design with 4 replications. Combined application of NPK, FYM and Zn ($N_{120}P_{40}K_{40}$ + Znf + FYM) significantly increased the grain yield (6.22 tonnes/ha) of rice over all the other treatments except $N_{120}P_{40}K_{40}$ + FYM (6.20 tonnes/ha) and $N_{180}P_{80}K_{40}$ + Znf + FYM (6.19 tonnes/ha). The treatment $N_{180}P_{80}K_{40}$ + Znf + FYM recorded the highest soil available nitrogen and phosphorus (229.5 kg/ha and 25.1 kg/ha), which was significantly at par with $N_{120}P_{40}K_{40}$ + FYM (225.3 kg/ha and 24.6 kg/ha) and $N_{120}P_{40}K_{40}$ + Znf + FYM (223.9 kg/ha and 24.8 kg/ha). The available soil potassium content was low to medium in range (183.1–220.0 kg/ha). The FYM application improved the rice yield and sustained soil fertility. Soil organic matter content reported in 1984 (2.1 %) was found maintained in FYM containing treatments (2.15–2.17%), while declining with inorganic treatments. The uptake of N, P and K was found to be associated with production of total dry matter resulted by the addition of NPK fertilizer and FYM application.

Key words **:** Long-term soil fertility, Nutrient management, Nutrient uptake, Rice productivity, Rice–wheat system

Long-term fertility experiments are good indicator for monitoring soil quality and crop productivity. The study of soil fertility and crop productivity under long-term cropping has long been the subject of immense importance. In India, the long-term experiments were initiated towards the close of the last and beginning of the 20th century. These experiments generated valuable information on the effect of use of organic manures and chemical fertilizers on crop yields, nutrient removal and soil properties. The rice–wheat rotation is one of largest agricultural production system in India, occupying 10.5 mha productive lands in Indo–Gangetic plains (IGP). This rice–wheat system brings together conflicting and complementary practices. Because of high productivity, stability and less risk, the wide adoption of rice–wheat system will also play a major role in future planning to sustain self sufficiency of food grains in the years to come (Singh *et al*., 2012).

But, there are indications of declining crop productivity and soil quality due to depletion in soil organic matter, over mining of nutrient reserves, factor productivity and losses of nutrients. Moreover, both rice and wheat being exhaustive crops deplete the soil fertility. The repeated transitions from aerobic to anaerobic growing conditions deteriorate soil structure, nutrient relations and the growth of the component crops. Presently, the major concern in agriculture is to arrest any further decline in the crop productivity and soil fertility. However, the system is under production fatigue as yields have started declining due to continuous rice–wheat cultivation (Yadav, 1998). To obtain a good yield of rice, a minimum level of about 120 kg N, 60 kg P_2O_5 and 40 kg K_2O along with 5 t FYM/ha is required to be applied in the IGP. To sustain the soil health and provide adequate plant nutrition, it is important to explore the plant nutrient sources other than the chemical fertilizers and their application in integration with organics is essential (Singh, *et al*. 2011). Since the current study

[1]**Corresponding author Email:** tarun.bckv@gmail.com
[1]Ph.D. Scholar, Agronomy, IARI, New Delhi-110 12; [2&3]Professor; [4]Senior Research Officer, Department of Agronomy, GBPUAT, Pantnagar; [5]Lecturer, Department of Agriculture, Doon P.G. College of Agriculture, Science and Technology, Selapui, Dehradun, Uttarakhand

was conducted to investigate the effects of continuous use of different combinations of N, P, K, Zn and FYM on growth, yield attributes, yield and nutrient uptake in rice and fertility status of soil.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) season of 2010 and 2011 (a part of an on–going long–term fertility field experiment in rice–wheat cropping system, initiated in 1984–85) at the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The experimental site lies in *tarai* plains about 30 km southward of foothills of 'Shivalik' range of Himalayas at 29^0 N, 79^0 29' E and 243.94 m above the mean sea level. The *tarai* belt falls under the sub-humid and sub-tropical climate zone with hot dry summers and cool winters. Generally, south-west monsoon sets-in during the first week of June and continues upto the end of September. The seasonal (June–November) rainfall was 1,921.6 mm and 2,153 mm during 2010 and 2011 respectively. The surface soil (0–15 cm) was silt-loam and neutral to slightly alkaline. It was rich in organic matter and medium in phosphorus and potassium. Soil samples were analyzed for pH, electrical conductivity (EC), organic carbon, available N, available P and available K and plant samples for N, P and K by using standard procedures. Twelve treatments. viz. control, N_{120}, $N_{120}P_{40}$, $N_{120}K_{40}$, $P_{40}K_{40}$, $N_{120}P_{40}K_{40}$, $N_{120}P_{40}K_{40}$ + Znf (@0.05%), $N_{120}P_{40}K_{40}$ + FYM (5 tonnes/ha), $N_{120}P_{40}K_{40}$ + Znf + FYM, $N_{180}P_{80}$ + Znf, $N_{180}P_{80}K_{40}$ + Znf and $N_{180}P_{80}K_{40}$ + Znf + FYM, were maintained in fixed layout right from the beginning (1984–85) of the experiment in a randomized block design with 4 replications. The seedlings of rice 'Pant Dhan 4', sown on June 07 (both 2010 and 2011) were raised by adopting wet bed method. Seedlings were transplanted at a distance of 20 cm × 20 cm. All the recommended agronomic practices were done throughout the crop season. Harvesting was done manually during the third week of October in both years. The N, P and K were supplied through urea, single superphosphate and muriate of potash, respectively. Half of the urea and entire amount of single superphosphate and muriate of potash were applied at the time of final land preparation. Rest of the urea was applied as two split doses–at tillering stage (20 DAT) and panicle initiation stage (40 DAT). At the beginning of the experiment (1984–85) soil having pH (8.0) neutral to slightly alkaline, low in EC (0.12 dS/m), high in organic matter (2.1%) and medium in available N (240 kg/ha), P (20 kg/ha) and K (222 kg/ha). Data were statistically analyzed by variance technique appropriate to randomized block design and significant differences were distinguished by 5% level of probability (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Growth and yield attributes

Rice plants grew with the imposition of $N_{120}P_{40}K_{40}$ + Znf + FYM and $N_{180}P_{80}K_{40}$ + Znf + FYM treatment, which were significantly taller than the plants under other treatments except $N_{120}P_{40}K_{40}$ + FYM. The treatment $N_{180}P_{80}K_{40}$ + Znf + FYM recorded more number of tillers and dry matter (255/m^2 and 1381g/m^2 respectively). The FYM enriched treatments, viz., $N_{180}P_{80}K_{40}$ + Znf + FYM, $N_{120}P_{40}K_{40}$ + Znf + FYM and $N_{120}P_{40}K_{40}$ + FYM, had pronounced effect on plant growth and produced taller plant, more numbers of tillers and dry matter (Table 1).

Table 1. Growth, yield attributes and the yield of rice as influenced by different nutrient treatments under long-term rice–wheat system (pooled data of 2 years).

Treatment	Plant height (cm)	Dry matter accumulation (g/m^2)	Tillers/ m^2	Panicles/ m^2	Filled spikelets/ panicle	Sterility (%)	Test weight (g)	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)	Harvest index
Control	91.5	669	149	144	80	15.9	27.6	3.03	3.11	0.49
N_{120}	92.6	797	154	148	93	27.8	27.9	3.49	3.75	0.48
$N_{120}P_{40}$	99.2	1128	195	194	95	16.2	28.4	4.75	5.59	0.46
$P_{40}K_{40}$	96.3	830	159	150	98	14.8	27.4	3.73	3.82	0.49
$N_{120}K_{40}$	98.0	841	158	151	93	31.1	28.7	3.62	3.95	0.48
$N_{120}P_{40}K_{40}$	102.2	1172	213	201	95	19.2	28.8	5.22	5.83	0.47
$N_{120}P_{40}K_{40}$ + Znf (@0.5%)	104.7	1159	219	206	94	21.4	28.7	5.30	5.59	0.49
$N_{120}P_{40}K_{40}$ + FYM (5 t/ha)	106.9	1340	240	231	97	21.9	29.0	6.20	6.62	0.48
$N_{120}P_{40}K_{40}$ + Znf + FYM	107.3	1381	240	233	97	21.9	29.1	6.22	6.71	0.48
$N_{180}P_{80}$ + Znf	98.7	1079	206	187	95	25.3	28.5	4.91	5.40	0.48
$N_{180}P_{80}K_{40}$ + Znf	106.0	1242	233	215	94	21.3	28.4	5.70	6.28	0.48
$N_{180}P_{80}K_{40}$ + Znf + FYM	107.3	1362	255	238	97	20.3	28.8	6.19	6.68	0.48
SEm±	0.4	50	6	4	4	1.9	0.2	0.12	0.21	0.009
CD (P=0.05)	1.0	144	16	12	13	5.4	0.5	0.35	0.61	NS

The more number of panicles was noted with $N_{180}P_{80}K_{40}$ + Znf + FYM, which was significantly higher than all other treatments except $N_{120}P_{40}K_{40}$ + FYM (231) and $N_{120}P_{40}K_{40}$ + Znf + FYM (233). The filled spikelets/panicle was also highest with FYM containing treatments which remained statistically at par with all the treatment except control, N and NK. The highest test weight was obtained with $N_{120}P_{40}K_{40}$ + Znf + FYM treatment. Application of FYM along with N, P and K with or without Zn increased the yield-attributing characters over chemical fertilizer alone and were found to have increased grain yield of rice.

Grain and straw yields

The highest grain yield was obtained with $N_{120}P_{40}K_{40}$+ Znf + FYM which was statistically higher than all the treatments except $N_{120}P_{40}K_{40}$+ FYM, $N_{180}P_{60}K_{40}$ + Znf + FYM and $N_{180}P_{60}K_{40}$ + Znf. This could be due to the continuous and balanced supply of N, P, K and Zn along with FYM. The increase in rice yield might be attributed to higher number of panicles/plant, number of grains/panicle and increased weight of grains. However, the increased dozes of N and P along with FYM, i.e. $N_{180}P_{80}K_{40}$ + Znf + FYM, did not show any significant response in grain yield over $N_{120}P_{40}K_{40}$ + Znf + FYM and $N_{120}P_{40}K_{40}$ + FYM. From pooled yield, it was found that grain yield of rice had increased by 80 kg/ha due to Zn ($N_{120}P_{40}K_{40}$ + Znf over $N_{120}P_{40}K_{40}$) and 20 kg/ha ($N_{120}P_{40}K_{40}$ + Znf + FYM over $N_{120}P_{40}K_{40}$ + FYM). Farmyard manure (FYM), which is being a store house of nutrients, perhaps able to supply Zn commensurate with the crop requirement. Combination of NPK along with FYM and Zn increased the yields because of attaining better fertility status resulting good supply of nutrients. Our results confirm the findings of Nambiar and Abrol (1989); Bisht (1990); Hegde and

Table 2. Effect of nutrient management treatments soil fertility parameters as under long-term rice–wheat system (pooled data of 2 years).

Treatment	Soil EC	pH	Soil organic matter (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Control	0.333	8.26	1.50	148.3	9.9	187.5
N_{120}	0.325	8.16	1.52	175.5	9.7	183.1
$N_{120}P_{40}$	0.327	8.31	1.72	183.8	17.2	184.9
$P_{40}K_{40}$	0.338	8.30	1.49	127.7	17.4	210.5
$N_{120}K_{40}$	0.326	8.21	1.63	186.4	9.4	197.0
$N_{120}P_{40}K_{40}$	0.328	8.21	1.75	197.3	17.4	206.7
$N_{120}P_{40}K_{40}$ + Znf	0.326	8.18	1.76	192.8	18.3	203.7
$N_{120}P_{40}K_{40}$ + FYM	0.324	8.15	2.15	226.0	24.5	220.0
$N_{120}P_{40}K_{40}$ + Znf + FYM	0.321	8.16	2.15	222.9	24.5	215.8
$N_{180}P_{80}$ + Znf	0.317	8.12	1.78	207.5	22.1	195.8
$N_{180}P_{80}K_{40}$ + Znf	0.326	8.20	1.70	192.0	23.0	205.5
$N_{180}P_{80}K_{40}$ + Znf + FYM	0.320	8.11	2.17	229.9	24.7	211.9
SEm±	0.012	0.19	0.09	4.7	0.7	5.4
CD (P=0.05)	NS	NS	0.26	13.5	2.1	15.6

Table 3. Nutrient accumulation in different plant parts of rice as influenced by different nutrient management treatments under long-term rice-wheat system (pooled data of 2 years).

Treatment	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Control	35.4	9.5	44.8	8.1	3.8	11.8	11.0	40.6	51.6
N_{120}	50.0	14.9	64.9	9.5	3.8	13.3	13.0	48.2	61.2
$N_{120}P_{40}$	68.6	24.6	93.1	17.6	6.7	24.3	17.2	69.0	86.1
$P_{40}K_{40}$	42.3	12.2	54.5	14.5	4.8	19.4	14.1	50.0	64.1
$N_{120}K_{40}$	54.5	16.4	70.9	9.7	4.0	13.7	14.8	51.7	66.5
$N_{120}P_{40}K_{40}$	77.6	26.7	104.3	19.6	8.5	28.1	20.6	75.3	96.0
$N_{120}P_{40}K_{40}$ + Znf	77.1	25.6	102.7	20.2	7.2	27.4	22.7	73.2	95.9
$N_{120}P_{40}K_{40}$ + FYM	92.6	32.5	125.1	22.9	11.0	33.9	25.1	89.0	114.1
$N_{120}P_{40}K_{40}$ +Znf + FYM	92.7	29.3	122.0	24.1	10.7	34.8	27.0	94.7	121.6
$N_{180}P_{80}$ + Znf	72.0	25.1	97.1	18.9	6.9	25.8	21.0	70.3	91.3
$N_{180}P_{80}K_{40}$ + Znf	84.3	28.6	113.0	21.4	10.2	31.5	23.0	83.3	106.3
$N_{180}P_{80}K_{40}$ + Znf + FYM	92.9	31.8	124.7	24.2	11.7	35.9	27.5	94.9	122.4
SEm±	2.0	1.3	2.7	0.5	0.3	0.7	0.8	3.3	3.5
CD (P=0.05)	5.8	3.7	7.8	1.6	0.9	2.0	2.2	9.4	10.1

Dwivedi (1992); Dawe *et al*. (2000) and Yadav and Kumar (2009). Like grain yield, the highest straw yield was obtained with $N_{120} P_{40} K_{40}$ + Znf + FYM, followed by $N_{180} P_{80} K_{40}$ + Znf + FYM, $N_{120} P_{40} K_{40}$ + FYM and $N_{180} P_{80} K_{40}$ + Znf and these values were significantly higher than rest of the treatments (Table 1).

Nutrient uptake

The values of nutrient uptake followed the patterns of yield obtained in different treatments. The highest nitrogen uptake by grain was recorded with $N_{180} P_{80} K_{40}$ + Znf + FYM which was significantly higher than all the fertility treatments except $N_{120} P_{40} K_{40}$ + Znf + FYM and $N_{120} P_{40} K_{40}$ + FYM. The highest nitrogen uptake by straw was recorded with $N_{120} P_{40} K_{40}$ + FYM which was significantly higher than all the treatments except $N_{120} P_{40} K_{40}$ + Znf + FYM and $N_{120} P_{40} K_{40}$ + FYM. Similar trend was also recorded with total nitrogen uptake. The treatment $N_{180} P_{80} K_{40}$ + Znf + FYM resulted in the highest phosphorus uptake as well as potassium uptake by grain, straw and total P uptake (Table 3). Application of FYM makes temporary linkages with a part of nutrient elements and prevents them from leaching, fixation and other losses. Also, these nutrients are released slowly in the later period of crop growth and then are made use of by the crop plants (Greenland, 1971). The higher N, P and K content and uptake by grain and straw of rice were recorded with treatments enriched with FYM with or without Zn than chemical fertilizer alone this might be due to continuous release of nutrients from the soil enriched with FYM. These results are in conformity with Bhardwaj (1983); Bisht (1990) and Rathore, *et al*. (2002) who reported that nutrient uptake was higher with the application of NPK along with organic manures.

Fertility status

All the FYM enriched fertilizer treatments ($N_{180} P_{80} K_{40}$ + Znf + FYM, $N_{120} P_{40} K_{40}$ + Znf + FYM and $N_{120} P_{40} K_{40}$ + FYM) resulted in significantly higher values of organic matter content over all the inorganic fertilizer treatments. The highest available nitrogen was recorded with $N_{180} P_{80} K_{40}$ + Znf + FYM, which was significantly higher than all other treatments except $N_{120} P_{40} K_{40}$ + FYM and $N_{120} P_{40} K_{40}$ + Znf + FYM. The available soil phosphorus content increased with all phosphorus containing treatments and declined to critical level in all phosphorus deficient treatments. The highest available phosphorus was recorded with $N_{180} P_{80} K_{40}$ + Znf + FYM, which was statistically at par with $N_{120} P_{40} K_{40}$ + FYM, $N_{120} P_{40} K_{40}$ + Znf + FYM and $N_{180} P_{80} K_{40}$ + Znf. This might be due to the balance and additional supply of phosphorus. It was found that the available soil potassium content was low to medium in range. The soil EC and pH values recorded in different treatment did not vary significantly among them. Application of FYM along with P and K fertilizer had pronounced effect on the buildup of soil available P and K of the soil (Table 2).

The crop productivity and soil fertility could only be sustained when organic carbon of the soil is maintained at high level through addition of organic manure. Present study indicates that balanced application of inorganic and organic sources of nutrients resulted in the high yields and increased nutrient status of soil as compared to the use of chemical fertilizers alone. Increased uptake of P and K was associated with continuous use of NPK fertilizers along with FYM and Zn. Contrary to this, imbalance and indiscriminate use of these nutrient elements decline yields and depletes fertility status of the soil.

REFERENCES

Bhardwaj, V. 1983. Some soil properties, crop yield and nutrient uptake as affected by intensive cropping and fertilization in the long–term fertilizer experiment at Pantnagar. *Ph.D. thesis,* Govind Ballabh Pant University of Agricultue and Technology, Pantnagar, Uttarakhand.

Bisht, P.S. 1990**.** Monitoring of changes in soil fertility, productivity and nutrient status of crops in rice based cropping (rice–wheat). *Ph.D. thesis*, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, Pantnagar, India.

Dawe, D., Dobermann, A., Moya, P., Ladha, J.K., Yadav, R.L., Lin, B., Gupta, R.K., Lal, P., Panaullah, G., Sariam, O., Singh, Y., Swarup, A. and Zhen, Q.X. 2000. How widespread are yield decline in long-term rice experiments in Asia? *Field Crop Research* **83**: 191–13.

Greenland, D.J. 1971. Changes in the nitrogen status and physical condition of soils under pastures, with special reference to the maintenance of the fertility of Australian soils used for growing wheat. *Soils and Fertilizers* **34**: 237–51.

Hegde, S.M. and Dwivedi, B.S. 1992. Nutrient management in rice–wheat cropping system in India. *Fertiliser News* **37**: 27–42.

Nambiar, K.K.M. and Abrol, I.P. 1989. Long-Term Fertilizer Experiments in India: An overview. *Fertiliser News* **34**: 11–20 and 26.

Rathore, R.S., Lal, P., Pandey, P.C. and Bisht, P.S. 2002. Crop productivity and soil fertility under long-term fertilizer application in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system. (In) *Extended Summaries, vol. 1, Second International Agronomy Congress*, 26–30, November 2002, New Delhi, India, pp. 57.

Singh, D.K., Khurshid, A., Sofi and Joshi, G. 2011**.** Increasing productivity and N use efficiency of rice as influenced by integrated source of nutrient management in rice-based cropping system in Kashmir. *Pantnagar Journal of Research* **9**(1): 12–15.

Singh, O., Kumar, S. and Awanish. 2012. Productivity and profitability of rice (*Oryza sativa*) as influenced by high fertility levels and their residual effect on wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **57**(2): 143–47.

Snedecor, G.W. and Cochran, W.G. 1967. *Statistical methods*. Oxford & IBH Publishing Co., New Delhi.

Yadav, D.S. and Kumar, A. 2009. Long-term effect of nutrient management on soil health and productivity of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system. *Indian Journal of Agronomy* **54**(1): 15–23.

Yadav, R.L. 1998. Factor productivity trends in a rice-wheat cropping system under long-term use of chemical fertilizer. *Experimental Agriculture* **34**(1): 1–18.