



Himalayas farmer participatory evaluation of balanced application of nutrients in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system in Kumaon hills

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ABSTRACT

A study was conducted by involving 24 farmers in their fields during 2011–13 in lower Kumaon hills, to study the response of rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) system to balanced nutrient application. The highest mean grain yields of rice (7.21 t/ha) and of wheat (5.14 t/ha) were recorded with the recommended doses of nitrogen, phosphorus and potassium (120, 60 and 40 kg/ha respectively, to both the crops) applied along with the sulphur @ 20 kg/ha followed by recommended NPK alone without micronutrients (7.01 and 5.01 t/ha, respectively, for rice and wheat). During both the years, grain yields of rice and wheat under the farmers' practice of nutrient application were significantly lower than the other treatments except control and N alone. In rice crop, application of recommended doses of N, P and K provided additional mean grain yield of 1.50 t/ha over the farmers' practice, whereas it was 1.04 t/ha in wheat. Application of sulphur @ 20 kg/ha over the recommended dose of NPK to both the crops resulted in additional grain yield of rice and wheat by 200 and 130 kg/ha, respectively, it also resulted in the highest production efficiency (45.4 kg/ha/day). The highest net returns were found under the treatment receiving recommended dose of NPK along with sulphur @ 20 kg/ha (₹150.15 × 10³/ha) and it was 54.8% higher over the farmers' practice of fertilizer application. The soil fertility status after harvesting of wheat in rice–wheat cropping system revealed that highest available nitrogen (298 kg/ha), phosphorus (16.9 kg/ha) and potassium (200 kg/ha) were observed with recommended doses of N, P and K along with sulphur @ 20 kg/ha to rice and wheat crops in sequence.

Key words : Fertilizer, Productivity, Profitability, Rice–wheat cropping system, Sulphur

Rice–wheat is the major food production system of India as well as of the world, occupying about 10.0 million ha in India and 24 million ha area worldwide (Ladha *et al.*, 2000; Timsina and Connor, 2001). Though this system is considered as the backbone of food self-sufficiency, it is facing a sustainability problem due to practices of modern production system with indiscriminate use of chemical fertilizers and pesticides (Prasad, 2005). The concerns like declining factor productivity, depletion of soil organic carbon and mineral nutrients content (Prakash *et al.*, 2008), waterlogging and salinization, increasing nitrate (NO₃) concentration in well water etc. are the consequences of modern rice–wheat production techniques.

In Uttarakhand state too, rice–wheat is the major crop rotation. In the state rice and wheat are grown on 0.262 and 0.348 million ha, respectively, and production of these crops is 0.578 and 0.842 million tonnes respectively. The productivity of rice and wheat is 2.29 and 2.42 t/ha respectively. Majority of the farmers in the state (90.9%) are marginal or small and these farmers do not have risk-bearing capacity and thus follow traditional and subsistence farming. During the 2013–14, total 0.135 million tonnes nitrogen, 0.022 million tonnes phosphorus and 0.006 million tonnes potassium were used in the state in the form of chemical fertilizers. The estimated per hectare consumption of N, P and K fertilizers in the state during 2013–14 was 119, 19 and 6 kg/ha respectively. It shows clearly the inadequate and imbalanced fertilizer use, which is the major constraint in achieving the higher production level (GBPIHED, 2015).

Though information on nutrient management on individual crops is abundant, the system-based information is

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meager. Moreover, single-nutrient approach has been replaced by multi-nutrient so as to boost up crop productivity and nutrient-use efficiency. Besides, nutrient management in cropping system is more efficient and judicious than individual crop, as succeeding crops take care of the residual effect of nutrients. In the recent years, widespread deficiency of sulphur in India is also a factor in decline in the productivity of rice and wheat crops (Biswas *et al.*, 2004). The present experiment was therefore undertaken in farmers' participatory approach to study the response of rice-wheat cropping system to nitrogen, phosphorus, potassium and sulphur (NPK and S) fertilizers input in terms of yield, nutrient-use efficiency as well as net monetary returns.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (*kharif*) and winter (*rabi*) seasons of 2011–12 and 2012–13 by involving 48 farmers' fields (24 farmers' fields each year) in 6 villages spread over 2 blocks of district (Suryajala, Dogda and Jantwal villages in Bhimtal block and Ginti Gaon, Bhandari Seemal and Saunjala villages in Kotabagh block). The experimental soil was sandy loam. The soils were having near neutral pH (6.4 to 7.2), low to medium in available nitrogen (260 to 388 kg/ha), medium in available phosphorus (14.0 to 20.5 kg/ha), low to medium in potassium (164 to 263 kg/ha), medium to high in organic carbon (0.65 to 0.98%). In every village, each year, 4 farmers' fields were selected for conducting the experiment. Seven treatments, viz. control, recommended dose of nitrogen (150 kg/ha for rice and wheat), recommended dose of nitrogen and phosphorus (60 kg/ha for rice and wheat), recommended dose of nitrogen and potassium (40 kg/ha for rice and wheat), recommended dose of nitrogen, phosphorus and potassium, recommended dose of nitrogen, phosphorus and potassium + sulphur @ 20 kg/ha and farmers practice of nutrient application to rice (*kharif*) and wheat (*rabi*) in sequence were evaluated. The experiment was conducted in a randomized block design with 24 replications, taking every farmer as replication. The net plot size was 50 m² for each treatment. During the first year, rice cultivar 'NPH 567' and wheat cultivar 'UP 2572' were used, while during second year 'PRH 10' and 'DBW 17' respectively. Transplanting of rice was done in the second fortnight of July, while sowing of wheat was done in November of each year. The recommended dose of N: P₂O₅: K₂O considered for rice and wheat was 150 : 60 : 40 kg/ha/crop, while sulphur was applied @ 20 kg/ha for both the crops. Under farmers' practice, it was observed that 114 : 46 : 0 and 112 : 42 : 0 kg N : P₂O₅ : K₂O/ha were applied to rice and wheat respectively. Nitrogen, phosphorus and potassium were applied through urea,

diammonium phosphate (DAP) and muriate of potash respectively. Entire dose of P and K was applied at the time of sowing to both the crops, while N was applied in 3 equal splits to both the crops. Farmers applied N and P through urea and DAP; DAP was applied at the time of sowing while urea was applied in 2 to 3 splits to both the crops. Both the crops were raised with recommended package of practices and were evaluated in terms of grain and straw yields, net returns and benefit: cost ratio. On system basis, wheat grain yield was converted into rice grain equivalent yield taking into account the farm gate prices of rice and wheat grains of respective years. Data of both the years were pooled and analyzed as per standard procedure. Production efficiency (kg/ha/day) was calculated by dividing the rice equivalent yield with total duration of the rice-wheat cropping system. Response of rice and wheat to fertilizer nutrients and partial factor productivity were calculated as:

$$\text{Response of nutrient (s)} = \frac{\text{Additional yield obtained by use of nutrient(s) (kg)}}{\text{Amount of nutrient(s) applied (kg)}}$$

$$\text{Partial factor productivity} = \frac{\text{Yield obtained by use of nutrient (kg)}}{\text{Amount of nutrients applied (kg)}}$$

The composite soil samples from 0 to 15 cm from each location were analyzed using standard methods before sowing of the crop and after each cropping sequence, to determine the soil status in respect of soil pH, available N, available P, available K, organic carbon and electrical conductivity.

Initial soil status of the experimental sites is given in table 1.

Table 1. Initial physico-chemical properties of soil (mean over 2 years)

Parameter	Maximum	Minimum	Mean
Available N	369	263	299
Available P	19.9	14.3	19.5
Available K	254	170	203
Organic carbon (%)	0.95	0.69	0.80
pH	7.1	6.4	6.8
Electrical conductivity (dS/m)	0.79	0.46	0.67

RESULTS AND DISCUSSION

Rice

The highest pooled grain and straw yields of rice and wheat were recorded with the recommended doses of N, P and K along with S @ 20 kg/ha (7.21 and 5.14 t/ha grain and 8.29 and 6.07 t/ha straw, in rice and wheat respectively) (Table 2). In rice crop during both the years, significantly higher crop yield was observed in NPK+sulphur

than the other treatment except during 2011–12 where it was at par with the treatment having recommended doses of N, P and K. It was followed by recommended doses of N, P and K and it was significantly superior to rest of the treatments. During both the years, the lowest grain yield was recorded under the control and it was significantly lower than the rest of the treatments. During both the years, grain yield under the treatment of farmers' practice of fertilizer application had significantly lower grain yield than the rest of treatments except the control and the treatment having recommended dose of N. The increase in mean grain yield of rice with the application of N P K + S was 99.7 and 30.5 over the control and farmers' practice respectively. In rice crop application of recommended doses of N, P and K resulted in additional mean grain yield of 3.40 t/ha over the control treatment, whereas application of recommended doses of N, P and K along with sulphur @ 20 kg/ha resulted in additional mean grain yield of 0.19 t/ha over the treatment having recommended doses

of N, P and K. The nutrient application gap between the recommended NPK and the farmers' practice was 36, 14 and 40 kg/ha for N, P and K, respectively, and the soils of the experimental sites were in general low to medium for available N, medium to available P and low to medium to available K. Application of recommended doses of N, P and K provided additional mean grain yield of 1.50 t/ha over the farmers' practice of fertilizer application.

Wheat

In wheat crop during both the years, treatments having recommended doses of N, P and K and recommended doses of N, P and K along with sulphur @ 20 kg/ha resulted in statistically similar grain yield, however grain yields under these two treatments were significantly higher than the rest of the treatments. During both the years, control treatment recorded the lowest grain yield and it was significantly lower than the rest of the treatments. During both the years, grain yield under the treatment having farmers' practice of fertilizer application had significantly lower grain yield than the rest of treatments except the control and the treatment having recommended dose of N. The % increase in mean grain yield of wheat owing to application of N P K + S was 100.2 and 29.3 over the control and farmers' practice respectively. In case of wheat crop application of recommended doses of N, P and K resulted in additional mean grain yield of 2.44 t/ha over the control treatment, whereas application of recommended doses of N, P and K along with sulphur @ 20 kg/ha resulted in additional mean grain yield of only 0.13 t/ha over the treatment having recommended doses of N, P and K. The nutrient application gap between the recommended NPK and the farmers' practice was 38, 18 and 40 for N, P and K, respectively, and though the soils of the experimen-

Table 2. Effect of nutrient application on grain and straw yield of rice and wheat in rice–wheat cropping system (pooled data of 2 years)

Treatment	Grain yield (t/ha)		Straw yield (t/ha)	
	Rice	Wheat	Rice	Wheat
Control	3.61	2.57	4.29	3.08
N	4.94	3.65	5.82	4.30
NP	6.35	4.42	7.30	5.21
NK	5.86	4.11	6.79	4.88
NPK	7.01	5.01	8.04	5.90
NPK+S	7.21	5.14	8.29	6.07
FP*	5.52	3.97	6.27	4.68
SEm±	0.09	0.05	0.10	0.06
CD (P=0.05)	0.24	0.14	0.27	0.17

*FP=Farmer's practice

Table 3. Effect of fertilizer inputs on rice-equivalent yield of the system (SEY), economics and production efficiency, nitrogen efficiency and nutrient response of rice–wheat cropping system (pooled data of 2 years)

treatment	SEY (t/ha)	Net returns			Benefit: cost ratio			Production Efficiency (kg/ha/day)	Nitrogen efficiency (kg/kg)		Nutrient response ratio (kg/kg)	
		Rice	Wheat	System	Rice	Wheat	System		Rice	Wheat	Rice	wheat
		(× 10 ³ ₹/ha)	(× 10 ³ ₹/ha)	(× 10 ³ ₹/ha)								
Control	6.31	20.65	16.78	37.43	0.54	0.48	0.51	22.7	-	-	-	-
N	8.79	41.78	35.36	77.14	1.03	0.94	0.98	31.6	8.9	7.2	8.9	7.2
NP	11.01	62.94	48.03	110.97	1.46	1.25	1.36	39.6	18.3	12.4	13.1	8.8
NK	10.20	55.78	43.84	99.62	1.33	1.12	1.22	36.7	15.0	10.3	11.9	8.1
NPK*	12.29	91.72	58.43	150.15	2.04	1.38	1.71	44.2	22.7	16.3	13.6	9.8
NPK+S	12.62	73.43	56.24	129.67	1.54	1.39	1.46	45.4	24.0	17.2	13.3	9.5
FP*	9.70	47.04	49.90	96.94	1.13	2.64	1.59	34.9	16.8	12.5	11.9	9.1
SEm±	0.12	8.01	4.30	9.30	0.17	0.21	0.11	-	-	-	-	-
CD (P=0.05)	0.33	22.40	12.04	26.01	0.47	0.59	0.31	-	-	-	-	-

FP, Farmer's practice

tal sites were in general low to medium for available N, medium to available P and low to medium to available K, application of recommended doses of N, P and K provided additional mean grain yield of 1.04 t/ha over the farmers' practice of fertilizer application.

The increased grain yields by application of recommended doses of nutrients might be to favourable influence on soil fertility. The similar increase in grain and straw yields was reported by Prasad *et al.* (2002), Rinwa *et al.* (2003) Sharma *et al.* (2007) and Kumar and Singh, (2009). Substantial yield gains owing to sulphur fertilization was also reported by Singh and Kumar (2013).

System productivity and production efficiency

The highest system productivity (12.62 t/ha) in terms of rice–grain-equivalent yield (SEY) and production efficiency (45.4 kg/ha/day) were obtained with the application of recommended N, P and K along with sulphur fertilization (20 kg/ha) to both the crops (rice and wheat) on pooled basis (Table 3). This was mainly owing to significant increase in grain yield of component crops in the system. Hile *et al.* (2007) and Jain *et al.* (2012) also reported significantly higher system productivity and production efficiency with balanced application of NPK in maize–wheat cropping system. The lowest values of system productivity (6.31 t/ha) and production efficiency (22.7 kg/ha/day) were recorded under the control treatment due to lower yield of both the crops grown in sequence.

Response to nutrients and nitrogen-use efficiency

The response (kg grain increase/kg nutrient applied) of rice to N, P and K revealed that maximum response (13.6) with the application of N, P and K together, while the lowest (8.9) with application of N alone (Table 3). Wheat crop responded to applied nutrients and the maximum response (9.8) was recorded with the application of N, P and K together owing to more yield improvement/kg nutrient applied and lowest (7.2) with application of N alone. Kumar

et al. (2009) also recorded similar findings. Imbalanced fertilization affected the nitrogen-use efficiency (kg grain increase/kg applied nutrient) of rice–wheat cropping system. Nitrogen-use efficiency was higher in NPK-fertilized plots, while the lowest in case of only N-fertilized plots for rice and wheat. Application of recommended doses of nutrients along with sulphur to both the crops improved the nitrogen-use efficiency and it was found that phosphorus was more important than potassium in improving nitrogen-use efficiency (Table 3). Improvement in nitrogen-use efficiency owing to P and K application was also reported by Dhyani *et al.* (2007) and Gupta *et al.* (2007).

Partial factor productivity and agronomic efficiency of the system

Partial factor productivity (PFP) for N was the highest with the farmers practice of fertilizer application (42.9), followed by the treatment having recommended dose of NPK along with S @ 20 kg/ha (42.0) and recommended dose of NPK (40.9). However, PFP for P, was the highest with the recommended dose of NPK along with S @ 20 kg/ha (105.1), followed by recommended dose of NPK (102.4) and the treatment having recommended doses of NP (91.8). In case of K, the PFP was the highest with the treatment having recommended dose of NPK along with S @ 20 kg/ha (157.8). Agronomic efficiency was recorded the lowest (8.2) under the treatment having recommended dose of N and it was recorded highest (11.9) under the treatment having recommended dose of NPK (Table 4).

Economic analysis

Application of recommended doses of N, P and K to rice and wheat crops resulted in the highest net returns (₹ 150.15 × 10³/ha) and benefit: cost ratio (1.71) in rice–wheat cropping system which was significantly superior to rest of the treatments except the treatment having recommended doses of N, P and K along with 20 kg/ha S to rice and wheat crops, besides that for the benefit: cost ratio treatment having farmers' practice of fertilizer application

Table 4. Effect of fertilizer inputs on partial factor productivity, agronomic efficiency, and marginal returns of the system (pooled data of 2 years)

treatment	PFP (kg/kg nutrient applied)			AE (kg/kg nutrients applied)	Marginal returns (10 ³ ₹/ha)
	N	P	K		
Control	–	–	–	–	–
N	29.3	–	–	8.2	39.71
NP	36.7	91.75	–	11.2	73.54
NK	34.0	–	127.5	10.2	62.19
NPK	40.9	102.4	153.6	11.9	112.72
NPK+S	42.0	105.1	157.8	11.6	92.24
FP*	42.9	80.8	–	10.8	59.51

FP, Farmer's practice; PFP, partial factor productivity; AE, agronomic efficiency

was also at par with the above mentioned two treatments (Table 2).

Highest marginal returns ($\text{₹}112.72 \times 10^3/\text{ha}$) were recorded with the treatment having recommended dose of NPK, followed by recommended dose of NPK along with S @ 20 kg/ha, recommended doses of N and P, recommended doses of N and K, farmers' practice and recommended dose of N (Table 4).

Maurya *et al.* (2013) also reported higher system-equivalent yield and higher net returns under the treatment having state recommendation of fertilizer application over the farmers' practice of fertilizer application in rice–wheat system. Substantial yield gains and higher value: cost ratio due to S fertilization was also reported by Singh and Kumar (2013).

Soil fertility

The soil fertility status after harvesting of wheat in rice–wheat cropping system (Table 4) revealed that highest available nitrogen, phosphorus and potassium were observed with recommended doses of N, P and K along with sulphur @ 20 kg/ha to rice and wheat crops in sequence, and for available nitrogen it was significantly higher over the rest of the treatments, whereas for available potassium it was at par with the recommended doses of N, P and K and the farmers' practice of fertilizer application, for the available phosphorus increase was not significant. Significant improvement in post-harvest soil fertility in elevated doses of fertilizer was earlier reported by Hile *et al.*, (2007), Jain *et al.* (2012) and Dechassa Hirpa Dibaba *et al.* (2014).

Thus, it may be concluded that nutrient (NPK) @ 150:60:40 kg/ha (state recommendation) to rice and wheat crops in sequence is to be advocated for achieving higher net returns and benefit: cost ratio, while use of sulphur @ 20 kg/ha along with recommended fertilization of N, P and K may be advocated to achieve higher system produc-

tivity, production efficiency and better residual soil fertility to rice–wheat system.

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Table 5. Residual soil-fertility status (kg/ha) in terms of available nitrogen, phosphorus and potassium at the end of rice–wheat cropping system (pooled data of 2 years)

Treatment	N	P	K
Control	283	16.2	193
N	286	16.2	193
NP	286	16.5	194
NK	287	16.8	195
NPK	288	16.5	196
NPK+S	298	16.9	200
FP*	286	16.3	198
SEm±	3.5	0.2	1.4
CD (P=0.05)	9.7	NS	4.0

FP, Farmers' practice;

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