Yield and Soil Fertility Trends in a 20-Year Rice-Rice-Wheat Experiment

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Declining yields and soil nutrient balance in a long-term rice-rice-wheat study suggest depletion of soil potassium (K) and inadequate K fertilization seem to be primary reasons for limited and declining crop yields.

The rice-wheat rotation is a major cropping system in the Indo-Gangetic plains of South Asia. In Nepal, about 0.5 million ha under the rice-wheat system, mostly in the Tarai plain, meets about 75% of the country's total food demand. Productivity and profitability are quite low. A doubling of rice production in the next 25 years is needed to meet Nepal's estimated population growth. Arable land is becoming limited. Improving productivity and increasing cropping intensity is required to meet future food needs. Adequate soil fertility will be essential to improve and sustain yields.

Increased cropping intensity was evaluated using data from a 20-yr study at the Regional Agricultural Research Station, Bhairhawa, Nepal. Fertility treatments of nitrogen (N), phosphorus (P), K, and farmyard manure (FYM) in a continuous rice-rice-wheat system were analyzed to examine and explain yield trends and monitor soil nutrient status.

Rice and wheat yields were significantly influenced by NPK and FYM (**Table 1**). Yields were consistently higher in the NPK and FYM treatments than in treatments where one or more nutrients were lacking. Treatments lacking P and K in rice had the greatest rate of decline, while there was no difference in the rate of decline of yields of rice fertilized with recommended rates of NPK and FYM. Fertility treatment had no effect on rate of yield decline in wheat. Yields in the unfertilized control plots were lowest in Year 1 and declined to zero with time (data not shown). The N and NK treatments maintained high yields

Table 1. Mean yield (t/ha/yr) and yield change (t/ha/yr) in a 20-yr long-term experiment, Bhairhawa, Nepal (1978-98).

	First rice		Second rice		Wheat	
Treatment	Mean yield, t/ha	Yield[1] change, t/ha/yr	Mean yield, t/ha	Yield change, t/ha/yr	Mean yield, t/ha	Yield change, t/ha/yr
Control	0.399	-0.089a	1.066	-0.083b	0.532	-0.040a
N	0.719	-0.166b	1.330	-0.118c	0.588	-0.050a
NP	2.577	-0.073a	2.465	-0.020a	1.200	-0.070a
NK	0.630	-0.155b	1.300	-0.132c	0.611	-0.060a
NPK	2.760	-0.088a	3.082	-0.005a	2.301	-0.050a
FYM	2.797	-0.075a	3.138	-0.019a	2.202	-0.050a

[1]Slope values in a column followed by a common letter are not significantly different at p = 0.05.

similar to the NPK and FYM treatments for the first few years, then followed trends similar to the control, eventually decreasing to zero.

The apparent N balance for the average yield over the 20 years was positive, ranging from 3.4 to 96.7 kg N/ha/yr in the NPK, FYM, and control treatments (**Table 2**). A net loss of 4.0 kg P/ha/yr was estimated for the control treatment, whereas the NPK and FYM treatments had an apparent net P gain of 22.2 and 32.6 kg P/ha/yr, respectively. The apparent K balance was negative in all plots. The control plot also had a negative balance of 12.1 kg K/ha/yr.

Table 2. Annual N, P, and K balance in the long-term rice-rice-wheat experiment in Bhairhawa, Nepal.

	Input, kg/ha/yr					Output, kg/ha/yr		
	Manure/ fertilizer	Irrigation	Biological fixation	Rain	Seed	Crop removal	Loss[1]	Balance
				Nitrogen				
Control	0	30.6	25	3.4	8.2	33.6	30.2	3.4
NPK	300	30.6	25	3.4	8.2	138.0	200.2	29.0
FYM	240	30.6	35	3.4	8.2	137.0	83.5	96.7
				Phosphorus				
Control	0	0.5	0	0.2	1.0	5.7	0	-4.0
NPK	43.7	0.5	0	0.2	1.0	23.2	0	22.2
FYM	54.0	0.5	0	0.2	1.0	23.1	0	32.6
				Potassium				
Control	0	20.4	0	5.0	4.9	36.4	6.0	-12.1
NPK	75	20.4	0	5.0	4.9	150.3	17.3	-62.3
FYM	120	20.4	0	5.0	4.9	148.8	16.7	-15.2

[1]Includes volatilization, denitrification, and leaching from soil for N and leaching for K.

Insufficient application of K primarily limited yield in both NPK and FYM treatments. Crops fertilized with NPK averaged 47 kg/ha/yr more negative K balance than the FYM plots due almost entirely to lower K application. It is possible to bridge the yield gap and reverse the yield decline through appropriate nutrient management. A sustainable fertilizer management strategy must ensure high and stable overall productivity and sufficient nutrient supply for potential yield increases. The present recommendation of 100, 13, and 25 kg/ha N, P and K for rice and 100, 17.5, and 25 kg/ha for wheat is inadequate for N and K, but optimum for P.

Potassium application rates are generally low and masked by other nutrient limitations or imbalances. Hence, farmers are reluctant to take the risk to apply K. It is difficult to build up soil N, P, and K once they are depleted. Further studies are required to validate the recommendations in farmers' fields and evaluate the economic feasibility. Such a fertilizer management strategy must be revised after some years to account for the change in indigenous N, P, and K status that may have occurred because of a positive or negative N, P, and K input-output balance. **BCI**

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