Effect of Fertilizers and Organic Manures on Crop Yields and Soil Properties in Rice-Wheat Cropping System

R S Rekhi, D K Benbi, and Bhajan Singh[1]

Abstract

The crop yields and soil properties after 13 cycles of rice-wheat cropping in a long-term experiment, on a loamy sand (Typic Ustipsament) at the Punjab Agricultural University farm, Ludhiana, India were studied. Both rice and wheat gave significant responses to N and P application. In rice, response to N was 1.43 t ha^{-1} over control, and NP combination enhanced it further by 0.82 t ha^{-1}. In wheat, the response to N application was small but application in combination with P greatly increased yield. In the rice-wheat system, when wheat received recommended amount of P-fertilizer, even if the rice was not given any P, there was no adverse effect of this on rice yield. Integrated use of green manure and inorganic N in rice compensated for 60 kg fertilizer N ha^{-1} and farmyard manure compensated for 40 kg fertilizer N ha^{-1}. The application of organic manures raised the initially low status of soil organic carbon to medium after 13 cycles of cropping.

Introduction

In the initial years of long-term experiments, nitrogen (N) was the king pin for increasing crop yields. A small starter dose of N helped the crop to meet its requirements for all macro- and micronutrients from already existing pool of nutrients in the soil. Gradually, the inherent pool of nutrients exhausted and response to phosphorus (P) or potassium (K) increased considerably due to depletion of readily available forms of these nutrients (Meelu et al. 1979; Biswas et al. 1987; Nambiar and Abrol 1989; Nand Ram 1992). Under progressively increasing intensity of cropping the emerging deficiencies of iron (Fe), zinc (Zn), sulfur (S), and recently manganese (Mn) have become critical and are being managed by soil fertility restoration practices, including application of organic manure, green manure (GM), and micronutrients. To sustain high crop yields without deterioration of soil fertility, it is important to work out optimal combination of fertilizers and manures in the cropping system. In this study, long-term effects of different combinations of N, P, K, and Zn applied singly or in combination with farmyard manure (FYM) and GM on crop yield and nutrient dynamics have been evaluated after 13 crop cycles.

Materials and Methods

A long-term fertilizer experiment with rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system is in progress since 1982 on a Fatehpur loamy sand (Typic Ustipsament) at the Punjab Agricultural University farm, Ludhiana (30°56' N and 75°27' E). At the start of the experiment, the field soil (0–15 cm) had 8.1 pH, 0.21 dS m^{-1} electrical conductivity, 4.6 c mol (p+) kg^{-1} soil cation exchange capacity (CEC),

1. Punjab Agricultural University, Ludhiana 141 004, Punjab, India.

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0.18% organic carbon (OC), 9.4 mg kg^{-1} ammoniacal-N, 3 kg ha^{-1} Olsen P, and 93 kg ha^{-1} NH_4OAc-extractable K.

The fertilizer treatments comprised: control (no NPK), application of recommended dose (100%) and one and a half times the recommended amount (150%) of N, NP, NPK, and NPKZn to wheat and half the amount of N through GM and the rest through prilled urea (PU) to rice [N(60PU+60GM)]; 90 kg N ha^{-1} plus recommended amounts of PKZn to wheat and 80 kg N ha^{-1} through urea and the rest through FYM to rice [N(80PU+40FYM)]. Recommended amounts of N:P:K:Zn are 120 kg N : 30 kg P_2O_5 : 30 kg K_2O : 3 kg Zn ha^{-1} for rice and 120 kg N : 60 kg P_2O_5 : 30 kg K_2O : 3 kg Zn ha^{-1} for wheat. The N, P, K, and Zn were applied through urea, single superphosphate, muriate of potash, and $ZnSO_4$ respectively. Nitrogen was applied to rice in 3 equal amounts: at transplanting, 3 weeks after transplantating, and 6 weeks after transplanting, and to wheat in 2 equal amounts: half at seeding and half at crown root initiation. All of the P and K were applied at transplanting of rice and seeding of wheat. Each treatment was replicated 6 times (plot size 8 m × 3 m, i.e., 24 m^2) in a randomized block design.

Rice was transplanted each year in the plant geometry of 15 cm × 20 cm in the second fortnight of June. After rice harvest in the third week of October, wheat was sown in the first fortnight of November. The crop was harvested in the third week of April for grain yield. Immediately after wheat harvest, GM crop (*Sesbania aculeata* Poir.) was seeded with a hand drill in between the harvested wheat rows with zero till. After 50 days growth, the GM crop was incorporated with a tractor-drawn disk harrow in the field, immediately before transplanting rice. Fresh biomass addition through GM ranged between 12 and 15 t ha^{-1}, containing 80–87% moisture with an N content of 2.2–2.4% on an oven-dry basis and had an average C:N ratio of 19:1 on dry weight basis.

The experimental area is characterized as a semi-arid, subtropical region. The mean monthly class A open pan evaporation exceeds precipitation during October–June. The mean monthly maximum air temperature ranges between 19°C in January and 38°C in June/July and the minimum between 5°C in January and 25.6°C in July.

Results and Discussion

Crop yield

Rice gave highly significant response to N at 120 and 180 kg ha^{-1}. A comparison of rice yield with that of control, irrespective of P, K, or Zn treatments, revealed a mean increase of 44–75% at N120 and 67–75% at N180 levels (Fig. 1; Table 1). The experimental soil contained very low amounts of organic matter and had a low N supplying capacity; response of rice to N on such soils and fertilizer N supply had been reported to control rice yields (Rekhi et al. 1982). Addition of P along with N enhanced rice yield by 16–21% at N120 and only 4–5% at N180. Low

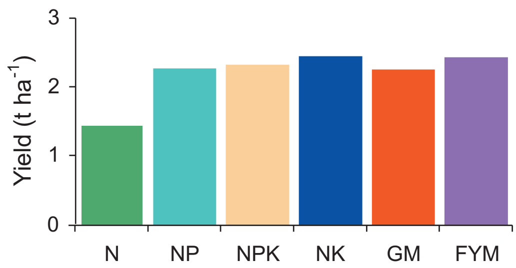

Figure 1. Response of rice to fertilizer and organic manures application in rice-wheat system at Ludhiana, Punjab, India (N=nitrogen, P=phosphorus, K=potassium, GM=green manure, and FYM=farmyard manure).

Table 1. Effect of continuous application of inorganic fertilizers and organic manures to rice on yield of rice in rice-wheat system at Ludhiana, Punjab, India.

Treatment[1] (kg ha^{-1})	Grain yield (t ha^{-1})			
	1992	1993	1994	Mean
Control	3.13	2.84	3.74	3.24
N120	4.57	4.56	4.89	4.67
N180	4.81	6.04	5.34	5.40
N120P30	5.18	6.19	5.11	5.49
N180P45	5.20	6.43	5.43	5.69
N120P30K30	5.25	6.21	5.17	5.54
N180P45K45	5.23	6.27	5.42	5.64
N120P30K30Zn3	5.16	6.29	5.26	5.57
N180P45K45Zn4.5	5.24	6.28	5.37	5.63
N120K30Zn3	5.06	6.54	5.40	5.67
N(60PU+60GM)P30K30Zn3	5.13	6.20	5.07	5.47
N(80PU+40FYM)P60K30Zn3	5.47	6.78	5.45	5.90
LSD (P = 0.05)	0.66	0.55	0.45	

1. N=nitrogen; P=phosphorus; K=potassium; Zn=zinc; PU=prilled urea; GM=green manure; FYM=farmyard manure.

response of rice to P application is very common and an increase in P availability upon flooding is generally used to explain it. In subtropical conditions of this experiment, high temperature and submerged conditions during rice agro-ecosystem are most congenial for increased P availability. This is confirmed by an earlier study of Gill and Meelu (1983) on this soil. They reported that soil reduction caused mobilization of insoluble phosphates and increased P availability of added and native phosphates. However, this is complicated by reported ability of rice to meet its requirement successfully in soil or culture media containing very low concentration of solution P and a greater diffusivity of P under submerged than under upland soil conditions. No significant response to K application was observed; probably because the experimental soil was found rich in K-bearing minerals. The K-bearing minerals in Punjab soils include mica, feldspar, and illite. Biotite is present in heavy sand fractions and light sand fractions contain muscovite and K-feldspar. Bhangu and Sidhu (1996) reported that biotite and illite appear to be sources of K release in these soils. High dose (150%) of NP, NPK, and NPKZn application did not increase yield significantly. Interestingly, in N120K30Zn3 treatment when wheat received recommended amount of P in the cropping system, it did not have any adverse effect on rice yield even when no fertilizers were applied to rice. Patrick and Mahapatra (1968) had also reported a similar behavior of rice towards residual and direct effect of applied P. This may be due to submergence induced solubilization of residual P through reduction and favorable changes in soil pH (Hundal et al. 1987). Addition of GM to rice compensated for 60 kg fertilizer N ha^{-1} while FYM gave a substitution of 40 kg N ha^{-1}.

Wheat gave a significant response of 0.28 and 0.67 t ha^{-1} over control at N120 and N180 levels respectively (Table 2; Fig. 2). Addition of P in combination with N increased wheat yield response to 1.82 and 2.06 t ha^{-1} over control at the corresponding N levels respectively. These results emphasized that under limited soil P supply, fertilizer P application resulted in high wheat yield and ensured efficient utilization of N. Wheat is grown in cool dry season between November and April. Low temperature during wheat seemed to be the cogent cause of limited P availability. A significant response to K application was obtained in two out of the three years. The inconsistent behavior of K response in different years at recommended as well as higher

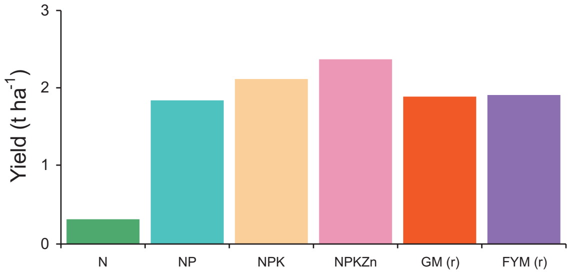

Figure 2. Response of wheat to fertilizer and residual (r) organic manures in rice-wheat system at Ludhiana, Punjab, India (N=nitrogen, P=phosphorus, K=potassium, GM=green manure, and FYM=farmyard manure).

Table 2. Effect of continuous application of inroganic fertilizers and organic manures to wheat on yield of wheat in rice-wheat system at Ludhiana, Punjab, India.

Treatment[1] (kg ha^{-1})	Grain yield (t ha^{-1})			
	1992	1993	1994	Mean
Control	2.04	1.93	1.81	1.93
N120	2.49	2.12	2.02	2.21
N180	2.87	2.57	2.37	2.60
N120P60	3.64	3.77	3.85	3.75
N180P90	3.83	4.06	4.08	3.99
N120P60K30	3.93	4.04	4.13	4.03
N180P90K45	4.00	4.05	4.32	4.12
N120P60K30Zn3	3.99	3.96	4.20	4.05
N180P90K45Zn4.5	4.16	4.24	4.44	4.28
N120P60K30Zn3 (to wheat) and N120K30Zn3 (to rice)	3.87	3.83	4.14	3.95
N120P60K30Zn3 (to wheat) NS and N(60PU+60GM)P30K30Zn3 (to rice)	3.93	3.81	3.65	3.80
N90P60K30Zn3 (to wheat) and N(80PU+40FYM)P60K30Zn3 (to rice)	3.78	3.85	4.01	3.88
LSD (P = 0.05)	0.29	0.33	0.25	

1. N=nitrogen; P=phosphorus; K=potassium; Zn=zinc; PU=prilled urea; GM=green manure; FYM=farmyard manure.

fertilizer rates is attributed to high content of K-bearing minerals in soil. Addition of FYM to rice resulted in a significant residual effect on wheat yield equivalent to 30 kg fertilizer N ha^{-1}. The GM to rice did not have a significant residual effect on the yield of succeeding wheat.

The yields of the two crops together, during the 11, 12, and 13 crop cycles, showed that a mean productivity of 5.2 t ha^{-1} yr^{-1} could be obtained without any fertilizer application and 6.9 t ha^{-1} with 120 kg N ha^{-1} to each crop. The productivity increased to 9.2 t ha^{-1} yr^{-1} with NP and 9.6 t ha^{-1} yr^{-1} with NPK/NPKZn at recommended levels. High (150%) nutrient application gave marginal increase of 0.3–0.4 t ha^{-1} yr^{-1} over recommended levels. The integrated use of GM/FYM with reduced levels of inorganic N gave gross yield at a par with recommended level of fertilizer application.

Soil properties

The effect of fertilizers and organic manure on soil properties showed that with continuous application of 100% or 150% NPK or their combinations with organic manures, the initial low status of available P raised to high and very high levels commensurate with P application (Table 3). A decrease in available soil P with continuous cropping, without adding P fertilizers, and an increase at optimal NPK levels have been reported at Pantnagar, Barrackpore, and Masaudha in India (Lal and Mathur 1988; Nand Ram 1992). Initial low level of OC was raised to medium level only in treatments with GM or FYM. Continuous cropping with 100% or 150%

Table 3. Effect of continuous application of inorganic fertilizers and organic manures on soil properties after 12 cycles of rice-wheat cropping at Ludhiana, Punjab, India.

Treatment[1] (kg ha^{-1})	Organic carbon (%)	Olsen P (mg kg^{-1})
Control	0.20	2.2
N120	0.30	2.4
N180	0.31	2.9
N120P60	0.32	10.5
N180P90	0.35	13.5
N120P60K30	0.37	14.0
N180P90K45	0.38	18.0
N120P60K30Zn3	0.34	11.0
N180P90K45Zn4.5	0.34	24.0
N120P60K30Zn3 to wheat and N120K30Zn3 to rice	0.33	7.0
N120P60K30Zn3 to wheat and N(60PU+60GM)P30K30Zn3 to rice	0.41	14.0
N90P60K30Zn3 to wheat and N(80PU+40FYM)P60K30Zn3 to rice	0.38	11.5
Initial value (1982)	0.18	3.0

1. N=nitrogen; P=phosphorus; K=potassium; Zn=zinc; PU=prilled urea; GM=green manure; FYM=farmyard manure.

NPK levels showed significant increase in OC but the change in status from low to medium was observed only in GM or FYM treatments.

Conclusion

In rice-wheat system, direct application of fertilizer P to wheat is necessary to sustain optimum crop yield whereas its application to rice may be omitted if the preceding wheat crop received the recommended P amount. Application of GM and FYM to rice in combination with reduced amount of inorganic N compensated for fertilizer N and improved soil OC status. Continuous application of phosphatic fertilizers resulted in build-up of Olsen P in surface soil.

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