Long-term Effects of Fertilizer Practices on Yield and Profitability of Rice-Wheat Cropping System

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Abstract

Field experiments were conducted to study the long-term effects of fertilizer practices on yield and profitability of rice-wheat cropping system at Kuthulia, Rewa in Madhya Pradesh, India, from *kharif* (rainy season) 1977/78 onwards using $3^2 \times 2$ factorial partially confounded design in 3 blocks. Eighteen treatment combinations consisting of 3 levels of nitrogen (N) (40, 80, 120 kg N ha^{-1}), 3 levels of phosphorus (P) (0, 40, 80 kg P_2O_5 ha^{-1}), and 2 levels of K (0, 40 kg K_2O ha^{-1}) with a control plot in each block were tested continuously at fixed site on rice and wheat during *kharif* and *rabi* (postrainy season). Data of 10 years (from 1977/78 to 1986/87), i.e., first phase of experimentation, were analyzed.

Increasing levels of N increased grain yield of rice significantly, the highest being at 120 kg N ha^{-1}. Similar trends were observed during most of the years on grain yields of wheat. Rice responded to P significantly during most of the initial years up to 40 kg P_2O_5 ha^{-1}, which increased up to 80 kg ha^{-1} in 1986/87. The effect of P on grain yields of wheat was more pronounced and increasing trends were observed up to 80 kg P_2O_5 ha^{-1} from 1980/81 to 1986/87. There was no effect of K application on yield of rice. However, grain yields of wheat increased significantly at 40 kg K_2O ha^{-1} over its zero level during later years. Continuous cropping with the highest fertilizer level (120 kg N ha^{-1} + 80 kg P_2O_5 ha^{-1} + 40 kg K_2O ha^{-1}) appeared to have prevented appreciable decline in grain yields; yield level declined sharply under control. Increase in grain yield under highest fertilizer level over control was 76% in rice and 233% in wheat in 1977/78 while in 1986/87 it was 180% in rice and 310% in wheat. The mean net return ha^{-1} $yr^{-1}$was also maximum under highest fertilizer level. Beneficial effects of balanced fertilization have been observed in other combinations also in terms of yields and mean net return with seasonal fluctuations due to climate.

Introduction

Stepping up food production per unit area using intensive cropping is needed in India to keep pace with population growth. The importance of an adequate supply of plant nutrients through fertilizer to ensure efficient crop production is well recognized in the statement of the noted agricultural scientist, Norman Borlaug, "If the high-yielding varieties were the catalyst that ignited the green revolution, the chemical fertilizers were the fuel that powered the forward thrust."

Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping sequence is the dominant cropping system in the Indo-Gangetic Plain, and occupies nearly 50% of its cropped area. Nutrients removal by rice-wheat rotation, producing almost a total grain yield of 8.8 t ha^{-1} yr^{-1} is about 660–700 kg of nitrogen, phosphorus, and potassium (NPK) as well as several kilograms of essential micronutrients (Pillai

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1985). Intensive cropping and higher yields are possible only through balanced fertilizer use.

Besides useful information expected in this direction from a long-term fertilizer experiment, there had been some apprehensions regarding soil fertility and crop yield being adversely affected by the prolonged use of inorganic fertilizers. With this background, the present investigation was initiated with the following objectives: (i) to find out the optimum fertilizer combination for the crop sequence under Kymore plateau conditions; (ii) to find out yield stability of rice-wheat sequence with the use of fertilizer combinations over the years; and (iii) to determine economic viability of NPK combinations for the sequence.

Materials and Methods

The experiments were conducted at the Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV) Campus, Kuthulia, Rewa in Madhya Pradesh, India, under Kymore plateau agroclimatic sub-zone of Madhya Pradesh. The soil of the experimental area is silty clay loam (19% sand, 49% silt, 32% clay). At the start of the experiment, the soil was low in available N, medium in available P, and high in available K and soil reaction was neutral (Table 1).

Kuthulia farm is situated in 40°30' N and 81°15' E at an altitude of 365.7 m above mean sea level. The climate of the place is subtropical. This agroclimatic region represents a vast area where the results of the experiments could be extrapolated but districts of Rewa, Satna, Sidhi, Shahdol, and Panna, part of Jabalpur and other similar areas will get full and special benefits.

The experiment was initiated with rice and wheat cropping system at the fixed experimental site under irrigated condition from *kharif* (rainy season) 1977 on a long-term basis. The site had rice-wheat cropping system with uniform doses of 60 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} in both seasons prior to experimentation. Data of ten years up to *rabi* (postrainy season) 1986/87 (i.e., first phase of investigation) have been taken into consideration. Eighteen treatment combinations consisting of 3 levels of N (40, 80, 120 kg N ha^{-1}); three levels of P_2O_5 (0, 40, 80 kg P_2O_5 ha^{-1}); and 2 levels of K_2O (0, 40 kg K_2O ha^{-1}), with a control plot in each block were tried using $3^2 \times 2$ factorial partially confounded design in three blocks with four replications. High-yielding varieties of rice and wheat were used during *kharif* and *rabi*. Nutrients were supplied to soil only through chemical fertilizers as urea, single superphosphate, and muriate of potash. Full quantity of P and K along with fraction

Table 1. Chemical analysis of surface (0–15 cm) soil before starting the experiment in 1977 at Kuthulia, Rewa, India.

Description	Value	Method used
Available nitrogen (kg ha^{-1})	207.00	Micro-Kjeldahl (Jackson 1967)
Available phosphorus (kg ha^{-1})	18.00	Chapman and Pratt (1961)
Available potassium (kg ha^{-1})	470.00	Triple acid digested material using EEL flame photometer (Jackson 1967)
Organic carbon (%)	0.22	Walkley and Black
pH	7.30	1:2 soil-water suspension
Electrical conductivity (mmhos cm^{-1})	0.22	Saturation extract

$^1/_3$ and ½ quantity of N (for rice and wheat respectively) were broadcast before planting rice and drilled below seed at the time of sowing wheat. Remaining quantity of N was top-dressed in two equal installments at tillering and panicle initiation stages of rice and at crown root initiation and maximum tillering stages of wheat. Neither farmyard manure (FYM) nor plant straw was externally applied at any stage in any season.

Results and Discussion

Effect of nitrogen on grain yield of rice and wheat

There was a pronounced increase in rice yield with N application. Consecutive increase in N level increased yield of rice significantly with highest grain yield being under 120 kg N ha^{-1} during all years. Similar trends were also observed with yield of wheat grain (Table 2). These findings were in conformity with Hari Shankar et al. (1976). Rawal and Yadav (1988) and Verma et al. (1988) observed a linear response of wheat to N. The yield of rice showed a declining trend with time irrespective of N levels, although magnitude of decline was more prominent in plots without added N. Time factor did not influence wheat yield in treatments except in control.

Effect of phosphorus on grain yield of rice and wheat

Addition of 40 kg P_2O_5 ha^{-1} showed remarkable positive effect on rice yield throughout the

Table 2. Effect of fertilizers on grain yield (t ha^{-1}) of rough rice and wheat under continuous cropping at Kuthulia, Rewa, India.

Treatment	1977/78 to 1980/81		1981/82 to 1983/84		1984/85 to 1986/87	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Control	2.70	1.05	1.95	0.95	1.78	0.84
N (kg ha^{-1})						
40	3.71	1.66	2.91	1.73	2.56	1.68
80	4.47	2.00	3.78	2.07	3.09	2.08
120	4.97	2.12	4.25	2.22	3.52	2.23
CD (P = 0.05)	0.17	0.12	0.18	0.16	0.13	0.13
P_2O_5 (kg ha^{-1})						
0	4.25	1.52	3.54	1.51	2.89	1.35
40	4.38	2.06	3.70	2.15	3.08	2.16
80	4.52	2.20	3.70	2.46	2.23	2.49
CD (P = 0.05)	0.17	0.12	0.18	0.16	0.13	0.13
K_2O (kg ha^{-1})						
0	4.36	1.92	3.60	1.92	3.04	1.92
40	4.40	1.94	3.96	2.09	3.09	2.08
CD (P = 0.05)	NS[1]	NS	NS	0.13	NS	0.11

1. NS=not significant.

experimentation; the crop responded up to 80 kg P_2O_5 ha^{-1} only at later stages (Table 2). Phosphorus at 80 kg P_2O_5 ha^{-1} was observed to have a significant effect on wheat grain yield continuously, for the whole period of study. The time factor reflected a negative trend of rice yield, irrespective of the levels of P supplied, but it was more prominent when P was not added. The productivity of wheat on the other hand, was either static or showed an upward trend with advancement of time under all P levels. But a sharp decline in yield of the crop was observed in plots receiving no P at later stage of study. Due to congenial conditions for availability of P during *kharif*, a better utilization of reserve quantity of that nutrient by rice might have resulted in non-significant differences in its yield under 40 and 80 kg P_2O_5 levels for longer period of experimentation. But in later years, deficiency of P caused due to uptake by crops showed response of rice to high dose, i.e., 80 kg P_2O_5 ha^{-1}. The findings of this study are supported by Pillai (1985), who observed P response for rice and wheat at several locations.

Effect of potassium on grain yield of rice and wheat

Potassium did not show any positive effect on rice yield (Table 2). Similar trend was noted in wheat during initial stages but later on the productivity of wheat enhanced significantly due to application of 40 kg K_2O ha^{-1}. Such a response of crops to K might be due to its high level in soil. Longer periods of cropping, however, indicated an overall declining trend in yield of rice, although productivity pattern of wheat remained nearly static even after 10 years.

Effect of N, P, and K combination on grain yield of rice and wheat under continuous cropping

The rice yields showed declining trend with time. However, magnitude of reduction was low under balanced fertilizer combinations in comparison to control, where yield declined sharply (Table 3). The mean yield 2.70 t ha^{-1} obtained during first 4 years in control reduced to 1.95 t ha^{-1} and 1.78 t ha^{-1} during subsequent 3-year periods, with a reduction of 28% during subsequent second phase and 34% during third phase, in comparison to the first phase. The corresponding values were 13% and 27% under N120P80K40; 12% and 27% under N80P40K40; 19% and 31% under N40P40K0 respectively showing beneficial effect of balanced fertilizer.

Unlike rice, effect of balanced fertilizer under continuous cropping was more pronounced in wheat and the yield level was static in comparison to control. Under most of the treatment combinations an increase was observed after first phase of four years but after next three years it was observed to be either static or declining. The mean yield 2.59 t ha^{-1} obtained with N120P80K40 during first 4 years increased to 3.93 t ha^{-1} during second phase and 3.09 t ha^{-1} during third phase, showing an increase of 52% and 19% during second and third phases respectively. The corresponding values were 15% and 13%; 6% and 4%; and –10% and –16% with N80P40K40, N40P40K0, and N0P0K0 respectively. However, with N alone the yield level was not maintained and the corresponding values of increase in yield during second and third phases when compared with those during the first phase were 2% and –21%; –7% and –10%; and –5% and –21% under 40, 80, and 120 kg N ha^{-1} respectively.

These values are clear indications of beneficial effects of balanced fertilizer under continuous cropping and manuring. These results obtained are in agreement with those of Venkateswarlu and Singh (1980), Pillai (1985), and Khan et al. (1996). The marked decline in yield of rice could be due to losses of nutrients

Table 3. Effect of different combinations of N, P, and K on grain yield (t ha^{-1}) under continuous cropping in rice-wheat system at Kuthulia, Rewa, India.[1]

Treatment (kg ha^{-1})			1977/78 to 1980/81		1981/82 to 1983/84		1984/85 to 1986/87	
N	P	K	Rice	Wheat	Rice	Wheat	Rice	Wheat
0	0	0	2.70	1.05	1.95	0.95	1.78	0.84
40	0	0	3.59	1.43	2.74	1.46	2.06	1.13
40	0	40	3.58	1.42	2.70	1.50	2.43	1.48
40	40	0	3.69	1.75	3.00	1.85	2.53	1.82
40	40	40	3.91	1.86	3.15	1.83	2.60	1.75
40	80	0	3.77	1.80	2.86	1.88	2.70	2.01
40	80	40	3.19	1.71	3.04	1.85	2.70	1.91
80	0	0	4.40	1.62	3.83	1.50	3.00	1.46
80	0	40	4.35	1.65	3.83	1.72	2.95	1.48
80	40	0	4.43	2.01	3.67	2.83	3.05	1.98
80	40	40	4.35	2.14	3.82	2.46	3.16	2.42
80	80	0	4.56	2.32	3.74	2.37	3.22	2.52
80	80	40	4.67	1.84	3.76	2.38	3.25	2.61
120	0	0	4.76	1.53	3.99	1.45	3.16	1.21
120	0	40	4.33	1.45	4.11	1.44	3.30	1.36
120	40	0	5.02	2.22	4.32	2.18	3.55	2.36
120	40	40	4.95	2.40	4.33	2.54	3.59	2.62
120	80	0	5.08	2.52	4.31	2.63	3.68	2.13
120	80	40	5.20	2.59	4.50	3.93	3.80	3.09

1. N=nitrogen; P=phosphorus (as P_2O_5); K=potassium (as K_2O).

during rainy season, causing imbalance or limited supply.

Economic returns

The data reveal that on the basis of prevailing rates of inputs and outputs during the year 1986/87, the mean net return of Rs 8,961 ha^{-1} yr^{-1} was obtained under balanced fertilizer level (120:80:40 kg NPK ha^{-1}) which was Rs 3,190 more than the net returns obtained by applying 120 kg N ha^{-1} alone (Fig. 1). The lowest mean return of Rs 3,008 ha^{-1} yr^{-1} was obtained under control (no fertilizer application) and an increase of Rs 1,703 was recorded due to application of 40 kg N ha^{-1} only; 40 kg P_2O_5 ha^{-1} with 40 kg N ha^{-1} recorded Rs 974 more net return and further Rs 96 was added due to addition of 40 kg K_2O ha^{-1}. Net return of Rs 6,127 ha^{-1} yr^{-1} was obtained with 80 kg N ha^{-1} alone and an increase of Rs 478 was observed due to addition of 40 kg P_2O_5 ha^{-1}. A further increase of Rs 686 ha^{-1} yr^{-1} was obtained with 40 kg K_2O ha^{-1} with the said dose.

The results are a clear indication of beneficial effect of balanced fertilization under continuous cropping. Application of N alone @ 40, 80, and 120 kg ha^{-1} recorded net return of Rs 4,711, Rs 6,127, and Rs 5,771 ha^{-1} yr^{-1} but

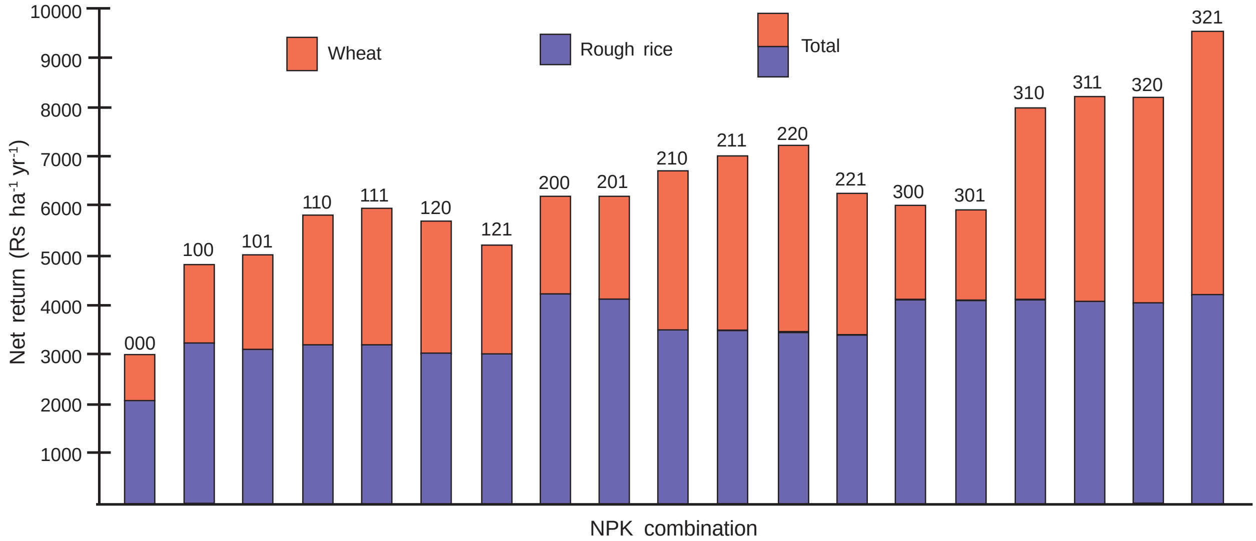

Figure 1. Ten-year (1978 to 1987) mean net return as affected by various NPK combinations (0=0, 1=40, 2=80, 3=120 kg ha^{-1}) under rice-wheat sequence at Kuthulia, Rewa, India.

increase of Rs 974, Rs 478 and Rs 1930 was observed with the addition of 40 kg P_2O_5 ha^{-1} with these doses. Further increase in P_2O_5 @ 80 kg ha^{-1} recorded additional decrease/increase as Rs –199, Rs 813, and Rs 497 respectively indicating better response to P application in combination with higher doses of N. The trend of produce obtained under various combinations in relation to variation in cost of fertilizers is attributed to the mean net return ha^{-1} yr^{-1}. Low magnitude of response to K application in mean net return was due to similar trend in yield of grain and straw under corresponding treatments.

Conclusion

Due to unforeseen climate and season, fluctuations in yields were observed which were common in all treatments. It can be concluded that yield of rice showed declining trend with time even after application of highest dose of fertilizer. But in wheat, yield level has been static or increasing particularly under balanced fertilization. However, a declining trend was observed when balanced fertilizer dose was not given which was highest under control. The increase in even most responsive nutrient N alone has not maintained the yield level. If reduction in fertilizer dose is essential then it should be reduced in a balanced manner as 120:80:40, 80:40:40, 40:40:0 kg NPK ha^{-1} combinations. In order to prevent decline in yield and maintain soil fertility the experiment may be redesigned and treatments may be modified as there is scope to increase fertilizer dose and obtain higher yield/income than the highest yield/income obtained under highest fertility levels tested. It was observed that after 6–7 years there was a downward trend in yield, which can be prevented by supplementing nutrients in terms of doses, or even providing additional nutrients including microelements through the provision of new treatments.

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References

Chapman, H.D., and **Pratt, P.F.** 1961. Methods of analysis for soils, plants and waters. California, USA: Division of Agricultural Sciences, University of California.

Hari Shankar, Baburam, and **Rathi, K.S.** 1976. Effect of neem cake blended urea on the yield and uptake of nutrients by rice grown under transplanted and direct sown conditions. Journal of the Indian Society of Soil Science 24:211–213.

Jackson, M.L. 1967. Soil chemical analysis. New Delhi, India: Prentice Hall of India Pvt. Ltd. 498 pp.

Khan, R.A., Jain, M.P., Sharma, P.B., and **Urkurkar, J.S.** 1996. Balanced fertilization with NPK for increasing rice production. Pages 20–34 *in* Balanced fertilizer use for increasing food grains production in western states. Dundahera, Gurgaon, Haryana, India: Potash and Phosphate Institute of Canada, India Programme.

Pillai, K.G. 1985. Long range effect of continuous cropping and manuring with nitrogen, phosphorus and potassium in selected crop sequences. Project Bulletin No. 4. Bangalore, India: All India Coordinated Agronomy Research Project, University of Agricultural Sciences.

Rawal, D.R., and **Yadav, G.L.** 1988. Comparative performance of newly released and standard varieties of wheat and their nitrogen requirement under irrigated conditions in Chittorgarh district. Annals of Agricultural Research 9:266–267.

Venkateswarlu, M.S., and **Singh, Mahatim.** 1980. Response of rice varieties to different spacings and fertility levels on yield attributes and yield. Indian Journal of Agronomy 25(2):263–272.

Verma, U.N., Srivastava, V.C., and **Verma, U.K.** 1988. Nitrogen management in wheat under conventional and no tillage conditions in rice-wheat sequence. Indian Journal of Agronomy 33(1):37–43.