

## Long-term influence of nutrient management on productivity and profitability of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system

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### ABSTRACT

A long-term fertilizer experiment on maize (*Zea mays* L.)–wheat (*Triticum aestivum* L.) cropping system was initiated during 1983 at the Birsa Agricultural University farm, Ranchi, Jharkhand. The present investigation was part of this long-term experiment started after 29 crop cycles during 2013–14 and 2014–15, to find out the effect of long-term fertilization on productivity and economics of maize–wheat cropping system. The experiment was laid out in partially confounded design with 18 treatments and 1 control with 4 replications. Treatment comprised 3 levels of nitrogen (40, 80 and 120 kg N/ha), 3 levels of phosphorus (0, 40 and 80 kg P<sub>2</sub>O<sub>5</sub>/ha) and 2 levels of potassium (0 and 40 kg K<sub>2</sub>O/ha). Results showed that balanced fertilization of maize–wheat cropping system with N<sub>120</sub>P<sub>80</sub>K<sub>40</sub> kg/ha resulted in the maximum grain yield of maize (4.21 t/ha), wheat (4.52 t/ha) as well as maize-equivalent yield (9.41 t/ha) with net returns of ₹67,396/ha and benefit: cost ratio (1.09). Continuous application of 120 kg N/ha alone for more than 30 years drastically reduced the grain yield of maize (0.94 t/ha), wheat (1.50 t/ha) and maize-equivalent yield (2.66 t/ha), which was 29.05% less than the control (1.32 t/ha, grain yield of maize). However, an application of 40 kg P<sub>2</sub>O<sub>5</sub>/ha along with nitrogen remarkably improved the productivity of individual crop as well as cropping system.

**Key words:** Cropping system, Economics, Long-term fertilization, Maize, Productivity, Wheat

Out of 30 important cropping systems, maize–wheat is the third most important cropping system – occupies about an area of 1.8 million ha with a productivity of 8–10 t/ha (Jat *et al.*, 2012). The contribution of this cropping system to total food grain production of the country is considerably large and it is pre-dominant system in Jharkhand with productivity of 3.25 t/ha (Kumar *et al.*, 2013). Cropping system involving cereal and cereal had led to mining nutrient from soil which resulted in deterioration of soil health (Porpavai *et al.*, 2011). Both maize and wheat are fertilizer responsive and exhibit full yield potential when supplied with adequate quantities of nutrients at proper time. Among the various production factors, fertilizer management is a key factor for increasing the yield of crop. The nitrogen requirement of crop is more than any

other nutrients and its deficiency at any stage of growth, especially tasseling and silking stage of maize may lead to virtual crop failure. However, continuous application of only nitrogen drastically reduces the grain yield of maize and wheat over years due to gradual increase in exchangeable acidity, deficiency of basic cations and imbalance among the nutrients (Sahay and Singh, 2004). Soils of Jharkhand are acidic (Alfisols) in reaction, low in availability of nitrogen and phosphorus, medium to high in potassium and poor in water-retention capacities. Alfisols are abundant in Fe, Al and Mn, phosphorus fixation is more, which creates nutrient imbalance in the soil resulting in the deficiency of certain plant nutrients. The average yield of cereals particularly maize and wheat in these acidic soils reveal low productivity. Therefore, to meet the demand of foodgrain for burgeoning population, there is need of sustainable production through the resource management and to maintain the soil fertility by judicious application of fertilizer. Hence present investigation was planned to find out the effect of long-term nutrient management on productivity and economics of maize–wheat system.

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## MATERIALS AND METHODS

A long-term field experiment was initiated during 1983 at the Birsa Agricultural University Farm, (23°17' N, 85°19' E, 625.22 m above mean sea-level) Ranchi, Jharkhand, and the present investigation was part of this long-term experiment started after 29 crop cycles during 2013–14 and continued for 2 consecutive years. At the beginning (1983), experimental soil was sandy-loam, having pH 6.4, available N 260 kg/ha, available P 19.5 kg/ha and available K 195 kg/ha. However, before the start of present experiment it varies depending on the fertilizer level. Maximum reduction in pH 4.65 was observed in plot receiving only nitrogen ( $N_{120}P_0K_0$  kg/ha). Climate of the experimental area is subtropical with hot and dry summer, comparatively cool rainy season followed by moderate winter. The average rainfall in both the years during the study period was 1,017.5 mm and 638.0 mm during 2013 and 2014 from June to October, while wheat crop received 75.3 mm and 59.1 mm from October to April during 2013–14 and 2014–15 respectively. The mean maximum and minimum temperature for maize was 28.9 and 22.0°C in the first year and 30.1 and 22.2°C in the second year. For wheat, the maximum and minimum temperature was recorded 25.6 and 10.2°C in the first year and 25.8 and 11.2°C in the second year respectively.

The experiment was laid out in partially confounded design with 18 treatments and 1 control, replicated 4 times. Treatments comprising 3 levels of nitrogen (40, 80 and 120 kg N/ha), 3 of phosphorus (0, 40 and 80 kg  $P_2O_5$ /ha) and 2 of potassium (0 and 40 kg  $K_2O$ /ha). Variety used for rainy season (*kharif*) maize and (*rabi*) winter season wheat was 'Suwan' and 'K 9107' respectively. Nitrogen, phosphorus and potassium were applied through urea, diammonium phosphate and muriate of potash respectively.

In maize, one-third dose of nitrogen and full doses of phosphorus and potassium were applied at the time of sowing, while remaining nitrogen was equally side-dressed at knee high (days after sowing) and tassel stages. At physiological maturity, cobs were harvested manually. After drying in the Sun, the grains were separated out and weighed to record economic yield. After harvesting of the *kharif* crop, wheat was sown in the same plots in the *rabi* season with same fertilizer dose. Half dose of nitrogen and full doses of phosphorus and potassium were applied at the time of sowing, while remaining nitrogen in 2 equal split was top-dressed at the first and second irrigation. Wheat was harvested at physiological maturity stage and after Sun drying and threshing, weighed to record grain and straw yields. Finally economic crop yields were recorded and their monetary re-

turns were calculated on the basis of prevailing market prices of the produce. System productivity was calculated in terms of maize equivalent yield (MEY).

Data obtained in the cropping sequence for 2 consecutive years were pooled and statistically analyzed using the F test, the procedures given by Gomez and Gomez (1984).

## RESULTS AND DISCUSSION

### Grain yield of maize

The maximum grain yield of maize was recorded in crop fertilized with 120 kg N/ha which was 14.7, 18.7 and 109.8% higher than 80, 40 kg N/ha and the control respectively (Table 1). The increment in yield might be owing to favourable effect of N on growth parameter and yield attributing characters. Results confirm the finding of Nasrollahzadeh *et al.* (2015).

Among phosphorus levels, the maximum grain yield of maize was recorded with 80 kg  $P_2O_5$ /ha, being which was 13.9, 219.0 and 159.9% higher than 40, 0 kg  $P_2O_5$ /ha and the control respectively. Drastic increase in yield might be owing to better nutritional environment in soil, positive and significant effect in root formation, proliferation and their functional activities. Our results confirm findings of Sepat and Rai (2013).

In case of potassium application, the maximum grain yield of maize was recorded with 40 kg  $K_2O$ /ha which was 10.2 and 99.1% higher than maize fertilized with 0 kg  $K_2O$ /ha and the control respectively. This was mainly because of healthy plant growth which keeps plant cells turgid by controlling osmotic processes in cell-sap, reduces lodging and resistant to diseases and pest. The majority of K accumulation occurs before silking might have positive effect on yield increase (Hanway, 1962; Karlen *et al.* 1988).

Regarding interaction effect of N and P, the maximum grain yield of maize was recorded in plot getting 120 kg N and 80 kg  $P_2O_5$ /ha which was 207.6% higher than the control and was significantly superior to rest of the combination of N and P level (Table 2). Increasing N level from 40 to 120 kg/ha without any phosphorus gradually decreased grain yield of maize might have been because of extreme lowering of soil pH and depleted the P in soil. However, addition of P either with 40 or 80 kg/ha significantly increased the grain yield of maize, irrespective of N level, owing to creating favourable condition for crop growth resulting in superiority of yield attributes. It also helped in the efficient absorption and utilization of the other required plant nutrients which ultimately increased the grain yield (Sepat and Rai, 2013).

Addition of 40 kg  $K_2O$  along with 120 kg N/ha increased the grain yield of maize (3.00 t/ha) by 33.9% in comparison to 40 kg N along with 0 kg  $K_2O$ /ha (Table 3).

This was possibly because of increase in the K application that promoted vigorous growth in plants when those plants received any doses of N. Seidel *et al.* (2015) also observed a positive interaction effect of N and K.

When P and K interact, the maximum grain yield of maize was recorded with 80 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O/ha, being 169.7% higher than the control (1.32 t/ha) and was significantly superior to rest of the combination of P and K level (Table 4), owing to favorable effect of P, causing vigorous growth of plant may process a storing of energy by photosynthesis as reported by Massood *et al.* (2011).

However, in balanced fertilization, grain yield of maize (4.21 t/ha) was recorded maximum with N<sub>120</sub>P<sub>80</sub>K<sub>40</sub> kg/ha which was at par with N<sub>120</sub>P<sub>40</sub>K<sub>40</sub> kg/ha (4.00 t/ha) and N<sub>120</sub>P<sub>80</sub>K<sub>0</sub> kg/ha (3.92 t/ha). Grain yield of maize was drastically reduced due to omission of phosphatic fertilizer irrespective of N and K level. However, addition of phosphorus changes the yield trend just reverse. This was possibly due to continuous application of N only, leading to extreme lowering of soil pH, but balanced use of fertilizer maintains the soil reactions and productivity (Sharma and Jain, 2014).

### Grain yield of wheat

Grain yield of wheat was statistically influenced by N and P levels as well as in N × P and P × K interactions. The maximum grain yield of wheat was recorded with 120 kg N/ha (3.18 t/ha) which was 10.6, 17.5 and 259.4% higher than 80, 40 kg N/ha and the control respectively (Table 1). Singh and Agarwal (2001) also reported the similar findings.

Among P levels, the maximum grain yield of wheat was recorded with 80 kg P<sub>2</sub>O<sub>5</sub>/ha, which was 11.4, 155.1 and 332.5% higher than 40, 0 kg P<sub>2</sub>O<sub>5</sub>/ha and the control respectively. Drastic increase in yield was possibly owing to cell elongation, root development, increased number of tillers and ultimately increased dry-matter accumulation. These results confirm those of Mumtaz *et al.* (2014).

In combination of N and P, the maximum grain yield of wheat was recorded with application of 120 kg N and 80 kg P<sub>2</sub>O<sub>5</sub>/ha which was 388.2% higher than the control and was significantly superior to rest of the combinations of N and P (Table 2). Increasing nitrogen level from 40 to 120 kg/ha without any P gradually decreased grain yield of wheat. However, addition of 40 and 80 kg P<sub>2</sub>O<sub>5</sub>/ha along with 120 kg N/ha drastically increase the grain yield of

**Table 1.** Grain yield of maize, wheat, maize-equivalent yield (MEY) and economics as influenced by long-term nutrient management in maize-wheat system (pooled data of 2 years)

Treatment	Grain yield (t/ha)			System economics		
	Maize	Wheat	MEY	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>	1.32	0.89	2.34	32,260	-5,986	-0.16
N level						
N <sub>40</sub>	2.34	2.71	5.46	74,922	24,154	0.44
N <sub>80</sub>	2.42	2.88	5.73	78,867	26,774	0.47
N <sub>120</sub>	2.77	3.18	6.44	88,323	34,906	0.58
SEm±	0.05	0.05	0.07	880	880	0.02
CD (P=0.05)	0.14	0.13	0.19	2,450	2,450	0.05
P level						
P <sub>0</sub>	1.08	1.50	2.81	38,740	-4,552	--0.10
P <sub>40</sub>	3.02	3.44	6.98	95,652	41,519	0.76
P <sub>80</sub>	3.44	3.83	7.85	107,720	48,866	0.83
SEm±	0.05	0.05	0.07	880	880	0.02
CD (P=0.05)	0.14	0.13	0.19	2,450	2,450	0.05
K level						
K <sub>0</sub>	2.39	2.92	5.75	78,992	28,276	0.51
K <sub>40</sub>	2.63	2.93	6.00	82,416	28,946	0.48
SEm±	0.04	0.04	0.05	672	672	0.01
CD (P=0.05)	0.11	NS	0.14	1,871	NS	NS
Interaction CD (P=0.05)						
N × P	2.23	0.21	0.30	3,969	3,969	0.08
N × K	0.19	NS	0.25	3,241	3,241	NS
P × K	0.19	0.17	0.25	3,241	3,241	0.06
N × P × K	0.33	NS	0.43	5,614	5,614	NS

wheat by 221.0 and 248.2%, respectively, in comparison to 120 kg N along with 0 kg P<sub>2</sub>O<sub>5</sub>/ha owing to favourable condition for crop growth, resulting in higher yield attributes and ultimately yield.

Maximum grain yield of wheat was recorded with 80 kg P<sub>2</sub>O<sub>5</sub> with 40 kg K<sub>2</sub>O/ha, which was 350.2% higher than the control and was significantly superior to rest of the combination of P and K level (Table 4), owing to favourable effect of phosphorus, causing vigorous growth of plant and storing of energy by photosynthesis. Results confirm the finding of Regmi *et al.* (2002).

**System productivity**

The maximum MEY (6.44 t/ha) was recorded in plot getting 120 kg N/ha, being 12.3, 18.0 and 174.8% higher than 80, 40 kg N/ha and the control respectively (Table 1).

However, among phosphorus level, maximum MEY (7.85 t/ha) was recorded with 80 kg P<sub>2</sub>O<sub>5</sub>/ha, which was 12.5, 179.7 and 234.9% higher than 40, 0 kg P<sub>2</sub>O<sub>5</sub>/ha and control respectively. Among the potassium level, maximum MEY (6.00 q/ha) was recorded with 40 kg K<sub>2</sub>O/ha, which was 4.4 and 156.2% higher than 0 kg K<sub>2</sub>O/ha and the control respectively.

Crop fertilized with 120 kg N and 80 kg P<sub>2</sub>O<sub>5</sub>/ha recorded the maximum MEY (9.04 t/ha). However, in interaction of N and K, the maximum (6.65 t/ha) was found with 120 kg N and 40 kg K<sub>2</sub>O/ha (Table 3). Again, interaction effect of P and K, the maximum MEY (8.16 t/ha) was recorded in 40 kg K<sub>2</sub>O with 80 kg P<sub>2</sub>O<sub>5</sub>/ha. In 3 factor interaction of N, P and K, significantly higher MEY (9.41 t/ha) was recorded with N<sub>120</sub>P<sub>80</sub>K<sub>40</sub> kg/ha which was 301.8% higher than the control.

**Table 2.** Interaction effect of nitrogen × phosphorus on grain yield of maize, wheat, maize-equivalent yield (MEY) and economics as influenced by long-term nutrient management in maize–wheat system (pooled data of 2 years)

Treatment	Grain yield (t/ha)			System economics		
	Maize	Wheat	MEY	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>	1.32	0.89	2.34	32,260	-5,986	-0.16
<i>N × P interaction</i>						
N <sub>40</sub> P <sub>0</sub>	1.30	1.73	3.29	45,300	3,333	0.08
N <sub>40</sub> P <sub>40</sub>	2.74	2.83	6.00	82,317	29,508	0.56
N <sub>40</sub> P <sub>80</sub>	2.97	3.57	7.08	97,150	39,620	0.69
N <sub>80</sub> P <sub>0</sub>	1.05	1.54	2.82	38,910	-4,382	-0.10
N <sub>80</sub> P <sub>40</sub>	2.94	3.50	6.97	95,633	41,500	0.77
N <sub>80</sub> P <sub>80</sub>	3.27	3.60	7.42	1,02,058	43,204	0.73
N <sub>120</sub> P <sub>0</sub>	0.88	1.24	2.31	32,009	-12,607	-0.28
N <sub>120</sub> P <sub>40</sub>	3.37	3.99	7.96	1,09,007	53,550	0.96
N <sub>120</sub> P <sub>80</sub>	4.07	4.33	9.04	1,23,953	63,775	1.06
SEm±	0.08	0.07	0.11	1,425	1,425	0.03
CD (P=0.05)	0.23	0.21	0.30	3,969	3,969	0.08

**Table 3.** Interaction effect of nitrogen × potassium on grain yield of maize, wheat, maize-equivalent yield (MEY) and economics influenced by long-term nutrient management in maize–wheat system (pooled data of 2 years)

Treatments	Grain yield (t/ha)			System economics		
	Maize	Wheat	MEY	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>	1.32	0.89	2.34	32,260	-5,986	-0.16
<i>N × K interaction</i>						
N <sub>40</sub> K <sub>0</sub>	2.24	2.65	5.29	72,702	23,311	0.45
N <sub>40</sub> K <sub>40</sub>	2.44	2.77	5.62	77,142	24,997	0.44
N <sub>40</sub> K <sub>80</sub>	2.38	2.92	5.73	78,831	28,115	0.51
N <sub>80</sub> K <sub>0</sub>	2.46	2.84	5.74	78,903	25,433	0.42
N <sub>80</sub> K <sub>40</sub>	2.55	3.19	6.23	85,444	33,403	0.58
N <sub>120</sub> K <sub>0</sub>	3.00	3.18	6.65	91,203	36,408	0.58
N <sub>120</sub> K <sub>40</sub>	3.00	3.18	6.65	91,203	36,408	0.58
SEm±	0.07	0.06	0.09	1,164	1,164	0.02
CD (P=0.05)	0.19	NS	0.25	3,241	3,241	NS

**Soil fertility**

Long-term fertilizer applications (1983-2013) of N, P and K through inorganic fertilizer as influence soil reaction, maximum reduction in soil pH (4.52) was recorded with  $N_{120}P_0K_0$  kg/ha and minimum reduction (5.61) with  $N_{40}P_0K_{40}$  kg/ha (Table 6). It might be due to use of only nitrogenous fertilizer which causes acidity by excessive accumulation of cation ion in soil. Control plot as well as balanced fertilizer treated plot had the least variation. Soil

pH influenced the N, P and K availability. Imbalanced use of nutrient (only N) through inorganic fertilizer had deleterious effect on soil health, leading to unsustainable productivity even less than the control. The results confirm the findings of Gathala *et al.* (2007), Kumari *et al.* (2013) and Singh and Wanjari, (2013).

**System economics**

Crop fertilized with 120 kg N/ha resulted in signifi-

**Table 4.** Interaction effect of phosphorus  $\times$  potassium on grain yield of maize, wheat, maize-equivalent yield (MEY) and economics influenced by long-term nutrient management in maize-wheat system (pooled data of 2 years)

Treatment	Grain yield (t/ha)			System economics		
	Maize	Wheat	MEY	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
$N_0P_0K_0$	1.32	0.89	2.34	32,260	-5,986	-0.16
<i>P <math>\times</math> K interaction</i>						
$P_0K_0$	1.15	1.70	3.11	42,977	1,062	0.03
$P_0K_{40}$	1.00	1.30	2.50	34,503	-10,166	-0.22
$P_{40}K_0$	2.71	3.39	6.60	90,544	37,788	0.71
$P_{40}K_{40}$	3.33	3.50	7.35	1,00,760	45,250	0.81
$P_{80}K_0$	3.31	3.68	7.54	1,03,456	45,979	0.80
$P_{80}K_{40}$	3.57	3.99	8.16	1,11,985	51,754	0.86
SEm $\pm$	0.07	0.06	0.09	1,164	1,164	0.04
CD (P=0.05)	0.19	0.17	0.25	3,241	3,241	NS

**Table 5.** Interaction effect of nitrogen  $\times$  phosphorus  $\times$  potassium on grain yield of maize, wheat, maize-equivalent yield (MEY) and economics influenced by long-term nutrient management in maize-wheat system (pooled data of 2 years)

Treatments	Grain yield (t/ha)			System economics		
	Maize	Wheat	MEY	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
$N_0P_0K_0$	1.32	0.89	2.34	32,260	-5,986	-0.16
<i>N <math>\times</math> P <math>\times</math> K Interaction</i>						
$N_{40}P_0K_0$	1.40	1.92	3.60	49,712	9,122	0.22
$N_{40}P_0K_{40}$	1.20	1.54	2.97	40,888	-2,456	-0.06
$N_{40}P_{40}K_0$	2.57	2.72	5.69	78,077	26,646	0.52
$N_{40}P_{40}K_{40}$	2.91	2.95	6.31	86,556	32,371	0.60
$N_{40}P_{80}K_0$	2.75	3.33	6.58	90,318	34,166	0.61
$N_{40}P_{80}K_{40}$	3.20	3.82	7.58	1,03,981	45,075	0.77
$N_{80}P_0K_0$	1.12	1.70	3.07	42,414	499	0.01
$N_{80}P_0K_{40}$	0.99	1.38	2.57	35,407	-9,262	-0.21
$N_{80}P_{40}K_0$	2.77	3.49	6.78	92,985	40,229	0.76
$N_{80}P_{40}K_{40}$	3.11	3.52	7.16	98,281	42,771	0.77
$N_{80}P_{80}K_0$	3.25	3.57	7.36	1,01,095	43,618	0.76
$N_{80}P_{80}K_{40}$	3.29	3.63	7.47	1,03,021	42,790	0.71
$N_{120}P_0K_0$	0.94	1.50	2.66	36,805	-6,435	-0.15
$N_{120}P_0K_{40}$	0.83	0.99	1.97	27,214	-18,780	-0.41
$N_{120}P_{40}K_0$	2.79	3.95	7.34	1,00,571	46,491	0.86
$N_{120}P_{40}K_{40}$	3.95	4.02	8.58	1,17,443	60,609	1.07
$N_{120}P_{80}K_0$	3.92	4.13	8.67	1,18,955	60,153	1.02
$N_{120}P_{80}K_{40}$	4.21	4.52	9.41	1,28,951	67,396	1.09
SEm $\pm$	0.12	0.11	0.15	2,015	2,015	0.04
CD (P=0.05)	0.33	NS	0.43	5,614	5,614	NS

cantly higher gross returns (₹88,323/ha), net returns (₹34,906/ha) and benefit: cost ratio (0.58) (Table 1). Benefit: cost ratio (B:C) with 120 kg N/ha was 23.4 and 31.8% higher than 80 and 40 kg N/ha, whereas in the control, higher dose of only nitrogen and omission of phosphorus fertilized plot gave negative value. Effect of 120 kg N/ha on beneficial return was reported by Upasani *et al.* (2013).

Among the phosphorus levels, crop fertilized with 80 kg P<sub>2</sub>O<sub>5</sub>/ha recorded significantly the maximum gross returns (₹1,07,720/ha), net returns (₹48,866/ha) and B : C ratio (0.83). Maximum B : C ratio was 9.2% higher than crop fertilized with 40 kg P<sub>2</sub>O<sub>5</sub>/ha in a system as a result of significant increase in yield owing to phosphorus application. Again crops fertilized with 0 kg P<sub>2</sub>O<sub>5</sub>/ha in a system showed negative B:C ratio due to very poor yield.

Among the potassium levels, the maximum gross returns (₹82,416/ha) was recorded with 40 kg K<sub>2</sub>O/ha; however, net returns and B : C ratio were not influenced and both were more or less statistically similar because of potassium application was not as responsive as the phosphorus.

The maximum gross returns (₹123,953/ha), net returns (₹63,775/ha) and benefit: cost ratio (1.06) were recorded with 120 kg K<sub>2</sub>O with 80 kg P<sub>2</sub>O<sub>5</sub>/ha as a result of system

significant increase in yield owing to phosphorus application. However, interaction effect of N and K resulted maximum gross returns (₹91,203/ha) and net returns (₹36,408/ha) in the crop fertilized with 120 kg N with 40 kg K<sub>2</sub>O/ha owing to very higher yield.

By the 3 factor interaction of N, P and K the maximum gross returns (₹1,28,951/ha) and net returns (₹67,396/ha) were recorded with higher level of fertilizer dose N<sub>120</sub>P<sub>80</sub>K<sub>40</sub> kg/ha. It indicates that crops grown at higher fertilizer dose as well as all the combinations of N, P and K levels were economically viable except crop fertilized without P fertilizer. Kumar *et al.* (2005) also and Pathak *et al.* (2005) reported similar results.

Thus, it may be concluded that balanced use of fertilizer with N<sub>120</sub>P<sub>80</sub>K<sub>40</sub> kg/ha in long-term maize-wheat cropping system maintained maximum individual crop yield of maize (4.21 t/ha), wheat (4.52 t/ha) as well as maize-equivalent yield with net returns of ₹67,396/ha and B:C ratio of 1.09. Whereas, continues use of nitrogenous fertilizer alone not only deteriorated soil fertility but also drastically reduced yield in acidic soil of Jharkhand.

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**Table 6.** Fertility status of soil after crop harvesting (31 crop cycle) as influenced by long-term nutrient management in maize-wheat system (pooled data of 2 years)

Treatment	Soil pH	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
N <sub>0</sub> P <sub>0</sub> K <sub>0</sub>	6.05	215.1	13.1	137.3
N <sub>40</sub> P <sub>0</sub> K <sub>0</sub>	5.14	198.6	23.2	129.4
N <sub>40</sub> P <sub>0</sub> K <sub>40</sub>	5.61	225.5	19.7	176.0
N <sub>40</sub> P <sub>40</sub> K <sub>0</sub>	5.56	213.0	93.9	118.8
N <sub>40</sub> P <sub>40</sub> K <sub>40</sub>	5.45	251.8	87.9	166.3
N <sub>40</sub> P <sub>80</sub> K <sub>0</sub>	5.36	237.4	201.3	115.1
N <sub>40</sub> P <sub>80</sub> K <sub>40</sub>	5.53	268.7	183.7	152.9
N <sub>80</sub> P <sub>0</sub> K <sub>0</sub>	4.91	225.7	17.2	120.6
N <sub>80</sub> P <sub>0</sub> K <sub>40</sub>	5.46	256.5	12.9	171.6
N <sub>80</sub> P <sub>40</sub> K <sub>0</sub>	5.20	234.4	88.0	116.3
N <sub>80</sub> P <sub>40</sub> K <sub>40</sub>	5.43	264.9	84.0	146.2
N <sub>80</sub> P <sub>80</sub> K <sub>0</sub>	5.27	243.4	193.3	112.4
N <sub>80</sub> P <sub>80</sub> K <sub>40</sub>	5.31	264.1	165.4	127.2
N <sub>120</sub> P <sub>0</sub> K <sub>0</sub>	4.52	262.7	12.2	106.1
N <sub>120</sub> P <sub>0</sub> K <sub>40</sub>	4.54	271.2	13.7	136.7
N <sub>120</sub> P <sub>40</sub> K <sub>0</sub>	5.10	283.0	85.3	104.2
N <sub>120</sub> P <sub>40</sub> K <sub>40</sub>	5.02	292.2	76.8	88.0
N <sub>120</sub> P <sub>80</sub> K <sub>0</sub>	5.19	286.0	153.5	91.6
N <sub>120</sub> P <sub>80</sub> K <sub>40</sub>	5.22	328.6	150.3	108.6
SEm±	0.07	9.92	3.58	6.31
CD (P=0.05)	0.20	NS	NS	17.89
Initial (1983)	6.40	260	19.5	195

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