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Research Paper

Long term effect of nutrient management practices on performance of quality protein maize under maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping sequence

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ABSTRACT

An investigation was carried out during (2009–11) at Ranchi, Jharkhand, in the field under long-term experiment since 1983, to evaluate the performance of 'HQPM 1' maize (*Zea mays* L.) as affected by continuous application of different nutrient-management practices under maize (*Zea mays* L.)–wheat [*Ttriticum aestivum* (L.) emend. Fiori & Paol.] cropping sequence. Combined application of organic sources, namely farmyard manure (FYM), cut paddy straw and green *karanj* [*Pongamia pinnata* (L.) Pierre] leaves along with chemical fertilizers improved maize grain yield, yield-attributing characters, viz. cobs/plant, length of cob, girth of cob, grain rows/cob, grains/row, grains/cob and 1,000-grain weight, and growth parameters, viz. plant height, leaf area index (LAI), dry matter production (DMP), net assimilation rate (NAR) and crop growth rate (CGR). Highest LAI (3.6), DMP (1190.6 g/m^2), NAR (6.4 g/m^2/day), CGR (12.2 g/m^2/day), maize grain yield (4.37 t/ha), MEY (9.69 t/ha), production efficiency (40.4 kg/ha/day), protein content (9.56%) and benefit: cost ratio (0.87) was observed for the treatment receiving integrated nutrient-management practices through FYM. The results revealed that substitution of N through FYM up to 50% along with 50% RDF for maize followed by 100% RDF for wheat was found to be superior for increasing growth and yield parameters of QPM, protein content, higher income and enhances soil fertility under maize–wheat cropping sequence in upland soils of Jharkhand.

Key words **:** Economics, Growth, Maize equivalent yield, Nutrient management, Production efficiency, Protein quality, Soil chemical properties, System productivity

Maize–wheat cropping system is third most important system in India and is practiced on 1.8 million ha (Jat *et al*., 2011). It is also prevalent cropping system adopted in uplands of Jharkhand. Maize is such an important crop that each part of it is used for one or the other purpose and nothing is goes to waste (Joshi *et al*., 2016). With development of high-yielding varieties and hybrids of maize, it is gaining importance now-a-days and having an edge over other cereals with respect to farm profitability and resource-use efficiency under diverse climatic conditions. The most important goal for enhancing productivity of quality protein maize is to reduce malnutrition through direct human consumption in tribal-dominated areas, where maize is staple food (Kaul, 2013). 'HQPM 1' is the first yellow grain QPM single-cross hybrid, which is responsible for enhancing lysine and tryptophan content of maize endosperm protein (Panwar *et al*., 2016). Most of the farmers in this region use only urea (N fertilizers) for crop cultivation and this fertilizer-use pattern results in multiple-nutrient deficiencies as well as promotes soil bankruptcy. Therefore, it is needed to maintain long-term soil health and crop productivity in intensive cropping system through integrated use of nutrient sources. A permanent manurial trial with different nutrient-management practices from both organic and inorganic sources under maize–wheat cropping system is in progress since 1983 at Research farm of Birsa Agricultural University (BAU), Kanke, Ranchi. The present investigation was carried out during 2009–10 and 2010–11 to study effect of continuous cropping, fertilizer and manure application on the yield and yield attributes, growth parameters and quality of maize under maize–wheat cropping sequence

MATERIALS AND METHODS

A long-term nutrient management experiment initiated during the rainy season (*kharif*) 1983 under All In-

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dia Co-ordinated Research Project (AICRP) on Cropping System Research on Maize–Wheat system at the Birsa Agricultural University, Ranchi. The experiment was laid out in randomized block design (RBD) with a gross plot size of 50.4 m^2/plot with 12 treatments, replicated three times. Treatments comprised T_1, $N_0P_0K_0$ – $N_0P_0K_0$; T_2, 50% RDF – 50% RDF; T_3, 50% RDF – 100% RDF; T_4, 75% RDF – 75% RDF; T_5, 100% RDF –100% RDF; T_6, 50% N through FYM + 50% RDF –100% RDF; T_7, 25% N through FYM + 75% RDF –75% RDF; T_8, 50% N through cut paddy straw + 50% RDF –100% RDF; T_9, 25% N through cut paddy straw + 75% RDF –75% RDF; T_{10}, 50% N through green *karanj* leaves + 50% RDF – 100% RDF; T_{11}, 25% N through green *karanj* leaves + 75% RDF –75% RDF; and T_{12}, 50 kg – 50 kg urea/ha for maize–wheat respectively. The recommended fertilizer dose (100% RDF) of N, P and K was 100, 21.83 and 20.83 kg/ha, respectively, for both the crops, of which one-third of N and full dose of P and K were applied basal. The remaining dose of N was divided into 2 equal parts and applied 21 and 45 days after sowing to as per treatments. The sources of N, P and K were urea, single superphoshate and muriate of potash respectively. Organic manure, viz. FYM and crop residues, viz. cut paddy straw (CPS) and green *karanj* leaf (GKL) were applied on the basis of N content as per the treatment 15 to 20 days before sowing in *kharif* of every year. The present study was undertaken on the above long-term nutrient-management experiment with maize cv. 'HQPM 1' during the rainy season (*kharif*) 2009 and 2010. Number of cobs/plant were recorded from 5 randomly selected 5 plants from each plot and averaged as number of cobs/plant. At harvesting, 5 cobs from the sample of 5 randomly selected tagged plants from each plot were taken out and the length were measured with the help of meter scale and a mean was recorded as average length (cm)/cob. Girths of above 5 cobs were measured at 3 places around each cob, namely at bottom, at middle and at top positions, then the 3 values were averaged out to give average girth (cm) of a single cob. At harvesting, 5 cobs from the sample of 5 random plants from each plot were taken out and number of grain rows in cobs was counted and then a mean was recorded as average number of grain rows in a cob. Grains/row were counted in 5 randomly selected cobs and then a mean was recorded as grains/row. Grains from each of 5 randomly selected cobs were separated with the help of hand maize sheller, counted separately and then average was worked out. Samples were drawn randomly from the total grain produce of each treatment and counted 1,000-grains in each case, dried in the sun and weighed on electrical top-pan balance. The weight was expressed in g. Data on height of maize were collected at 25, 50, 75 days after sowing (DAS) and at harvesting from 5 randomly selected plants in the sampling area of each plot. Height was measured in cm from the ground surface to the top most nodes (i.e. base of tassel) with the help of meter scale and the means were taken into consideration. One representative plant (taken for dry-matter production) was randomly selected from each plot and all green leaves were separated. Then, leaves were cut into 10-cm-long pieces and leaf area (cm^2) reading was taken by automatic LA meter. Leaf area obtained was divided by land area covered by 1 plant to get the leaf area index at 25, 50, and 75 DAS.

In maize, plant from the border row was selected randomly and taken out for studying dry-matter production. The whole plant along with leaf (after measuring LA) was dried, first in sun and then in an oven at 65 ± 5°C till reached a constant weight. Dry weight obtained was converted into g/m^2 for DMP (dry matter production). Crop-growth rate (CGR)/unit area/unit time, expressed as g/m^2/day was determined between 25 and 50, 50 and 75 DAS and 75 DAS and maturity of maize crop as per Radford (1967).

Net assimilation rate (NAR) was calculated for two stages (25 to 50, 50 to 75 DAS) of maize. It was calculated from the data of leaf area and dry-matter yield as:

$$(\text{NAR } (g/m^2/\text{day}) = \frac{W_2 — W_1}{t_2 — t_1} \times \frac{\ln L_2 — \ln L_1}{L_2 — L_1}$$

where W_2 and W_1 were the dry weight; L_2 and L_1 were the leaf area at time t_2 and t_1 respectively.

System productivity as maize equivalent yield (MEY) in maize–wheat cropping system was calculated by using price and yield of both the crops (maize and wheat).

The data on various growth, yield and yield attributes of maize, system productivity as maize- equivalent yield based on the prevailing price of the crops have been computed and statistically analyzed following analysis of variance method (Gomez and Gomez, 1984).

Post-harvest surface soil samples were collected treatment-wise from all replications of on-going permanent manurial trial after harvesting of wheat crop during 2009–10 and 2010–11. Post-harvest soil samples were analyzed for soil reaction (*p*H), organic carbon, available N, P and K by following standard methods.

RESULTS AND DISCUSSION

Growth parameters of maize and crop quality

Long-term effect of different nutrient-management practices on growth attributes and protein quality of maize were significant (Table 1). Variation in plant height was 165.7 to 233.9 cm at harvesting. Plant height reflects the vegetative growth behaviour of crop plants to applied nutrient-management inputs. Maximum increase in plant height was observed between 25 and 50 DAS and after that decreased gradually. Data clearly showed that treatment T_6 (50% N through FYM and 50%N through inorganic fertilizers) resulted in tallest plants of maize at all the growth stages. Plant height increased with balanced nutrient application and further, increase in plant height at different stages was observed for treatments receiving integrated nutrient-management practices. This might be attributed to rapid meristematic cell-division and cell elongation, adequate moisture in FYM-treated plots. Similar to plant height treatment T_6 (50% N nutrient substitution through FYM) exhibited higher leaf-area index (LAI) of maize. Variation in LAI was 1.8 to 3.6 at 75 DAS. Dry-matter production of maize gradually increased with age of crop. The plot applied with 50% organic + 50% inorganic sources produced higher dry matter than rest of treatments. Variation in dry-matter production was 228.5 and 1,190.6 g/m^2 at harvesting. The NAR was also significantly influenced by the applied nutrient inputs. The highest NAR was recorded during 50 and 75 DAS under treatment T_6, where substitution of 50% of N through FYM was applied. Variation in NAR was 2.3 and 6.4 g/m^2/day during 50–75 DAS. Crop-growth rate was the maximum during 50 and 75 DAS. It was higher than the preceding and succeeding growth phases. Treatment T_6 getting recommended dose of nutrients through organic and inorganic source FYM in 50 : 50 proportion recorded the highest crop growth rate at all the stages. Variation in CGR was 1.3 and 12.2 g/m^2/day during 75–100 DAS. Integrated use of chemical fertilizers with FYM had favourable influence on LAI, DMP, CGR, and NAR might be due to contribution of FYM towards increase in water-holding capacity of soil, resulting in increased available soil moisture and physical environment for maize grown under rainfed condition.

Data concerning crude protein content (Table 1) in maize were computed based on the N content in maize grain (Protein content=N*6.25) and found that protein content varied from 8.81 to 9.56 percent and significantly higher protein content was observed for treatment T_6, where substitution of 50% of N through FYM was applied which influence of nutrient-management practices on protein content in ‘HQPM 1’ maize. However, integrated use of nutrient sources resulted in 1.5% increase in protein content as compared to the treatment receiving balanced dose through chemical fertilizers. Balanced use of chemical fertilizers recorded 6.8% increase in protein content of maize as compared to the control.

Yield attributes

Long-term effect of different nutrient management practices on yield attributes of maize were significant (Table 2). Cobs/plant varied from 1.0 and 1.7, length of cob from 10.5 and 18.0 cm, girth of cob from 9.6 and 16.9 cm, Grain rows/cob from 11.1 and 13.00, grains/row from

Table 1. Effect of integrated nutrient management practices on growth parameter of ‘HQPM 1’ (pooled of 2 years)

Treatment		Plant height (cm) at harvesting	Leaf-area index 75 DAS	Dry-matter production (g/m^2) at harvesting	NAR (g/m^2/day) 50–75 DAS	CGR (g/m^2/day) 75–100 DAS	Protein content (%)
Kharif (rainy season)	*Rabi* (winter season)						
T_1, $N_0P_0K_0$	$N_0P_0K_0$	165.7	1.8	228.5	2.27	1.33	8.81
T_2, 50% RDF	50% RDF	201.8	2.4	650.6	4.78	6.11	9.09
T_3, 50% RDF	100% RDF	213.3	2.5	675.7	4.92	6.34	9.03
T_4, 75% RDF	75% RDF	211.8	2.5	673.1	5.01	6.57	9.16
T_5, 100% RDF	100% RDF	220.1	3.1	1017.3	6.24	9.47	9.41
T_6, 50% N (FYM) + 50% RDF	100% RDF	233.9	3.6	1190.6	6.40	12.20	9.56
T_7, 25% N (FYM) + 75% RDF	75% RDF	228.8	3.5	1080.9	6.21	8.24	9.47
T_8, 50% N (CPS) + 50% RDF	100% RDF	210.5	3.0	930.7	6.27	6.94	9.34
T_9, 25% N (CPS) + 75% RDF	75% RDF	208.9	2.9	906.4	6.10	6.80	9.22
T_{10}, 50% N (GKL) + 50% RDF	100% RDF	213.7	3.2	920.5	5.79	7.06	9.28
T_{11}, 25% N (GKL) + 75% RDF	75% RDF	206.2	3.0	785.3	5.04	5.70	9.16
T_{12}, Farmer’s practice urea @ 50 kg/ha	Farmer’s practice urea @ 50 kg/ha	169.1	2.0	293.8	2.50	1.91	8.88
SEm±		11.5	0.3	46.0	0.40	0.53	0.01
CD (P=0.05)		32.85	0.67	130.92	1.13	1.50	0.02
CV (%)		9.71	14.72	10.22	13.45	13.92	4.09

FYM, Farm yard manure; CPS, cut paddy straw; GKL, green *karanj* leaves; NAR, net assimitation rate; CGR, crop-growth rate; RDF, recommended dose of fertilizer

24.4 and 32.9, grains/cob from 269.8 and 428.1 and 1,000-grain weight from 234.5 and 335.7 g. Wide variation among the treatments showed the influence of nutrient-management practices on yield attributes of maize. Significantly, higher yield attributing characters were obtained owing to continuous use of integrated nutrient-management practices. The highest yield-attributing characters were recorded owing to continuous application of 50% N through FYM + 50% N through inorganic fertilizer in maize and 100% RDF in wheat. This might be because of adequate and synchronized availability of nutrients during the crop-growth period which resulted in improvement of the yield attributes. This results are in close conformity with Pathak *et al*. (2005) and Kumar (2008).

Yield and economics of QPM

The maximum grain yield of maize (4.37 t/ha) was recorded in the treatment T_6, (50% N through FYM + 50% through chemical fertilizer in maize and 100% RDF in wheat) and increase in mean grain yield was 0.53 t/ha for maize as compared to recommended dose of fertilizers (100% RDF) both in maize and wheat. Application of 50% N through FYM + 50% through chemical fertilizer in maize and 100% RDF in wheat was significantly superior to 100% recommended fertilizer applied to both the crops and remained on a par with 25% N substitution through FYM and 75% through inorganic source in maize and 75% RDF in wheat. Substitution of N through cut paddy straw or green *karanj* leaf significantly reduced the grain yield of maize and reduction in grain yield was up to 0.29 t/ha as compared to recommended dose of fertilizers, i.e. 100% RDF applied in both maize and wheat. Stone and stover yields followed the similar trends that of grain yield of maize (Table 3). This is in agreement with the results of long-term fertilizers experiments carried out in different agro-climatic situations of the country (Singh and Wanjari, 2013). The results of the present investigation have clearly shown that substitution through FYM up to 50% is a viable option. However, substitution of a part of N through cut paddy straw and fresh *karanj* leaf did not perform well possibly due to slow mineralization of organic N leading to its deficiency during growing period of maize. This finding indicated that the combined application of well-decomposed organic nutrient source and chemical fertilizers proved to be superior to sole inorganic fertilizer application. Kumar (2008), Jat *et al*. (2012), Manjhi *et al*. (2014) also observed the similar findings.

Pooled data on gross returns, net returns and benefit: cost ratio (Table 3) were affected by nutrient management practices. Mean gross return varied from ₹8,506 and ₹46,257/ha, with a net returns of ₹7,630 and ₹21,497/ha and benefit: cost ratio of –0.47 and 0.87 for the maize crop under maize–wheat cropping sequence. The treatment receiving 50% N through FYM + 50% RDF through inorganic fertilizer in maize and 100% RDF in wheat recorded significantly the highest economic return (₹21,497/ha) as well as with higher benefit: cost ratio (0.87) over the rest of the treatments. The treatment receiving 50% N through

Table 2. Effect of integrated nutrient management practices on yield attributes of 'HQPM 1' maize (pooled of 2 years)

Treatment: *Kharif* (rainy season)	Treatment: *Rabi* (winter season)	Cob/plant	Length of cob (cm)	Girth of cob(cm)	Grain rows/cob	Grains/row	Grains/cob	1,000-grain weight (g)
T_1, $N_0P_0K_0$	$N_0P_0K_0$	1.0	10.5	9.8	11.1	24.4	269.8	234.5
T_2, 50% RDF	50% RDF	1.2	15.5	14.6	11.5	28.9	333.4	270.2
T_3, 50% RDF	100% RDF	1.1	16.7	15.5	12.3	29.4	350.4	281.7
T_4, 75% RDF	75% RDF	1.1	16.6	15.7	12.1	28.3	341.8	283.8
T_5, 100% RDF	100% RDF	1.3	17.9	16.6	12.4	29.8	367.8	319.7
T_6, 50% N (FYM) + 50% RDF	100% RDF	1.7	18.0	16.8	13.0	32.9	428.1	335.7
T_7, 25% N (FYM) + 75% RDF	75% RDF	1.4	17.8	16.9	12.6	32.4	408.2	320.1
T_8, 50% N (CPS) + 50% RDF	100% RDF	1.3	17.2	16.0	12.5	31.9	397.9	317.4
T_9, 25% N (CPS) + 75% RDF	75% RDF	1.1	16.7	15.7	12.0	27.8	333.1	309.8
T_{10}, 50% N (GKL) + 50% RDF	100% RDF	1.3	17.0	16.0	12.5	31.6	395.0	303.2
T_{11}, 25% N (GKL) + 75% RDF	75% RDF	1.1	17.0	15.4	11.7	29.8	350.1	291.7
T_{12}, Farmer's practice urea @ 50 kg/ha	Farmer's practice urea @ 50kg/ha	1.1	10.8	9.6	11.4	24.7	281.4	245.5
SEm±		0.1	1.0	1.0	0.4	1.8	22.8	8.7
CD (P=0.05)		0.29	2.96	2.89	1.05	5.20	64.90	24.75
CV (%)		14.0	11.2	11.82	5.28	10.79	11.15	5.14

FYM, Farm yard manure; CPS, cut paddy straw; GKL, green *karanj* leaves; RDF, recommended dose of fertilizer

FYM + 50% RDF through inorganic fertilizer in maize and 100% RDF in wheat resulted in significantly higher net returns (₹21,497/ha)/ha) and benefit: cost ratio (0.87) over the recommended fertilizer practice of 100% RDF in both crops. The FYM substitution up to 50% was observed to be the most effective INM practice as compared to the other sources.

System productivity and production efficiency

System productivity as maize-equivalent yield (MEY) based on the economic value of the crops under maize–wheat cropping system was found to be significantly influenced by the nutrient-management practices (Table 4). Maize-equivalent yield varied from 1.91 and 9.69 t/ha under maize–wheat cropping system on the typical upland soils of Jharkhand. Production efficiency varied from 8.0 to 40.4 kg/ha/day. The highest system productivity as well as production efficiency were obtained for treatment where application of 10t FYM + 50 kg N + 10.90 kg P + 10.38 kg k/ha in maize and 100 kg N + 21.80 kg P + 20.75

Table 3. Effect of integrated nutrient management practices on yield and economics of 'HQPM 1' maize (pooled of 2 years)

Treatments: *Kharif* (rainy season)	Treatments: *Rabi* (winter season)	Grain yield (t/ha)	Stover yield (t/ha)	Stone yield (t/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
T_1, $N_0P_0K_0$	$N_0P_0K_0$	0.80	1.17	0.23	8,506	-7,630	-0.47
T_2, 50% RDF	50% RDF	2.42	3.61	0.67	25,630	6,104	0.31
T_3, 50% RDF	100% RDF	2.51	3.77	0.69	26,581	7,055	0.36
T_4, 75% RDF	75% RDF	2.72	4.19	0.72	28,770	7,548	0.36
T_5, 100% RDF	100% RDF	3.84	5.68	0.99	40,508	17,590	0.77
T_6, 50% N (FYM) + 50% RDF	100% RDF	4.37	6.65	1.22	46,257	2,1497	0.87
T_7, 25% N (FYM) + 75% RDF	75% RDF	3.82	5.54	1.05	40,396	16,557	0.69
T_8, 50% N (CPS) + 50% RDF	100% RDF	3.55	5.28	0.91	37,439	7,446	0.25
T_9, 25% N (CPS) + 75% RDF	75% RDF	3.39	5.12	0.89	35,838	6,766	0.23
T_{10}, 50% N (GKL) + 50% RDF	100% RDF	3.09	4.71	0.88	32,755	12,182	0.59
T_{11}, 25% N (GKL) + 75% RDF	75% RDF	2.67	3.92	0.80	28,239	6,494	0.30
T_{12}, Farmer's practice urea @ 50 kg/ha	Farmer's practice urea @ 50 kg/ha	1.02	1.47	0.32	10,818	-5,945	-0.35
SEm±		0.19	0.33	0.05	2,367.38	567.45	0.02
CD (P=0.05)		0.55	0.96	0.15	6,943.71	1,664.38	0.07
CV (%)		11.30	13.31	11.40	13.60	12.33	13.28

FYM, Farm yard manure; CPS, cut paddy straw; GKL, green *karanj* leaves; RDF, recommended dose of fertilizer

Table 4. Mean grain yield of maize and wheat, maize-equivalent yield (MEY) and production efficiency of the system as affected by nutrient-management practices

Treatment: *Kharif* (rainy season)	Treatment: *Rabi* (winter season)	Maize (t/ha)	Wheat (t/ha)	MEY (t/ha)	Production efficiency (MEY*kg/ha/day)
T_1, $N_0P_0K_0$	$N_0P_0K_0$	0.80	0.98	1.91	8.0
T_2, 50% RDF	50% RDF	2.42	2.65	5.42	22.6
T_3, 50% RDF	100% RDF	2.51	3.89	6.97	29.0
T_4, 75% RDF	75% RDF	2.72	3.41	6.61	27.5
T_5, 100% RDF	100% RDF	3.84	4.05	8.41	35.1
T_6, 50% N (FYM) + 50% RDF	100% RDF	4.37	4.71	9.69	40.4
T_7, 25% N (FYM) + 75% RDF	75% RDF	3.82	4.07	8.41	35.1
T_8, 50% N (CPS) + 50% RDF	100% RDF	3.55	4.00	8.07	33.6
T_9, 25% N (CPS) + 75% RDF	75% RDF	3.39	3.60	7.46	31.1
T_{10}, 50% N (GKL) + 50% RDF	100% RDF	3.09	3.80	7.41	30.9
T_{11}, 25% N (GKL) + 75% RDF	75% RDF	2.67	3.51	6.67	27.8
T_{12}, Farmer's practice	Farmer's practice	1.02	1.25	2.38	9.9
SEm±		0.19	0.21	0.43	-
CD (P=0.05)		0.55	0.60	1.19	-
CV (%)		11.30	10.93	11.23	-

FYM, Farm yard manure; CPS, cut paddy straw; GKL, green *karanj* leaves; RDF, recommended dose of fertilizer

Table 5. Effect of integrated nutrient-management practices on soil properties after 28 years of cropping, fertilizer and manure application under maize–wheat cropping sequence

Treatment		*p*H	Soil organic carbon (%)	Available N(kg N/ha)	Available P(kg P/ha)	Available K (kg K/ha)
Kharif (rainy season)	*Rabi* (winter season)					
T_1 $N_0P_0K_0$	$N_0P_0K_0$	6.28	0.35	225.6	15.4	146.7
T_2, 50% RDF	50% RDF	6.15	0.36	240.1	48.8	134.6
T_3, 50% RDF	100% RDF	6.27	0.37	247.6	61.9	132.1
T_4, 75% RDF	75% RDF	6.20	0.38	245.4	64.5	129.7
T_5, 100% RDF	100% RDF	6.12	0.40	272.2	100.5	127.3
T_6, 50% N (FYM) + 50% RDF	100% RDF	6.77	0.60	375.2	112.8	144.3
T_7, 25% N (FYM) + 75% RDF	75% RDF	6.43	0.51	329.5	94.1	139.4
T_8, 50% N (CPS) + 50% RDF	100% RDF	6.28	0.50	321.1	85.5	134.6
T_9, 25% N (CPS) + 75% RDF	75% RDF	6.25	0.45	293.1	74.3	129.7
T_{10}, 50% N (GKL) + 50% RDF	100% RDF	6.27	0.47	305.2	74.6	132.1
T_{11}, 25% N (GKL) + 75% RDF	75% RDF	6.33	0.43	283.2	70.5	129.7
T_{12}, Farmer’s practice	Farmer’s practice	6.03	0.34	229.3	14.6	120.1
SEm±		0.15	0.03	19.68	4.48	8.15
CD (P=0.05)		0.44	0.08	57.74	13.13	23.90
CV (%)		4.19	10.67	12.14	11.37	10.58

FYM, Farm yard manure; CPS, cut paddy straw; GKL, green *karanj* leaves; RDF, recommended dose of fertilizer

kg K/ha in wheat. The % increase in MEY of maize–wheat cropping system owing to application nutrient-management practices was 183% and 407% over the control. Higher maize-equivalent yield and production efficiency were observed owing to integrated use of organics and chemical fertilizers. The results of the present investigation have clearly shown that substitution through FYM up to 50% is a viable option for typical upland acid soils of Jharkhand.

Soil properties

Soil parameters revealed significant effect of continuous cropping and nutrient-management practices on soil reaction, organic carbon, available N, P and K (Table 5). In general, balanced application of NPK fertilizers improved the soil properties. Integration of organics along with NPK further improved soil properties. Among the 3 sources of organics, FYM was found superior to the others. Effectiveness of organic sources, in general, is manifested in the fact that organic matters release nutrients after mineralization. Humus, the product of organic matter decomposition, on the other hand immensely improves the physical and chemical properties of soils like cation-exchange capacity (CEC), water-holding capacity, bulk density, aeration, soil reaction etc. (Yawalkar *et al.,* 1992). Improvement in these properties, in turn, improves availability and uptake of nutrients. Besides, making available major nutrients, the organic matters also release almost all the essential elements necessary for growth and development, which imparts superiority to combined use of inorganic and organic sources of nutrients over inorganic fertilizers.

On the basis of results of two years pooled data, it can be concluded that long-term application 10 t FYM + 50 kg N + 10.90 kg P + 10.38 kg k/ha in maize and 100 kg N + 21.80 kg P + 20.75 kg K/ha in wheat was found to be the best in respect of growth, yield and yield attributes of maize, maize equivalent yield and system productivity under maize–wheat cropping system.

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