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Effect of integrated nutrient management on growth, yield and economics in maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A long-term manurial trial initiated in 1983 at the Birsa Agricultural University, Kanke, Ranchi, was selected for this investigation during 1997-98 and 1998-99 to evaluate efficacy of organic sources, viz. farmyard manure (FYM), rice (*Oryza sativa* L.) straw and green leaves of kharif (*Pongamia pinnata* Pierre) in organo-inorganic combinations in maize (*Zea mays* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system. At the inception of the experiment during 1983, the soil was loam in texture, slightly acidic in reaction having low organic carbon content and medium status in available N, P and K. Growth parameters, yield attributes, yield and economics of maize were the best in substitution of 25% of the recommended dose of fertilizers (RDF) through FYM, while in wheat crop these parameters had the best reflection in treatment involving 50% substitution of RDF through FYM in maize + 100% RDF in wheat. Wheat–equivalent yield for the whole system established superiority of the 50% substitution of RDF through FYM in maize + 100% RDF in wheat, followed by 25% RDF substitution through FYM in maize + 75% RDF in wheat over all other treatments.

Key words : Integrated nutrient management, Maize–wheat system, Growth attributes, Yield attributes

Maize-wheat sequence is the most extensively adopted cropping system in uplands of Chotanagpur plateau region of Jharkhand. Role of organic manure in crop production and beneficial effect of its integration with inorganic fertilizers have drawn attention of agriculturists since long.

On the other hand, continuous application of high amounts of only inorganic fertilizers had deleterious effect leading to decline in productivity due to limitation of one or more of micro-nutrients (Nambiar and Abrol, 1989). Organic recycling has generated a still higher importance in the context of cropping systems, especially cereal based. Residual nature of organic

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sources makes them more value based for the whole system compared to individual crops. Recycling of organic matter and use of their moderate doses may also bring down the mounting pressure on inorganic fertilizers substantially. With the above facts under consideration, an experiment was carried out to know the effect of integrated nutrient management in maize–wheat cropping system.

MATERIALS AND METHODS

The experiment was carried out in permanent plots under the All-India Co-ordinated Research Project on Cropping System at the Birsa Agricultural University Farm, Ranchi, during rainy and winter seasons of 1997–98 and 1998–99. The climate of the area is subtropical. The rainfall received by maize crop in 1997 (with 63 rainy days) and 1998 (with 54 rainy days) were 1,435.4 and 1,274.9 mm respectively. At the start of the experiment in 1983, the surface soil (0–15 cm) had pH (6.5), bulk density (1.39 g/cm^3), mean weight diameter of soil aggregates (0.718 mm), water-holding capacity (19.8% and 11.3% at 33 K Pa and 1,500 K Pa respectively), organic carbon (0.41%), available N (255.0 kg/ha), available P (14.19 kg/ha) and available K (190.7 kg/ha). The soil was well drained, loam in texture. The treatments comprised 3 organic sources, viz. FYM, rice straw and green leaves of *karanj,* substituting 25% and 50% of the optimum doses of NPK during *kharif* season (6 treatments), which were evaluated against 4 varying levels of inorganic fertilizers along with each of unfertilized control and farmers' practice involving application of 50 kg urea/ha only (Table 1). The treatments were laid out in randomized block design with 3 replications. The recommended doses of N, P and K were 100, 50 and 25 kg/ha to both maize and wheat. Maize plants were given a spacing of 60 cm × 30 cm, whereas wheat rows were spaced 22.5 cm apart. The amount of organic materials as per treatments were decided on the basis of nitrogen content present in these materials. The nitrogen content in FYM, rice straw and green leaves of *karanj* on dry-weight basis were 0.945, 0.51 and 2.86 respectively. The wheat crop was fertilized only with inorganic fertilizers. The variety used in present investigation was 'Suwan' composite for maize and 'K 9107' for wheat.

RESULTS AND DISCUSSION

Growth characters

In maize plant height, leaf-area index, dry-matter accumulation, net assimilation rate and crop-growth rate showed the best expression in the treatment involving substitution of 25% inorganic NPK by FYM (T_7). This treatment was followed T_6 where 50% of the recommended inorganic NPK was substituted through FYM. The effectiveness of 2 other organic sources though not as effective as FYM, also exhibited an edge over the treatment receiving 100% recommended NPK dose in inorganic fertilizer form, but the difference was not significant. The net assimilation rate was higher between 25 and 50 days after sowing (DAS), whereas the crop-growth rate was the maximum between 50 and 75 DAS. Growth of wheat was also markedly

Table 1. Details of treatments applied in maize–wheat cropping system

Treatment	Maize	Wheat
T_1	No fertilizer, no organic manure (control)	No fertilizer, no organic manure (control)
T_2	50% of recommended NPK through fertilizers	50% of recommended NPK through fertilizers
T_3	50% of recommended NPK through fertilizers	100% of recommended NPK through fertilizers
T_4	75% of recommended NPK through fertilizers	75% of recommended NPK through fertilizer
T_5	100% of recommended NPK through fertilizers	100% of recommended NPK through fertilizers
T_6	50% of recommended NPK through fertilizers + 50% N through FYM	100% of recommended NPK through fertilizers
T_7	75% of recommended NPK through fertilizers + 25% N through FYM	75% of recommended NPK through fertilizers
T_8	50% of recommended NPK through fertilizers + 50% N through cut paddy straw	100 % of recommended NPK through fertilizers
T_9	75% of recommended NPK through fertilizers + 25% N through cut paddy straw	75% of recommended NPK through fertilizers
T_{10}	50% of recommended NPK through fertilizers + 50% N through green *karanj* leaves	100 % of recommended NPK through fertilizers
T_{11}	75% of recommended NPK through fertilizers + 25% N through green *karanj* leaves	75% of recommended NPK through fertilizers
T_{12}	Farmer's practice (only urea @ 50 kg/ha)	Farmer's practice (only urea @ 50 kg/ha)

100% N, 100 kg N/ha; 100% P, 50 kg P_2O_5/ha; 100% K, 25 kg K_2O/ha

influenced by organic matter substitution in the preceding crop of maize. The plot which received 50% of the recommended dose in maize through FYM and 100% NPK in wheat (T_6) had the best expression. This treatment, however, did not differ significantly with the treatments involving inorganic fertilizers substituted by rice straw and green leaves of *karanj* in the same proportion. Effectiveness of organic sources, in general, is manifested in the fact that organic matters release nutrients after mineralization which improves the physical and physico-chemical properties of soil (Yawalkar *et al.*, 1992). The greater efficacy of FYM in comparison to rice straw and green leaves might have been because the FYM used was fully decomposed. The mineralization of FYM is very rapid thus eliminating chances of immobi-

Table 2. Effect of integrated nutrient management on plant height, leaf-area index, dry-matter production, net assimilation rate and crop-growth rate of maize in maize–wheat cropping system (pooled value of 2 years, 1997 and 1998)

Treatment	Plant height (cm) at harvest	Leaf-area index (75 DAS)	Dry-matter production (g/m^2) at harvest	Net assimilation rate (g/m^2/day)		Crop-growth rate (g/m^2/day)		
				25 to 50 DAS	50 to 75 DAS	25 to 50 DAS	50 to 75 DAS	75 DAS to harvest
T_1	99.48	1.64	167.70	2.22	1.74	1.39	2.47	2.32
T_2	131.83	2.16	515.50	5.35	4.51	5.49	8.91	4.68
T_3	133.70	2.22	527.75	4.97	4.14	5.68	9.06	4.80
T_4	156.77	2.59	771.90	6.75	5.16	8.84	12.51	7.47
T_5	170.52	3.05	956.00	7.68	5.30	11.85	14.91	8.96
T_6	184.12	3.31	1,147.00	8.60	5.56	14.11	17.05	12.37
T_7	189.85	3.40	1,208.00	8.52	5.60	14.75	17.74	13.36
T_8	162.33	2.95	884.00	7.90	5.03	11.42	13.90	8.02
T_9	169.77	3.04	940.25	8.17	5.11	12.11	14.48	8.88
T_{10}	167.52	3.03	910.40	8.27	5.04	11.79	14.38	8.14
T_{11}	168.93	3.09	930.10	8.25	5.02	11.92	14.46	8.71
T_{12}	108.30	1.98	392.00	4.85	3.47	3.93	5.77	4.89
CD (P=0.05)	11.50	0.19	73.72	0.50	0.22	0.95	1.20	2.87

DAS, Days after sowing

Details of treatments are given in Table 1

lization of nutrients for a longer period. The findings are also in close conformity with the findings of Lal *et al.* (1995), Patel *et al.* (1995) and Pal *et al.* (1996).

Yield attributes

Yield attributes, viz. cobs/plant, cob length cob girth and 1,000-grain weight of maize were found maximum in the treatment T_7 getting 75% of the recommended dose of NPK in inorganic fertilizer forms and the balance 25% N substituted through FYM. However, grains/cob were the highest in T_6, the treatment receiving nutrients in 2 equal halves through inorganic fertilizer and FYM. But the differences in yield attributes under T_6 and T_7 did not differ significantly. Other organic sources, viz. rice straw and green leaves of *karanj* were not as effective as FYM. Organic matters applied to the preceding maize crop had residual effect on wheat which resulted in better expression of yield attributes in plants raised in plots which had experienced substitution of nutrients through organic sources in the preceding crop. The highest values for all the yield-attributing parameters of wheat were recorded from the treatment receiving 50% of NPK through FYM in the preceding crop and getting 100 % recommended NPK in wheat. The treatment which got only 75% of the recommended dose in wheat but involved 25% nutrient substitution through FYM in the preceding maize crop (T_7) had higher values for all the

Table 3. Effect of integrated nutrient management on plant height, leaf-area index, dry-matter production, net assimilation rate and crop-growth rate of wheat in maize–wheat cropping system (pooled value of 1997–98 and 1998–99

Treatment	Plant height (cm) at harvest	Leaf-area index (100 DAS)	Dry-matter production (g/m^2) at harvest	Net assimilation rate(g/m^2/day)		Crop-growth rate (g/m^2/day)			
				25 to 50 DAS	50 to 75 DAS	25 to 50 DAS	50 to 75 DAS	75 to 100 harvest	100 DAS to harvest
T_1	57.47	1.63	293.5	2.77	2.96	2.02	3.89	1.72	1.96
T_2	71.25	2.94	600.5	5.17	2.73	5.40	5.74	4.44	3.81
T_3	84.27	3.36	765.0	5.55	2.88	7.08	7.24	5.90	4.79
T_4	80.58	3.20	702.5	5.19	2.90	6.04	6.73	5.32	4.65
T_5	87.43	3.41	801.5	5.63	3.08	7.26	7.77	6.36	4.89
T_6	93.05	3.78	953.5	6.31	3.85	8.50	10.69	7.34	5.30
T_7	89.65	3.62	863.5	6.22	3.44	8.06	9.10	6.82	4.77
T_8	91.15	3.60	870.5	6.37	3.51	8.14	9.25	6.78	4.85
T_9	86.07	3.50	758.0	5.73	2.94	7.10	7.52	5.88	4.52
T_{10}	90.63	3.64	901.0	6.46	3.67	8.26	9.79	6.94	4.99
T_{11}	86.83	3.53	812.5	6.09	3.16	7.44	8.13	6.54	4.04
T_{12}	58.57	1.68	276.5	2.51	2.73	2.06	3.77	1.44	1.63
CD (P = 0.05)	5.25	0.20	56.9	0.31	0.63	0.64	1.53	1.37	0.57

DAS, Days after sowing
Details of treatments are given in Table 1

Table 4. Effect of integrated nutrient management on yield attributes of maize and wheat in maize–wheat cropping system (pooled data of 1997-98 and 1998-99)

Treatment	Yield attributes of maize					Yield attributes of wheat		
	Cobs/ plant	Cob length (cm)	Cob girth (cm)	Grains/ cob	1,000-grain weight (g)	Heads/ m	Grains/ ear	1,000-grain weight (g)
T_1	0.515	8.29	9.19	146.43	157.87	34.97	34.20	35.692
T_2	1.097	13.08	11.36	252.87	212.22	41.20	44.27	38.369
T_3	1.087	13.22	11.40	279.47	215.09	48.22	45.93	40.505
T_4	1.114	13.55	11.69	314.30	217.15	47.40	44.60	39.492
T_5	1.110	14.94	12.67	374.23	228.77	51.15	47.57	40.577
T_6	1.160	15.49	13.00	413.87	234.74	58.35	52.44	42.475
T_7	1.161	15.55	13.31	412.83	241.61	54.58	49.97	41.258
T_8	1.118	14.90	12.27	338.37	224.32	54.97	50.40	41.476
T_9	1.134	14.64	12.58	356.00	226.01	48.77	46.77	40.462
T_{10}	1.118	14.53	12.25	347.03	225.48	56.23	50.47	41.831
T_{11}	1.124	14.46	11.95	343.57	223.91	49.87	47.87	40.889
T_{12}	0.945	10.70	10.45	202.17	158.89	34.15	34.54	35.556
CD (P = 0.05)	0.055	0.93	0.88	23.76	5.21	3.43	2.43	1.097

Details of treatments are given in Table 1

Table 5. Effect of integrated nutrient management on yield as well as benefit : cost ratio of maize, wheat and maize–wheat system (pooled data of 1997–98 and 1998–99)

Treatment	Grain yield (q/ha)			Benefit : cost ratio		
	Maize	Wheat	Wheat-equivalent yield	Maize	Wheat	Maize–wheat system
T_1	4.73	11.04	14.87	–0.56	–0.15	0.31
T_2	17.43	25.55	39.74	0.37	0.79	0.61
T_3	18.39	32.72	47.71	0.46	1.07	0.83
T_4	23.19	30.32	49.23	0.72	1.02	0.89
T_5	29.39	34.54	58.48	1.05	1.19	1.13
T_6	34.21	43.47	71.37	0.94	1.76	1.37
T_7	36.37	39.31	68.94	1.27	1.61	1.45
T_8	27.49	39.47	61.86	0.43	1.50	0.97
T_9	29.05	33.44	57.11	0.73	1.22	0.99
T_{10}	28.66	40.46	63.81	0.96	1.56	1.30
T_{11}	27.44	35.36	57.73	0.89	1.35	1.15
T_{12}	11.10	9.81	18.84	–0.01	–0.26	–0.15
CD (P=0.05)	2.87	2.95	3.80	0.19	0.19	0.14

Details of treatments are given in Table 1

yield attributes than the treatment receiving 100% NPK dose through inorganic fertilizer in both maize and wheat (T_5). Greater efficacy of FYM in comparison with other organic sources might have been the result of rapid mineralization and release of nutrients. The findings on yield attributes support those of Patel *et al.* (1995) and Deshmukh *et al.* (1996).

Yield

The highest maize grain yield was obtained with the application of 75% recommended dose through inorganic fertilizers and the balance 25% substituted through FYM (T_7). The treatment, however, exhibited statistical parity with the treatment getting half of the recommended dose as inorganic fertilizer and the remaining half in the form of FYM (T_6), which gave an yield of 34.21 q/ha of maize grain. Substitution of inorganic fertilizers by rice straw and *karanj* leaves (T_8, T_9, T_{10} and T_{11}) had the yields at par with that obtained under the application of full dose of nutrients as inorganic fertilizer (T_5). Thus simply changing the source of nutrients from inorganic to FYM, there was a rise in productivity of maize grain by 27.65% in 50% substitution and 30.09% by 25% substitution through FYM. In case of wheat grain, the treatment involving 50% of the recommended dose of nutrients substituted through FYM during *kharif* in maize and getting full recommended dose in inorganic fertilizer form in wheat (T_6) gave grain yield of 43.47 q/ha, significantly outyielding all other treatments. The plots receiving full recommended dose of nutrients in inorganic forms both in maize and wheat (T_5) yielded 34.54 q/ha. This treatment T_5 was significantly surpassed by all the treatments involving 50% substitution of nutrients through any of the organic sources, viz. FYM, rice straw and *karanj* leaves (T_6, T_8 and T_{10}), with grain yield of 43.47, 39.47 and 40.46 q/ha respectively. It was interesting to note that the treatment T_7 getting only 75% of the recommended nutrient dose in wheat but having received 25% of the recommended nutrient dose as FYM in maize also outyielded T_5 significantly. Wheat equivalent worked out for maize–wheat system revealed that the treatment involving 50% substitution in maize through FYM and getting full dose of fertilizer in wheat (T_6) had the highest wheat-equivalent yield of 71.37 q/ha. However, the treatment T_6 was statistically comparable with T_7 (25% substitution in maize as FYM + 75% recommended dose in wheat) having wheat-equivalent yield of 68.94 q/ha. The treatment T_5 getting full dose of fertilizer both in maize and wheat through inorganic fertilizer had wheat-equivalent yield of only 58.48 q/ha. Organic sources play the key role in enhancing efficient utilization of the native as well as added fertilizer nutrients which maintain a balance between growth and yield attributes. The FYM has higher quantum of decomposed organic matter which improves the physical and biological properties of soils. It has more available macro- and micro-nutrients. Residual effect of FYM was also more than those of green leaves of *karanj* and rice straw. These advantages of FYM over rice straw and *karanj* leaves might have been responsible

for higher yield under FYM substitution. The findings are in agreement with those reported by Hegde (1998), Lal (1998) Sharma and Gupta (1998) and Singh *et al.* (1999).

Economics

Significantly highest benefit : cost ratio of 1.27 in maize was obtained with 25% NPK substitution through FYM in maize and supplementing only 75% of the recommended dose in wheat (T_7). In case of wheat the highest benefit : cost ratio of 1.76 was recorded from the treatment T_6. Benefit : cost ratio calculated for the whole system indicated that the treatment T_7 had the highest benefit : cost ratio of 1.45, though being at par with T_6 having benefit : cost ratio of 1.37. Lower benefit : cost ratio under use of rice straw for organic substitution may be attributed to higher biomass used and the price involved.

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