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Integrated Nutrient Management Practice for Maize-Wheat Cropping System in Chhotanagpur Plateau Region

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***Abstract*:** The experiment was carried out during two consecutive years of 2020-22 under the ongoing permanent manurial trial with different nutrient management practices under maize-wheat system since 1983-84 at Birsa Agricultural University, Kanke, Ranchi to study the productivity and profitability under maize-wheat cropping system. The application of 50%N through FYM along with 50% RDF through chemical fertilizer to maize fb 100% RDF through chemical fertilizer to wheat produced maximum and significantly higher grain yield (46.92 and 47.96 q/ha of maize and wheat, respectively) than other nutrient management practices and statistically at par with application of 25%N through FYM along with 75% RDF through chemical fertilizer to maize fb 75% RDF through chemical fertilizer to wheat (45.04 and 45.53 q/ha of maize and wheat, respectively). Highest net return (₹. 50583.00 in maize and ₹.79643.00 in wheat) and B:C ratio (1.32 in maize and 1.87 in wheat) was with the application of 50%N through FYM along with 50% RDF in *kharif* and 100% RDF in *rabi* which was statistically at par with the application of 25%N through FYM along with 75% RDF in *kharif* and 75% RDF in *rabi* (₹.47900.00 and ₹. 75237.00) & B:C ratio (1.28 and 1.83) in maize and wheat respectively.

***Keywords*:** Integrated nutrient management, Productivity, Profitability and Maize-wheat cropping system

Maize (*Zea mays* L.) - wheat (*Triticum aestivum* L.) is the third most important cropping system after rice (*Oryza sativa* L.)-wheat and rice-rice in India, and is grown on about 1.80 million ha each year (Jat et al 2013). Maize and wheat are the main source of world's food energy and also contain significant amounts of proteins, vitamins and minerals, which are essential nutrients for human health. Maize, a crop with high yield and market potential, fits well into rice-wheat systems by replacing rice. It is the third most important food grain crop in India, considered as a most important option for diversifying agriculture in upland areas of India which has high production potential compared to any other cereal crop. Wheat, is another major important staple cereal, supplies the bulk of calories and nutrients in the diets of a large proportion of the world population (Chatzav et al 2010). Globally, India is the second largest wheat-producing country and contributes about 11.9% to the world wheat production from about 12% of world area (Singh et al 2010). The continuous rice–wheat cropping has led to the exhaustion of natural resources and deteriorated soil fertility, producing agricultural outcomes (Hashim et al 2017). Thus, a paradigm shift in cropping systems with different crops is required to enhance profitability. Alternate systems management practices may prove beneficial to improve soil fertility and maintain environmental health. For crop diversification, maize-wheat cropping system has been identified as a suitable alternative to rice–wheat system (Brankov et al 2021). Insufficient application of nutrients and poor soil management, along with harsh climatic conditions and other factors, have contributed to the degradation of soils including soil fertility depletion. To replenish the soil nutrient depletion, application of chemical fertilizers is essential but the efficiency of applied chemical fertilizers is increased when applied along with organic manures. The current energy crisis prevailing higher prices and lack of proper supply system of inorganic fertilizers calls for more efficient use of organic manure, green manure, crop residues and other organic sources along with the inorganic fertilizers to sustain the yield levels (Sathish et al 2011). Organic manures supply nutrients to the current crop and also leave a substantial residual effect on the succeeding crops in different sequential cropping systems. The efficiency of applied chemical fertilizers is also increased when applied along with organic manures. Therefore, better management of soil nutrients is required that delivers sustainable agriculture and maintains the necessary increases in food production while minimizing waste, economic loss and environmental impacts. Integrated nutrient management (INM) is the feasible solution for sustaining the crop productivities, as nutrient requirements of both the crops are high and have shown superior response towards higher

levels of nutrient application (Sharma et al 2020). The balanced use of nutrients is the key to improving the sustainable production of crops (Mani et al 2011). The inorganic fertilizers, through soil or foliar application, have shown tremendous results in terms of agricultural productivity (Brankov et al 2020, Ferrari et al 2021). Furthermore, the use of inorganic nutrient sources coupled with organic sources is a feasible approach for higher agricultural productivity and monitoring soil health (Kumar et al 2021). The utilization of well-decomposed farmyard manure (FYM) in soil management practices is a well-known practice for enhancing crop yield, enhancing SOM, promoting microbial activities, promoting friendly soil environmental management (Blair et al 2005 and Kundu et al 2006), increasing the total organic sources supply, and increasing the plant-available macro and micronutrients in soil. Keeping these points in view, an investigation on suitable INM practice for maize-wheat cropping system in Chhotanagpur Plateau Region has been undertaken with the objective to study the productivity and profitability under maize-wheat cropping system.

MATERIAL AND METHODS

A field experiment was conducted at Birsa Agricultural University, Kanke, Ranchi during *kharif* and *rabi* seasons of two consecutive years, 2020-22. The present experiment is a long term being conducted since *Kharif* 1983 with maize-wheat cropping system. The experimental soil was loam in texture (42.4 % sand, 23.4 % silt and 34.2% clay) with slightly acidic (6.5) in reaction having low organic carbon (4.1 g/kg soil) and available nitrogen (255.0 kg/ha), medium in available phosphorous (12.50 kg/ha) and available potash (195.0 kg/ha) consisting 11.13 18.65 and 3.85 ppm available iron, manganese and zinc. Experiment was laid out in RBD with 12 treatments replicated thrice (Table 1). RDF for both component crop was @ 100:50:25 N: P_2O_5: K_2O kg/ha. "Suwan Composit-1" maize and "K 9107" wheat was the test crop variety. Recommended dose of fertilizer for both component crops were @ 100 kg N, 50 Kg P_2O_5 and 25 kg K_2O /ha. Integrated use of manure (FYM, cut paddy straw and green karanj leaf) along with chemicals at different rate of substitution, farmers' practice of fertilizer use and the control. Residual effect of organic manure application was tested in *rabi* wheat crop along with different levels of inorganic fertilizers. FYM, paddy straw and *karanj* green leaves having 0.5, 0.5 and 2.0 per cent N on oven dry basis were 3 organic sources of nutrients (50%N through FYM @10 ton, 50%N through cut paddy straw @10 ton and 50%N through green karanj leaves @2.5 ton). For substitution of inorganic fertilizers by organic sources, the calculation was done on the basis of N-concentration in organic manure and contents of P and K were ignored. Organic manure was incorporated in the soil well in advance prior to sowing of *kharif* maize only. Application of fertilizers at the time of sowing of crops were followed. The optimum dose of fertilizers for both the crops was N, P_2O_5 and k_20:100:50:25 kg/ha. Wheat was grown as test crop at 50, 75 and 100%)of chemical fertilizers only after harvest of maize. In farmers' practice urea @ 50kg/ha is applied which is equivalent to 23 kg N/ha.

Table 1. Long term effect of integrated nutrient management on yield of maize under maize-wheat cropping system (Pooled data of 2020-21 and 2021-22)

Treatment details		Maize yield (q/ha)			Wheat yield (q/ha)	
Kharif	*Rabi*	Grain	Stover	Stone	Grain	Straw
$T_1 N_0P_0K_0$	$N_0P_0K_0$	9.01	20.42	3.37	10.10	29.91
T_2 50%RDF	50%RDF	25.81	48.77	5.77	24.46	61.93
T_3 50%RDF	100%RDF	26.90	51.08	5.83	32.37	67.91
T_4 75%RDF	75%RDF	28.53	53.32	6.14	35.26	69.70
T_5 100%RDF	100%RDF	43.33	63.83	8.64	43.69	78.03
T_6 50%-N (FYM) + 50% RDF	100%RDF	46.92	70.53	8.81	47.96	82.28
T_7 5%N (FYM) + 75% RDF	75%RDF	45.04	65.19	8.75	45.53	78.73
T_8 50%N (CPS) + 50% RDF	100%RDF	38.78	60.66	8.10	41.69	76.28
T_9 25%N (CPS) + 75% RDF	75%RDF	36.30	57.85	7.98	38.41	73.25
T_{10} 50%N (GKL) + 50% RDF	100%RDF	37.64	59.04	8.05	39.38	75.71
T_{11} 25%N (GKL) + 75% RDF	75%RDF	30.65	55.15	6.24	36.69	72.49
T_{12} Farmer's practice (urea @ 50kg/ha)	Farmer's practice (urea @ 50kg/ha)	11.74	21.61	3.83	14.76	47.11
CD (p=0.05)		6.10	8.97	1.20	6.39	12.27
CV (%)		11.36	10.13	10.41	11.04	10.69

DAS: Days after sowing; CPS:- Cut paddy straw; GKL:- Green karanj leaves FYM- Farm yard manure

RESULTS AND DISCUSSION

Maize

Grain yield: Grain yield of maize in maize-wheat system influenced significantly by nutrient management practices (Table1). Grain yield of maize with application of 50% N through FYM+50% RDF through chemical fertilizer to maize fb 100% RDF through chemical fertilizer to wheat (46.9 q/ha) being like 100% RDF through chemical fertilizer to both crops (43.3 q/ha) and 25% N through FYM+75% RDF through chemical fertilizer to maize fb 75% RDF through chemical fertilizer to wheat (45.4 q/ha) recorded higher yield than all other nutrient management practices owing to more grains/cob, grins/row and heavier grain.

Stover yield: Pooled data on stover yield of maize revealed that nutrient management practices (inorganic fertilizer and in combination with organic sources) significantly influenced the stover yield of maize (Table 1). The highest stover yield (70.53 q/ha) was obtained in treatment receiving 50% N through FYM+50% RDF through chemical fertilizer to maize fb 100% RDF through chemical fertilizer to wheat. It was significantly higher than all other nutrient management practices except 100% RDF through chemical fertilizer to both crops (63.8 q/ha) and 25% N through FYM+75% RDF through chemical fertilizer to maize fb 75% RDF through chemical fertilizer to wheat 100%RDF (65.2q/ha).

Stone yield: INM practices (inorganic fertilizer and in combination with organic sources) significantly influenced the stone yield of maize (Table 1). The highest stone yield (8.81 q/ha) was in $T_6$50% N through FYM+50% RDF through chemical fertilizer to maize fb 100% RDF through chemical fertilizer to wheat. It was significantly higher than T_7 (25% N through FYM+75% RDF) recorded (8.75 q/ha) and all other INM practices (ranging from 6.24 to 8.81). T_5 and T_7 were *at par* in stone yield. The lowest stone yield (3.37 q/ha) was recorded in control T_1 ($N_0P_0K_0$). Stone yield of maize varied from 3.37 to 8.81 q/ha.

Grain, stover and stone yields were highest in T_6 receiving substitution of 50 per cent inorganic NPK by FYM on N basis which was significantly superior to rest of the treatments. The increment in yield due to combined application of chemical fertilizer along with FYM (50% substitution on the basis of N) was 8, 10 and 2% for grain, stover and stone yield of maize, respectively, as compared to balanced application of 100% RDF (chemical fertilizers). Application of other organic sources viz., paddy straw and green karanj leaves resulted in 11 and 13 % reduction in grain yield of maize as compared to balanced application of 100% RDF (as chemical fertilizers) and the level of reduction was higher with *karanj* leaves than cut paddy straw depending upon the mineralization potential and nutrient content. Application of different levels of NPK indicated a gradual and significant rise in yield levels with successive increment well up to the highest dose, which was the recommended dose of NPK for this agro climatic condition. The increase in nutritional dose from 50%RDF to 100%RDF and from 75%RDF to 100%RDF through FYM was instrumental in increasing grain yield by 80.0 and 41.0

Table 2. Long term effect of integrated nutrient management on economics of maize and wheat under maize-wheat cropping system (Pooled data of 2020-21 and 2021-22)

Treatment details		Net return (₹. /ha)		B:C Ratio	
Kharif	*Rabi*	Maize	Wheat	Maize	Wheat
T_1 $N_0P_0K_0$	$N_0P_0K_0$	-13033	-6200	-0.43	-0.17
T_2 50%RDF	50%RDF	15735	29860	0.48	0.76
$T_3$50%RDF	100%RDF	17816	44200	0.54	1.04
T_4 75%RDF	75%RDF	19327	52040	0.55	1.27
T_5 100%RDF	100%RDF	45613	69838	1.25	1.64
T_6 50%N (FYM) + 50% RDF	100%RDF	50583	79643	1.32	1.87
T_7 25%N (FYM) + 75% RDF	75%RDF	47900	75237	1.28	1.83
T_8 50%N (CPS) + 50% RDF	100%RDF	20204	65305	0.38	1.53
T_9 25%N (CPS) + 75% RDF	75%RDF	23951	59445	0.53	1.45
T_{10}50%N (GKL) + 50% RDF	100%RDF	37065	60611	1.08	1.42
T_{11}25%N (GKL) + 75% RDF	75%RDF	22830	55826	0.64	1.36
T_{12} Farmer's practice (urea @ 50kg/ha)	Farmer's practice (urea @ 50kg/ha)	-8992	7854	-0.29	0.21
CD at 5%		4539	9818	0.12	0.23
CV (%)		11.53	11.72	11.49	11.18

DAS: Days after sowing; CPS:- Cut paddy straw; GKL:- Green karanj leaves FYM- Farm yard manure

per cent, respectively, as against the increase of 58.0 and 41.0 per cent by giving the same increment through inorganic fertilizers. This increase in grain yield of maize may be attributed to the application of nutrient through organic and inorganic sources causing synchronized availability of plant nutrients in soil as well as more availability and absorption of nutrients by the plants resulting in cell elongation, root development and ultimately growth and yield of maize. The increase in yield of stover and stone also exhibited more or less a same trend. Significantly higher green fodder yield (452.5 q/ha) were achieved in Maize + Ricebean (1:1 ratio) with 100% RDF +PGPR application as reported by Rundan (2021). The findings in respect of yield of maize with integrated nutrient management practices are in close agreement earlier researchers (Kumar and Dhar 2010, Singh and Wanjari 2013, Kakraliya et al 2017, Singh et al 2017, Jain et al 2018, Lakum et al 2020, Chandra et al 2021).

Wheat

Grain yield: Grain yield of wheat in maize-wheat system influenced significantly by nutrient management practices (Table 1). Grain yield of wheat with application of 50% N through FYM+50% RDF through chemical fertilizer to maize fb 100% RDF through chemical fertilizer to wheat (47.96 q/ha) was at par with 100% RDF through chemical fertilizer to both crops (43.69 q/ha) and 25% N through FYM+75% RDF through chemical fertilizer to maize fb 75% RDF through chemical fertilizer to wheat (45.53 q/ha) recorded higher yield than all other nutrient management practices owing to more effective tillers/m^2 (362.2), grains/spike (45.8) and heavier grain (41 g).

Straw yield: The of application of inorganic fertilizers and organic sources in *kharif* crop, significantly influenced straw yield in *rabi* crop of wheat (Table 1). Straw yield varied from 29.91 to 82.28 q/ha. The highest straw yield was in 50% N through FYM+50% RDF through chemical fertilizer to maize fb 100% RDF through chemical fertilizer to wheat. It was similar to all other integrated nutrient management practices as well as 100% RDF to both crops but significantly higher than rest of the treatments. The findings in respect to yield of wheat are in line with the findings of Bannu et al (2008), Ali et al (2019a) and Kandil et al (2020).

Economics

Net Return

Maize: Perusal of data revealed that effect of continuous fertilizer & manure application (i.e. INM practices) in continuous cropping system of maize-wheat was significant on net return of the maize. Significantly highest net return of Rs. 50583 per hectare was recorded in treatment T_6 (getting 50 per cent of N through FYM+ 50 per cent recommended dose of nutrients through chemical fertilizers in maize and 100 percent RDF in succeeding wheat crop) over rest of the treatments. Farmers' practice (@ 50 kg urea/ha in both crops) gave the lowest & loss in net return i.e. Rs.8992 while control ($N_0P_0K_0$) gave further loss i.e. Rs.13033. Application of inorganic fertilizers T_5 (100% RDF in both crops) gave net return Rs.45613. Application of INM practice-T_6 (getting 50 per cent of N through FYM+ 50 per cent recommended dose of nutrients through chemical fertilizers in maize and 100 percent RDF in succeeding wheat crop) gave significantly highest net return of Rs. 50583 per hectare over rest of the treatments and it was 11% higher than that of T_5 (100% RDF in both crops). Other INM practices - T_8-½ N through CPS +½ RDF (inorganic) gave reduction in net return up to 60% compared to T_5(100% RDF in both crops) and it was significantly lower and T_{10}- ½ N through GKL +½ RDF (inorganic) resulted reduction in net return up to the tune of 27% compared to RDF and was significantly inferior to it. Net returns in T_8 and T_{10} were at par in maize-wheat system. Therefore, substitution up to ½ N through FYM was effective as one component along with ½ RDF (inorganic) in INM practices followed by T_7 -25% N through FYM+75% RDF (inorganic).

Wheat: Continuous cropping system of maize-wheat was significant on net return of the wheat. Significantly highest net return of Rs. 79643 per hectare was recorded in T_6 (getting 50 per cent of N through FYM+ 50 per cent recommended dose of nutrients through chemical fertilizers in maize and 100 percent RDF in succeeding wheat crop) over rest of the treatments. Farmers' practice (@ 50 kg urea/ha in both crops gave the net return i.e. Rs.7854 while control ($N_0P_0K_0$) gave lowest of Rs.6200. Application of inorganic fertilizers T_5 gave net return Rs. 69838. Application of INM practice-T_6 (getting 50 per cent of N through FYM+ 50 per cent recommended dose of nutrients through chemical fertilizers in maize and 100 percent RDF in succeeding wheat crop) gave significantly highest net return of Rs. 79643 per hectare over rest of the treatments and it was 14% higher than that of T_5 (100% RDF in both crops). Other INM practices - T_8-½ N through CPS +½ RDF (inorganic) gave reduction in net return up to 6% (Rs. 65305.00/) compared to T_5(100% RDF in both crops) and was significantly lower. T_{10}- ½ N through GKL +½ RDF (inorganic) resulted reduction in net return up to the tune of 13% compared to RDF and was significantly inferior to it. Net returns in T_8 (Rs. 65305.00/-) and T_{10} (Rs.60611.00/-) were *at par* in maize-wheat system. Therefore, substitution up to ½ N through FYM was found to be effective as one component along with ½ RDF (inorganic) in INM practices followed by T_7 -25% N through FYM+75% RDF (inorganic) (Rs.75237).

Benefit: cost ratio

Maize: Effect of continuous fertilizer & manure application

(i.e. INM practices) in continuous cropping system of maize-wheat was significant on benefit: cost ratio of the system. Significantly highest B:C ratio of 1.32 was in treatment T_6 over rest of the treatments and it was 6% higher than that of T_5. Farmers' practice (@ 50 kg urea/ha in both crops) produced lowest B:C ratio i.e.-0.43 while control ($N_0P_0K_0$) gave further loss. Application of inorganic fertilizers in T_5 gave B:C ratio of 1.25. INM practices - T_8 gave significant reduction in B:C ratio up to 71% (0.38) compared to T_5. T_{10} resulted significant reduction in B:C ratio up to 18% (1.08) compared to RDF. Therefore, substitution up to ½ N through FYM was effective as one component along with ½ RDF (inorganic) in INM practices followed by T_7.

Wheat: The effect of continuous fertilizer & manure application (i.e. INM practices) in continuous cropping system of maize-wheat was significant on benefit: cost ratio of the system. Significantly highest B:C ratio of 1.87 was in treatment T_6 over rest of the treatments and it was 8% higher than that of T_5. Farmers' practice (@ 50 kg urea/ha in both crops) produced lowest B:C ratio i.e.-0.17 while control ($N_0P_0K_0$) gave further loss i.e. 0.21. Application of inorganic fertilizers T_8 gave significant reduction in B:C ratio up to 39% (1.53) compared to T_5. The T_{10} resulted significant reduction in B:C ratio up to 13% (1.42) compared to RDF. Therefore, substitution up to ½ N through FYM was effective as one component along with ½ RDF (inorganic) in INM practices, followed by T_7. This is in agreement with the findings of Pathak et al (2002), Manjhi et al (2014), Hashim et al (2015) and Verma (2018).

CONCLUSION

Substitution up to 50% N through FYM + 50% RDF in *kharif* and 100% RDF in *rabi* in maize-wheat cropping system was best for higher productivity and profitability of maize and wheat cultivation in Chhota Nagpur plateau region of Jharkhand.

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