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Short Communication

Effect of integrated nutrient management in rice on vegetative growth and economic profitability of wheat under long term rice-wheat cropping system

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Wheat (*Triticum aestivum*) is one of the principal cereal crops and is the second most important staple food after rice in India. Globally, wheat is grown in an area of 222.21 Mha with a production and productivity of 779.03 Mt and 3510 kg ha^{-1}, respectively (USDA, 2022). Generalized recommendations currently followed with respect to NPK fertilizers alone are leading towards depletion of nutrients, poor soil quality and thus application of proper balanced nutrients should be followed. Under the present situation, the concept of balanced fertilization cannot be limited to N, P and K alone. It should include application of all the essential plant nutrients required for high agricultural productivity. Nutrient applied either through chemical fertilizers, organic manure, crop residues or biofertilizers cannot meet the entire nutrient need of a crop in modern intensive agriculture (Darjee *et al.*, 2022). Rather, these need to be used in an integrated manner following a management technology that is integrated nutrient management which is practicable, economically viable, socially acceptable and ecologically sound (Patra *et al.*, 2022; Ullah *et al.*, 2021). Combined use of organic and chemical fertilizers significantly improved crop yield over the recommended dose of inorganic fertilizers alone (Saha *et al.*, 2018; Sarwar *et al.*, 2021). Application of organic manure helps to overcome the deficiency of micronutrients, which is due to the continuous use of high-analysis chemical fertilizers (Singh and Saini, 2021). Integrated use of organic manures and inorganic fertilizers has gained immense importance for sustaining crop production.

The field experiment was conducted at the research farm of Bihar Agricultural University, Sabour, Bhagalpur during the *rabi* season of the year 2020-2021. Since a permanent experiment was carried out in the experimental plot for the last thirty-six years (since 1984) only rice and wheat were grown in *kharif* and *rabi* seasons respectively, over the years followed by fallow in *zaid*. The initial physicochemical properties of the experimental plot were: pH (7.40), electrical conductivity (0.29 dS m^{-1}), organic carbon (0.46%), available N (194 kg ha^{-1}), available P (23 kg ha^{-1}) and available K (155 kg ha^{-1}). The experiment was laid out in randomized block design (RBD) with three replications and 11 treatment combinations. The treatments were: T_1: Control (No fertilizer, no organic manure) in both rice and wheat., T_2: 50% RDF (recommnded dose of fertilizers) in both rice and wheat., T_3: 50% RDF in rice and 100% RDF in wheat., T_4: 75% RDF in both rice and wheat.,T_5: 100% RDF in both rice and wheat., T_6: 50% RDF and 50% N through FYM (farm yard manure) in rice and 100% RDF in wheat., T_7: 75% RDF and 25% N through FYM in rice and 75% RDF in wheat.,

T_8: 50% RDF and 50% N through wheat straw in rice and 100% RDF in wheat., T_9: 75% RDF and 25% N through wheat straw in rice and 75% RDF in wheat., T_{10}: 50% RDF and 50% N through GM (green manure) in rice and 100% RDF in wheat and T_{11}: 75% RDF and 25% N through GM in rice and 75% RDF in wheat. The recommended dose of fertilizer (RDF) was 120 kg N, 60 kg P_2O_5 and 40 kg K_2O per hectare, and fertilizers were applied as per treatment in all the treatments except control. The research trial was conducted on the wheat variety 'HD-2967'. The seeds of wheat cultivars were sown at a row spacing of 20 cm. The dimension of each treatment plot was about 8.5m × 4.95m. The data were statistically analyzed by using "ANOVA" (Analysis of Variance) technique on randomized block design (RBD). For each character, the standard error of mean (SEm) and least significant difference (LSD) at the 5% level of significance were calculated.

The growth attributes namely plant height, LAI (green manure) and number of tillers/m^{-2} differed significantly due to different integrated nutrient management practices (Table 1). Application of 50% RDF and 50% N through FYM in rice and 100% RDF in wheat (T_6) showed best performance in terms of plant height and number of tillers/m^{-2}. This showed residual effect of substitution of 50% inorganic N by FYM in rice on succeeding wheat. It was also relevant to notice that even other organic sources, i.e. wheat straw and green manure substituting for 50% RDF in rice and application of 100% RDF in wheat were equally productive, but was superior to application of 100% RDF in inorganic forms to both the crops. This shows the importance of organic source of nutrients in growth and development of crops. FYM was found more efficient in increasing the availability of nutrients. It is due to its fast nutrient conversion rate from organic to inorganic form (Puniya *et al.*, 2019). Wheat straw decomposes slowly as it contains higher amount of polysaccharides, waxes and silica. Although, *Sesbania aculeata* gets easily decomposed but FYM was found more effective than it. It is due to less total organic matter content on per unit nutrient basis of *Sesbania aculeata.* Therefore, these positive effects of FYM over wheat straw and green manuring with *Sesbania aculeata* resulted in its higher efficacy.

Table 1. Effect of integrated nutrient management practices on plant height (cm), LAI at maturity and number of tillers m^{-2} of wheat at different days after sowing

Treatment	Plant height	LAI	Number of tillers m^{-2}				
			30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	65.4	0.49	74	153	191	194	192
T_2	93.6	1.77	144	284	299	294	280
T_3	98.5	2.26	183	364	379	374	340
T_4	98.2	1.93	169	331	341	336	320
T_5	99.1	2.24	180	346	356	351	343
T_6	100.4	2.43	204	414	431	426	377
T_7	99.2	2.35	186	390	407	399	359
T_8	100.1	2.36	198	406	419	412	356
T_9	98.6	2.01	164	344	356	348	327
T_{10}	100.3	2.40	195	406	429	421	368
T_{11}	99.6	2.30	180	369	379	372	340
SEm(±)	1.4	0.17	5.6	10.9	10.6	10.5	9.5
CD (P=0.05)	4.2	0.51	16.5	32.2	31.2	31.1	28.2

Results showed that yield attributes such as number of earhead/m^{-2}, number of grains/earhead, length of earhead and 1000 grain weight differed significantly due to different integrated nutrient management practices (Table 2). Incorporation of organic matter has improved soil properties which has resulted in increased availability and uptake of nutrients. Due to accelerated uptake of nutrients, there was improvement in yield attributes. Application of 50% RDF and 50% N through FYM in rice and 100% RDF in wheat (T_6) recorded the highest value of yield attributes. The biomass yield of different treatments in this study showed that it was highest with the application of 50% RDF and 50% N through FYM in rice and 100% RDF in wheat (T_6) which was significantly superior over the rest of the treatments. The reason behind this can be the supply of essential nutrients by FYM throughout the entire crop growth period (Kavinder *et al.*, 2019; Jat *et al.*, 2021). Treatments involving substitution of 50% inorganic N by FYM and application of 50% RDF in rice followed by 100% RDF in wheat increased biomass yield by 25.3% over application of 100% RDF in both the crops (T_5). Application of other organic sources, i.e., wheat straw or green manuring in rice followed by 100% RDF in wheat also performed better than T_5 in respect of biomass yield. This can be due to the cumulative residual effect of organic manures over the years (Guo *et al.*, 2016). FYM is more effective than other organic sources due to its ability of improving physical and chemical properties of soil leading to proper crop growth and development (Kumari *et al.*, 2017).

Table 2. Effect of integrated nutrient management practices on biomass yield and yield attributes and economics of wheat

Treatment	Number of earhead m^{-2}	Number of grains/ earhead	Length of earhead (cm)	1000 grain weight (g)	Biomass yield (t ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit: Cost ratio
T_1	185	21	5.44	28.0	2.32	31073	-7118	-0.23
T_2	269	30	7.29	34.6	5.62	34103	24019	0.70
T_3	328	35	9.53	35.4	8.61	37133	51928	1.40
T_4	307	31	7.53	35.6	6.99	35618	36568	1.03
T_5	328	34	9.55	35.1	8.33	37133	48660	1.31
T_6	363	42	12.09	36.8	10.37	37133	69795	1.88
T_7	347	37	10.45	36.3	8.74	35618	56641	1.59
T_8	345	40	11.48	36.9	9.21	37133	57661	1.55
T_9	319	32	9.91	35.4	7.96	35618	46474	1.30
T_{10}	356	41	11.99	36.6	9.50	37133	60702	1.63
T_{11}	327	36	10.37	35.9	8.87	35618	55764	1.57
SEm(±)	10.44	1.50	0.27	0.75	0.45	-	4301.37	0.12
CD (P=0.05)	30.79	4.44	0.79	2.22	1.33	-	12689.03	0.36

The relationship between data of biomass yield and growth attributes (plant height and number of tillers/m^{-2}) was developed by regression analysis taking Y (plant height and number of tillers m^{-2} as dependent variables) and X (biomass yield as an independent variable) (Fig.1 and 2). Regression studies revealed a close linear relationship between biomass yield and plant height ($Y = 4.144X + 63.144$; $R^2 = 0.819$); biomass yield and number of tillers m^{-2} ($Y = 23.06X + 145.96$; $R^2 = 0.977$). It suggests that application of inorganic fertilizer along with organic sources of nutrients can enhance growth and biomass yield in wheat (Bharali *et al.*, 2017; Kakraliya *et al.*, 2017; Kumar *et al.,* 2019).

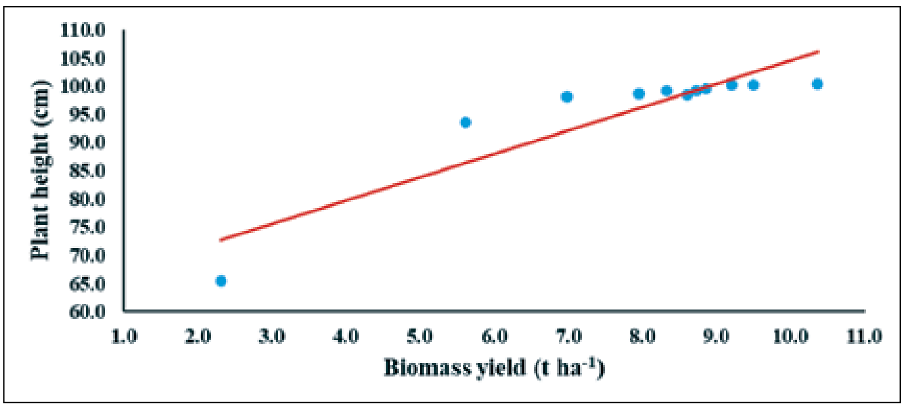

Fig 1. Relationship between plant height and biomass yield of wheat

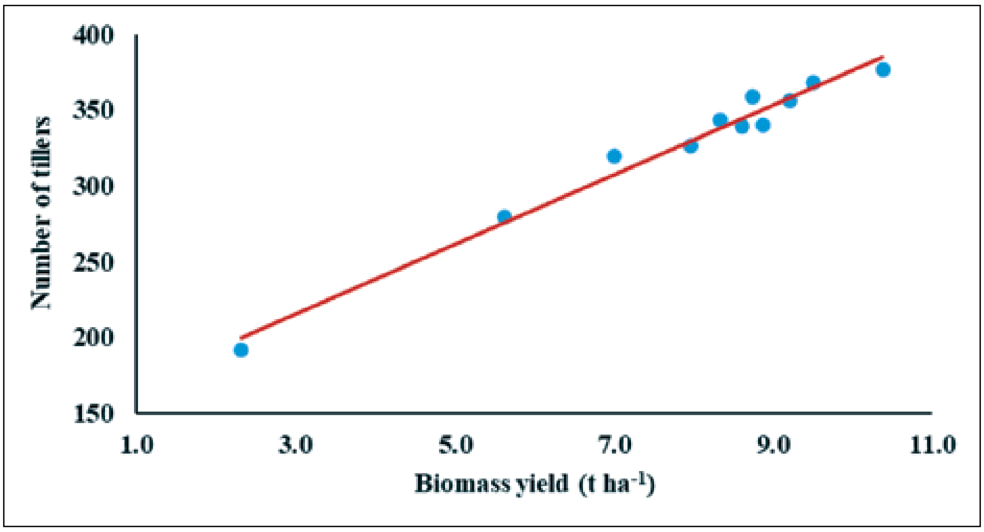

Fig 2. Relationship between number of tillers m^{-2} and biomass yield of wheat

Economic analysis reveals that the net returns and B:C ratio of wheat differed noticeably in different nutrient management options (Table 2) and that was directly related to the price of the crop produced and the cost incurred on nutrient inputs under different treatments. Variable cost was involved with the source of nutrient input in different treatments. Data showed that net return and B:C ratio in terms of wheat were higher with the application of 50% RDF and 50% N through FYM in rice and 100% RDF in wheat (T_6) which was significantly superior over the rest of the treatments. Treatments involving substitution of 50% inorganic N by FYM and application of 50% RDF in rice followed by 100% RDF in wheat increased net return by 43% over application of 100% RDF in both the crops (Fig. 3). The treatment showing a higher yield eventually resulted in increased profitability. The result confirmed that higher yield under the organic nutrient source treatments have been the reason behind its cost effectiveness (Yadav, 2003; Jat *et al.*, 2021).

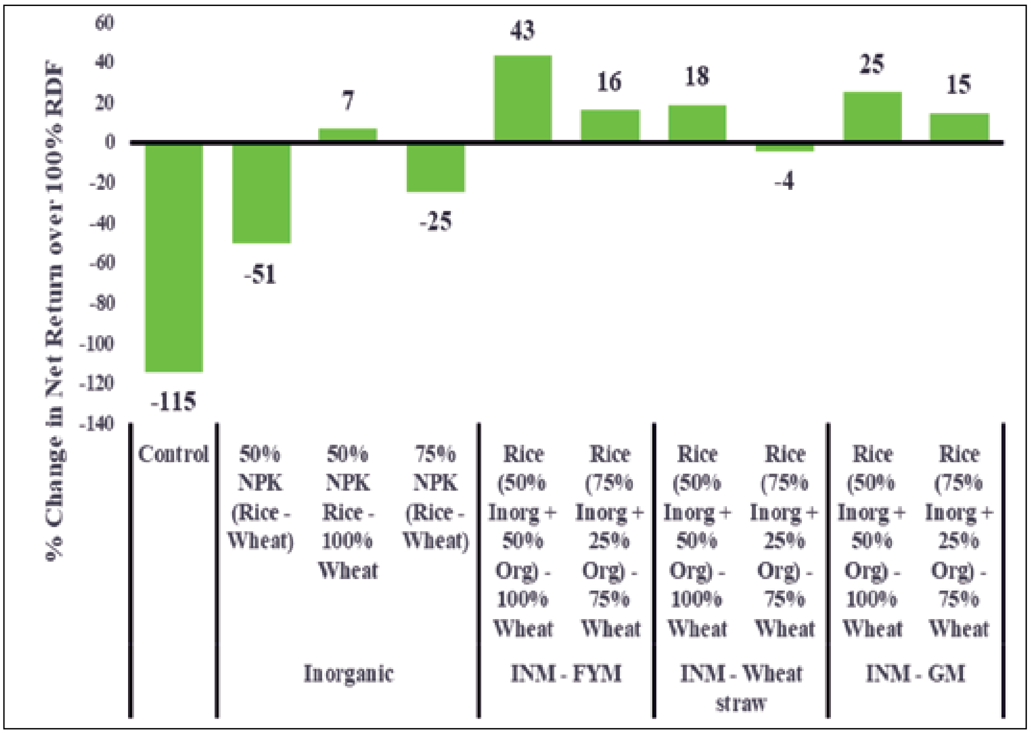

Fig 3. Wheat profitability as influenced by long term INM over conventional nutrient management practices

The results of 36 years long-term experiment concluded that farmers may adopt substitution of 50% inorganic N either through FYM or wheat straw or green manuring with *Sesbania aculeata* and 50% RDF in rice followed by 100% RDF in wheat for improving growth as well as profitability of wheat in the rice-wheat cropping system.

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Authors' contribution:

This article is fully based on M.Sc. research work of the first author (SR) under the supervision of SK as major advisor. SR collected the data. Designing of experiment and analysis by SR, SK and SKD. All the authors provided critical feedback and helped in preparation of the manuscript.

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