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Target yield based integrated nutrient management in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system

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ABSTRACT

Target yield equation-based integrated nutrient management studies were conducted to examine its importance in attaining target yields, improving soil nutrient status, and nutrient utilization in rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping sequence. The study was carried out for three years in the rice-wheat cropping system. The nitrogen (N), phosphorus (P), and potassium (K) requirement for attaining target yield of 7.5 t/ha for rice and 5 t/ha of wheat were estimated following soil test crop response-based target yield equations (TYE). The treatments consist of differential fertilization as the chemical source and farmyard manure (FYM) as the organic source. Results indicated that 97.2% of the target in rice and 94% in wheat, with negligible deviance from the quantified target yield, were achieved. Integrated nutrient management (INM) produced a significantly higher yield of rice (7.29 t/ha) and wheat (4.70 t/ha) when 100% INM was compensated with 75% fertilizer NPK and 25% organic N. The system productivity of 12.4 t/ha was the highest based on rice and rice equivalent yield of wheat in 100% INM. Likewise, nutrient uptake and nutrient productivity were also higher in crops with 100% INM. Moreover, the improved nutrient status and soil nutrient balance were more prominent with 100% INM. Therefore, the results demonstrated the beneficial effects of TYE-INM in the rice-wheat cropping system to obtain higher grain yields while maintaining soil health.

Keywords: Integrated nutrient management, Nutrient productivity, Nutrient uptake, Rice, Soil NPK, Target yield, Wheat

In a quest to attain more crop yields farmers generally inclined to overuse chemical fertilizers, which resulted in reduced productivity of rice and wheat crops (Yadav *et al.* 2000). The decision on efficient fertilizer use requires knowledge of crop response to applied fertilizer, inherent supply of nutrients by soil, and its short- or long-term fate of fertilizer applied (Dobermann *et al.* 2003). Generally, prior nutrient estimation of a crop with respect to native soil fertility status is not considered. Therefore, need-based fertilizer requirements for getting higher farm productivity with improved soil fertility demands for soil-test crop response (STCR) based nutrient management. Fertilizer prescriptions based on STCR ensure ample scope to fill the gap between crop needs and indigenous nutrient status of soil and help in achieving considerable economy in fertilizer use for pre-set yield targets (Saini 2001 and Singh *et al.* 2017). Most of the research linked to this subject is targeted mainly on the mono-cropping sequence and its validity under multiple cropping systems needs to be confirmed.

Applying chemical fertilizers alone may initially increase productivity, but their constant application may adversely affect the soil quality. Conjoint use of green manure (*Glyricidia sepium*) and inorganic fertilizers observed a significant increase in soil organic carbon (0.81%) as compared with no green manuring (0.65%) (Walia *et al.* 2010). The balanced use of nutrients through integrated plant nutrient supply system has evolved as one of the most reliable models for long-term management and sustainability of soil fertility and productivity. Under the rice-wheat cropping system, aerobic-anaerobic conditions may affect the nutrient availability to plants over the growth stages. Therefore, a better knowledge of such conditions advocates INM as one alternative to nutrient management that can ensure continuous nutrient supply throughout the growth stages of the crop. Thus, the present study was performed at the farmer's field to estimate N, P, and K requirements following site-specific target yield-based fertilizer prescription models for improving crops and nutrient productivity in the rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping sequence.

MATERIALS AND METHODS

The field studies were carried out on INM in rice and wheat crops during 2018–20 in farmer's field on sandy loam soil (*Typic Ustipsamment*) at Gurdaspur, Punjab. The

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site is located in the Indo-Gangetic plains of north-western India and accounts for sub-humid climate with an annual rainfall of 887 mm. At the onset of the experiment, the surface soils samples (0-15 cm) of the selected site have *p*H of 7.5, EC of 0.16 dS/m, soil organic carbon 4.65 g/kg, $KMnO_4$-extractable N 112 kg/ha, Olsen-P 21.0 kg/ha and 1 M ammonium acetate extractable-K 108 kg/ha. Each year rice (PR121) was generally transplanted between June 20–30th. Following the harvest of rice in October, wheat (HD3086) was sown between the 1–15th of November and harvested in April. The NPK requirement of both rice and wheat were calculated as per the following target yield equations.

For rice	For wheat
FN = 3.02T - 0.63 SN	FN= 4.23T-0.37SN
FP_2O_5 = 1.78 T – 8.37SP	FP_2O_5 = 2.63T-2.98SP
FK_2O = 2.75 T – 1.39 SK	FK_2O =1.66T-1.4SK

where, 'T' stands for target yield equation (q/ha), SN, SP, and SK represent soil test values of N, P, and K nutrients (kg/ha) tested before the transplanting of rice crop.

Five fertilizer treatments consisting of 100% estimated fertilizer NPK, 75% estimated fertilizer NPK + 25% N from FYM (100% INM), 75%NPK, 50% estimated fertilizer NPK + 25% N from FYM (75% INM) and no NPK fertilizers (Control) were evaluated. The P and K deficits in FYM amended plots were supplemented with their respective fertilizer sources, adjusting their estimated doses as per TYE. Therefore, integrated nutrient management included the conjoint use of well decomposed added fresh FYM (0.85% N, 0.23% P_2O_5, and 0.77% K_2O at 50% moisture content) as organic and synthetic fertilizers as the chemical source. Full dose of P and K was applied before rice transplanting and sowing of wheat. Nitrogen was applied in 3 equal split doses (0, 21, and 42 days after transplanting) to rice and in 2 equal splits to wheat (½ at sowing and ½ after 4 weeks of sowing). The FYM was incorporated before the planting of rice. The experiment was laid out in a randomized complete block design with three replications with each plot having an area of 8m × 3m. At maturity, the crops were harvested manually from each plot from the net area of 8.4 m^2. The grain and straw samples from each plot were taken at maturity and were analysed for total N, P, and K using standard methods. The soil samples were analysed for: organic carbon content (Walkley and Black 1934), available N (Subbiah and Asija 1956), available P (Olsen *et al.* 1954), and available K (Jackson 1967). Nutrient productivity was expressed as kg grain yield per kg of nutrients applied. Data recorded from the experiments were analyzed using Analysis of Variance (ANOVA) and mean comparisons were performed based on Duncan's multiple range test (DMRT) at 5% probability level to separate treatment means.

RESULTS AND DISCUSSION

Grain yield and system productivity: The average pooled data of rice and wheat crops indicated that integrated nutrient management following the target yield approach resulted in grain yield production consistently near the target compared to other treatments (Table 1). Significantly higher grain yield was recorded in 100% INM (75% NPK + 25% N from FYM) by ensuring 97.2% and 94% target yield of 7.5 t/ha for rice and 5.0 t/ha for wheat, respectively compared to 100% NPK. The corresponding rice equivalent yield of wheat also remained highest with estimating the value of 5.1 t/ha in 100% INM thereby increases the system productivity by 12.4 t/ha over the 100% fertilizer NPK. The increased grain yield of rice and wheat in INM treated plots over fertilizer NPK alone was due to higher total uptake of nutrients because of better root growth leading to more absorption of nutrients. Kumar *et al.* (2003) documented higher grain yields of rice in 100% INM treatments. Similarly, the highest wheat grain yield was recorded by Kumari *et al.* (2017), when 50% of the recommended fertilizer N dose was replaced with FYM in the rice crop. The system productivity was also higher with the application of 100% INM. Similar results were reported by Ghosh (2008) on INM in a field study conducted with jute and rice crops.

Nutrient uptake and nutrient productivity: The impacts of different fertilizer nutrient management practices on the nutrient uptake of N, P, and K fertilizers in rice and wheat crops are presented in Table 2. The target yield-based

Table 1 Grain yield of rice, percent achievement of target yield and system productivity under rice-wheat cropping sequence (Mean of three years)

Treatment	Grain yield of rice (t/ha)	Rice target yield achieved (%)	Grain yield of wheat (t/ha)	Wheat target yield achieved (%)	Rice equivalent$ yield of wheat (t/ha)	System productivity (t/ha)
100% NPK	6.74c#	89.9	4.35c	87.0	4.68	11.4
75% NPK + 25% FYM*	7.29d	97.2	4.70de	94.0	5.06	12.4
75% NPK	5.94b	79.2	3.40b	67.9	3.66	9.6
50% NPK + 25% FYM*	6.10b	80.8	3.64b	72.7	3.91	10.0
Control	3.69a		2.16a		2.32	6.0

*The deficit of P and K in FYM was supplemented with their fertilizer sources adjusting estimated doses as par TYE; $System productivity (rice yield + rice equivalent yield of wheat); #Means within a column followed by different letters are significantly different at P<0.05 by Duncan's multiple range test (DMRT).

Table 2 Nutrient uptake, agronomic nutrient-use efficiency, available nutrient status and nutrient balance in the final year of rice- wheat cropping system

Treatment	Nutrient uptake (kg/ha)					
	Rice			Wheat		
	N	P	K	N	P	K
100%NPK	126.1d[#]	21.3c	90.0d	90.6d	19.1d	69.7c
75% NPK + 25%FYM*	131.2e	22.8d	90.9d	106.3e	21.5e	74.1d
75% NPK	98.8b	16.0b	69.0b	67.1b	13.9b	59.5b
50% NPK + 25% FYM*	108.5c	16.9b	77.2c	77.7c	15.9c	65.7c
Control	47.9a	7.6a	39.3a	34.9a	4.0a	24.0a
	Nutrient productivity (kg grain/kg nutrient applied)					
100% NPK	20.9b		27.4ab	16.9b	24.8a	51.9a
75% NPK + 25% FYM*	22.2d		29.0ab	20.6c	30.2b	63.2c
75% NPK	19.0a		25.0a	12.7a	28.0a	58.6b
50% NPK + 25% FYM*	21.7c		28.5ab	15.2b	33.4b	70.0d
Control						
	Available nutrient status (after 3 years) (kg/ha)			*Nutrient balance (after 3 years) (kg/ha)*		
100% NPK	109.7b	43.7a	95.3bc	+23.3[$]	+1.5	+7.5
75% NPK + 25% FYM*	114.7c	45.2a	102.5c	+28.4	+3.0	+14.7
75% NPK	105.7b	43.4a	95.6bc	+19.3	+1.2	+7.8
50% NPK + 25% FYM*	109.9b	43.9a	99.3bc	+23.5	+1.7	+11.5
Control	87.7a	41.8a	84.7a	+1.3	-0.4	-3.1

*The P and K deficit was compensated with their fertilizer sources. [$] '+' indicates increased value over initial soil status. [#]Means within a column followed by different letters are significantly different at $p< 0.05$ by Duncan's multiple range test (DMRT).

integrated nutrient management accounted for significantly higher N, P, and K uptake, estimated 131.2, 22.8, and 90.9 kg/ha respectively for rice compared to 126.1, 21.3, and 90 kg/ha with 100% fertilizer NPK. A similar trend of NPK uptake was observed for the wheat crop. Even rice and wheat with 75% INM produced improved NPK uptake over 75% fertilizers NPK which was significantly lower than 100% INM and 100% fertilizer NPK. The possible explanation involves better demand-supply synchrony of nutrients in INM treatments compared to fertilizer NPK. In fertilized plots quick release of nutrients from applied fertilizer and the successive uptake of nutrients did not take place simultaneously leading to uncontrollable losses of nutrients from the soil-plant system (Cameron *et al.* 2012) thereby, leading to low nutrient use efficiency. However, in INM plots comparatively less yield deviation may be accredited to the steady decomposition of added FYM, leading to slow and continued release of NPK nutrients over a period of years. Guar *et al.* (1984) reported that 25-30% of N and 60-70% P and 75% K were made available in the year of FYM application and the remaining in subsequent years. The higher nutrient uptake in 100% INM amended plots was ascribed to more dry matter production and availability of nutrients from the decomposition of organic matter over time. These observations are in line with the findings of Kumar *et al.* (2008) and Mitra *et al.* (2010) for rice and wheat crops.

In relation to productivity, significantly higher N productivity was assessed in rice with 100% INM, estimating to 22.2 kg grain per kg N applied as compared to 20.9 kg grain per kg N applied compared to 100% fertilizer NPK application. Concurrently, higher N and P productivities were recorded in wheat with 100% INM. As per the target yield equation, rice needed no fertilizer P application. Statistically, no significant impact on K productivity was noticed both in rice and wheat crops. The integrated nutrient management approach found true with 75% INM for higher N, P, and K productivity compared with 75% fertilizer NPK application alone. Ali *et al.* (2020) reported that integration of organic manure and inorganic fertilizers not only improves soil fertility but also increases nutrient uptake and grain yield of crops. Additionally, 100% INM was found most conducive for increasing nutrient productivity. Mishra *et al.* (2003) also suggested similar views.

Available NPK status and nutrient balance: INM following target yield-based site-specific nutrient management in rice-wheat cropping sequence possessed variable response to soil available N, P, and K after 3 years of their successive application (Table 2). Significantly higher soil available N of 114.7 kg/ha in 100% INM was estimated over 109.7 kg/ha in 100% NPK and the rest of the treatments. Also, in 100% INM plots statistically significant increase in the soil available K was recorded over other treatments. However, no remarkable difference for available soil P was noticed among different treatments. Additionally, reasonable build-up of soil N, P, and K nutrient balance was observed. Apparently improved average nutrient balance of +28.4, +3.0, and +14.7 kg/ha respectively was obtained for N, P, and K, which was greater than +23.3, +1.5, and +7.5 kg/ha for the plots received 100% fertilizer NPK. However, the control plots that received no NPK had negative P (-0.4 kg/ha) and K (-3.1 kg/ha) balances due to the mining of these nutrients from the soil. The slow mineralization of organics in INM plots resulting in reduced nutrient losses, and improved soil health and productivity (Chen *et al.* 2010) over the treatments amended with sole mineral fertilizers. Asai *et al.* (2009) reported that INM has the potential to improve chemical attributes (nutrient availability, nutrient retention, nutrient cycling), physical properties of soil like bulk density, permeability, porosity, water-holding capacity, and soil biological activities, which in turn enhances nutrient-use efficiency and increased soil organic matter.

Based on the findings, it can be concluded that balanced nutrition in the rice-wheat cropping system can be practiced efficiently with INM practices than chemical fertilizers alone. Our study demonstrated the benefits of target yield-based site-specific nutrient management to satisfy the plant nutrients demand by improving soil fertility status, crop productivity, and enhancing nutrient-use efficiency.

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