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Fertilizer prescription for target yield of wheat (*Triticum aestivum*) in alluvial soils

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ABSTRACT

Soil test crop response correlation studies were carried out to establish target yield prescription equations for wheat (*Triticum aestivum* L.) under the Integrated Plant Nutrition System (IPNS) at Research Farm of Punjab Agricultural University, Ludhiana, Punjab during 2019–2021. Fertilizer prescriptions under NPK alone and IPNS were developed for wheat crops using Ramamoorthy's "Inductive cum Targeted yield approach". The amount of nutrients needed for producing 100 kg of wheat were 2.06, 0.78, and 1.95 kg/q of N, P_2O_5 and K_2O, respectively. The nutrients contributed by soil and fertilizer were found to be 52.3% and 54% N, 11.7% and 50% P, and 20.2% and 20.6% K, respectively. Likewise, the organic material in the form of rice residue incorporation contributed 42.0% N, 15.3% P, and 26.0% K and increased the nutrient (N, P and K) uptake. The incorporated rice residue increased the soil organic carbon and microbial population substantially resulting in more mineralization thereby increasing nutrient availability. Therefore, the site-specific targeted yield-based approach used for developing fertilizer prescription equations gives a shred of strong evidence for maintaining soil health with higher crop yields and efficient nutrient management.

Keywords: Chemical fertilizers, Fertilizer prescriptions, Target yield, Wheat

Fertilizer is one of the expensive inputs for getting higher crop productivity and their judicious use is necessary for sustainable yield and environmental safety (Kimetu *et al.* 2004). In the fate of increasing fertilizer prices and dwindling agriculture income, farmers are aspiring for efficient fertilizer management practices to cut down fertilizer input costs. Efficient fertilizer management involves response to applied fertilizer, inherent capacity of the soil to supply nutrients, and its effects over time (Dobermann *et al*. 2003). Wheat (*Triticum aestivum* L.) is the staple food next to rice and contributes about 30% of total grain production in India. By 2030, an additional food grain of 48 million tonnes will be needed to fulfil the country's demand from the same or even lesser land area. Numerous approaches have been promoted previously to recommend fertilizer doses to crops. Out of these, namely, state-level generalized fertilizer recommendation dose (GRD), soil test-based fertilizer recommendation (STRD) and target yield approach need special attention. The GRD approach is suited only for medium-fertility soils. While, the STRD is based on the grouping of soils, viz. low, medium and high in respect of the status of the nutrient in question. In this approach, for soils with nutrient status testing low or high, the fertilizer recommendation is increased or decreased by 25% respectively of the GRD. The major drawback of this approach is that it recommends the same fertilizer dose for very deficient and marginally deficient soils and similar for very high and moderately high soil. Therefore, a significant economy in fertilizer use is possible using site-specific soil test values. Thus, the need-based application of N, P and K call for soil test crop response (STCR) approach-based nutrient management, which is made based on soil test values, nutrient requirement of the crop, contribution of nutrients from the soil, rice residue incorporated and fertilizers. Due to lack of STCR data for wheat on alluvial soils, the present study was undertaken to investigate the significant relationship between soil test values and crop response to fertilizers and to develop fertilizer prescription models under integrated plant nutrition system (IPNS) for desired yield target of wheat crop.

MATERIALS AND METHODS

A field experiment was conducted at the Research Farm, Punjab Agricultural University, Ludhiana, Punjab during 2019–2021 on sandy loam soil (Typic Ustochrepts). The site is located in Indo-Gangetic plains of northwestern India. Ludhiana has subtropical climate with the annual rainfall of 733 mm. The mean minimum and maximum temperature of the region ranges from 15.8–30.8°C during the experimentation. In this study, the recommended

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procedure as defined by Truog (1960) and later modified by Ramamoorthy *et al.* (1967) as the "Inductive cum Targeted yield model" was used. This approach provides a scientific basis for the economical use of fertilizers by taking into account the balance between the applied nutrients and soil available nutrient forms. The experiment consists of creating three fertility gradient strips, prepared artificially by applying graded levels of N, P and K fertilizers for making a large variation in the same field to assess the actual relationship between crop yield and soil fertility. The first strip (S1) received no fertilizers ($N_0P_0K_0$), and the second (S2) and third strips (S3) received one and two times the recommended dose of N, P_2O_5 and K_2O respectively. An exhaustive crop of maize fodder was raised on three strips to stabilize the soil system. After the harvest of the exhaustive crop, the experiments on test crops rice (cv. PR128) in *kharif* and wheat (cv. HD3086) in *rabi* in sequence were conducted by dividing each fertility strip into 24 plots that received three nitrogen (N) rates (90, 120 and 150 kg N/ha), three K rates (20, 30 and 40 kg K_2O/ha) both rice and wheat crops and three P rates (20, 30 and 40 kg P_2O_5/ha) for rice and (45, 60, and 75 kg/ha) wheat. A control plot was kept within each residue management practice. Each fertility strip accommodated all the treatments. The Integrated Plant Nutrient System (IPNS) treatments, viz. NPK + rice residue removed, and NPK + rice residue incorporated at 6 tonnes/ha were superimposed across the strips. The full dose of P and K, fertilizers were applied at the time of sowing and N was applied in two splits (½ at sowing and ½ after 21 days of sowing with first irrigation) to the wheat crop. Surface (0–15 cm) soil samples were drawn from each plot before sowing and after the harvest of the wheat crop. The initial soil fertility status showed that the experimental field had a *p*H of 7.1, EC of 0.14 dS/m (1:2 soil:water), soil organic carbon (SOC) of 0.35% (Walkley and Black 1934), $KMnO_4$-N of 81 kg/ha (Subbiah and Asija 1956), $NaHCO_3$ extractable P of 27.0 kg/ha (Olsen *et al*. 1954) and neutral normal ammonium acetate extractable K of 112.0 kg/ha.

The crop was harvested manually at physiological maturity. Grain and straw yields were determined from each plot. Grain moisture was determined immediately after weighing and subsamples were dried in an oven at 65°C for 48 h. The grain yield was adjusted to 0.15 g H_2O/g. Straw yield was expressed on an oven-dry basis. Total N content in grains and straw samples was determined by the micro-Kjeldahl method. Total P and K content were determined by digesting the plant samples in a di-acid mixture of HNO_3 and $HClO_4$ (3:1). The total P content was estimated by vanadomolybdate phosphoric acid yellow color method using Olsen and Sommers (1982) method and K using flame photometer. The N, P and K uptake by wheat was computed by multiplying the total dry matter yield with respective nutrient concentration. The total nutrient uptake of wheat was calculated by summing the nutrient uptake by grain and straw.

Site-specific fertilizer adjustment equations for targeted yields of wheat were developed using Ramamoorthy *et al.* (1967) approach as:

Nutrient requirement (N_R; kg nutrient/q):

$$N_R = \text{TU (kg/ha) / GY (q/ha)}$$

Nutrient contribution from soil (% Cs):

$$C_S = [(\text{TU in control plot (kg/ha)}) / (\text{STV in control plot (kg/ha)})] \times 100$$

Nutrients contribution from fertilizer (% C_F):

$$C_F = [(\text{TU in treated plot (kg/ha)}) - (\text{STV in control plot (kg/ha)} \times \text{Average } C_S)] / \text{FA (kg/ha)} \times 100$$

Contribution from rice residue (% C_{RR}):

$$C_{RR} = [(\text{TU in rice residue incorporated plot (kg/ha)}) - (\text{STV in rice residue incorporated plot (kg/ha)} \times \text{Average } C_S)] / \text{Nutrient N/P/K added by rice residue (kg/ha)} \times 100$$

Here, TU, total nutrient (N, P_2O_5 or K_2O) uptake (kg/ha); GY, grain yield (q/ha); STV, soil test value (kg/ha) and FA, fertilizer N or P_2O_5 or K_2O applied (kg/ha). These parameters were then used to develop fertilizer prescription equations used to calculate the amount of fertilizer doses added for specific yield target on the initial soil test status of the nutrient. A fractional factorial design was used to analyze wheat as per the standard procedure for STCR studies (Singh *et al*. 2017). Using this design, the data were analyzed taking yield data as the dependent variable and soil available nutrients, nutrient uptake, fertilizer nutrients, and interactions between soil and fertilizer nutrient as the independent variables (Singh *et al*. 2017).

RESULTS AND DISCUSSION

Available nutrients status of soil: The plots receiving NPK alone or NPK+ Rice residue showed that the $KMnO_4$-N values increased from 32.3 kg/ha in S1 to 102.5 kg/ha in S2 with an average value of 59.3 and 65.9 kg/ha respectively in S1 and S2 (Table 1). Similarly, Olsen-P increased from 17.4–79.3 kg/ha in S1 and S2 with the mean value of 47.2 and 49.5 kg/ha and NH_4OAc-K from 130.0 in S1 to 366.0 kg/ha in S2 with the mean value of 197 and 241.2 kg/ha respectively in S1 and S2. In control plots of two fertility strips, the $KMnO_4$ extractable N varied from 29.6–61.5 kg/ha with an average of 54.0 kg/ha, soil available P from 15.2–57.2 kg/ha with an average value of 42.0 kg/ha, and NH_4OAc-K from 112–192.0 kg/ha with an average value of 152.0 kg/ha. The increasing available NPK trend in S2 than S1 was probably due to the addition of an increasing dose of fertilizer application which resulted in creating a fertility gradient in the same field (Chatterjee *et al*. 2010) and further incorporation of rice residue along with inorganic fertilizer increased the soil organic matter, and soil N, P and K content (Jin *et al*. 2020). Additionally, improved top soil quality with straw incorporation was reported by many workers (Wanjari *et al*. 2004, Zhang *et al*. 2016; 2021) which favours the plant root growth by increasing availability of water, air quality, nutrient absorption, reduced bulk density and improved soil health and increase in soil productivity (Singh *et al*. 2008, Verhulst *et al.* 2011). In some studies negative effects with *in situ* retention of crop residue with high C:N ratio due to microbial immobilization and temporary decrease of available N were also reported (Maschner *et al.* 2011, Cao *et al.* 2018).

Wheat grain yield and nutrient uptake: The wheat yield in rice residue incorporated S2 strip varied from 2974–7280 kg/ha compared to 3850–6331 kg/ha in rice residue removed S1 strip. In control treatments, the wheat yield ranged from 2106–2330 kg/ha with an average of 2237 kg/ha (Table 1). Similarly, maximum average nutrient uptake was recorded in the order of S2 followed by S1 strips. Basumatary *et al*. (2015) reported similar results in a field study on rice-rice cropping sequence in Inceptisols. Moreover, straw incorporation could improve the crop N and K nutrition, beneficial for photosynthesis and is helpful in minimizing the effects caused by climate change (Cong *et al.* 2020). The wide variability in crop yield and soil nutrient status in both strips are the basic parameters needed for establishing site-specific target yield-based prescription equations of wheat crops.

Basic parameters: Fertilizer prescription equations for wheat were developed using the parameters, viz. N_R, C_S, C_F and C_{RR}. The results showed that producing one quintal of wheat grain under NPK alone needed 2.06 kg N, 0.78 kg P_2O_5 and 1.95 kg K_2O. The per cent soils and fertilizer contributions were found to be 52.3 and 54.0 for N, 11.7 and 50.0 for P_2O_5 and 20.2 and 20.6 for K_2O, respectively in Table 2. The above results showed a lower contribution of all three nutrients by soil compared to fertilizer. Madhavi *et al.* (2020) reported similar results for sesame on Alfisol. Moreover, to evaluate the quantity of fertilizer reduced with rice residue incorporation, the contribution of N, P_2O_5 and K_2O needs to be computed. The rice residue contributed N, P_2O_5 and K_2O to the tune of 42.0%, 15.3% and 26.0%, respectively, indicating comparatively more contribution of N and K_2O than fertilizer and soil contribution. The high N and K uptake might be due to increased supplemented nutrient N and K availability by incorporated rice residue. Dobermann and Fairhurst (2002) revealed that rice residue incorporated after harvest is translated to 40% and 80–85%, respectively, N and K_2O taken up by the plants. Chivenge *et al.* (2020) reported that incorporation of rice straw not only enhanced SOC but, also nutrient contents as compared to straw removed or burned.

Fertilizer prescriptions for desired targets of wheat crop: The fertilizer prescription equations were established using basic parameters, for specified yield targets of wheat for NPK alone as well as NPK + rice residue (Table 2). Making use of these prescription equations, a ready reckoner table was prepared by calculating fertilizer doses for desired yield targets of 45, 50, and 55 q/ha of wheat over a range of soil test values (Table 3). It was estimated that for getting a target yield of 50 q/ha, with different soil available N, P and K values, the N dose required was in the range of 93–151 kg/ha, fertilizer P_2O_5 from 68–73 kg/ha, and fertilizer K_2O from 34–38 kg/ha. In rice residue amended plots along with NPK fertilizers, the amount of needed fertilizer N, P_2O_5 and K_2O ranges from 93–120 kg/ha, 56–61 kg/ha, and 29–33 kg/ha respectively. Similarly, for the target yield of 55 q/ha, the respective values were in the range of 112–170 kg/ha, 76–80 kg/ha and 38–42 kg/ha under NPK alone and 81–139 kg/ha, 64–68 kg/ha and 34–38 kg/ha under rice residue amended along with NPK fertilizer plots. The reduced amount of fertilizer doses under the integrated nutrient management system was due to enhanced SOC, maintaining soil favourable physical properties and balanced supply of essential nutrients throughout crop life that contributed in yield enhancement

Table 1 Initial soil available NPK, wheat yield, and NPK uptake by wheat (kg/ha)

Particular	Strip 1		Strip 2		Control	
	Range	Mean	Range	Mean	Range	Mean
$KMnO_4$ –N	32.3-96.6	59.3	35.1-102.5	65.9	29.6-61.5	54.0
Olsen–P	17.4-76.5	47.2	17.9-79.3	49.5	15.2-57.2	42.0
NH_4OAc-K	130.0-277.4	196.5	149.5-366.0	241.2	112-192	152
Wheat grain yield	3850-6331	4903	2974-7280	5551	2106-2330	2237
N uptake	79-136.5	103.4	87.6-128	106.1	38.1-60.6	43.9
P uptake	11.4-23.1	16.3	14.6-24.4	18.4	3.65-7.45	6.30
K uptake	60-119.1	81.5	68.6-139.0	83.5	20.1-47.7	30.5

Table 2 Basic data and fertilizer adjustment equations of wheat in alluvial soils

Nutrient	Basic data				Fertilizer prescription equation	
	N_R (kg/q)	C_S (%)	C_F (%)	C_{RR} (%)	NPK alone	NPK + Rice residue
N	2.06	52.3	54.0	42.0	3.78T-0.96SN	3.78T-0.96SN -0.77RR N
P_2O_5	0.78	11.7	50.0	15.3	1.54T-0.23S P_2O_5	1.54T-0.23S P_2O_5 – 0.30 RR_P_2O_5
K_2O	1.95	20.2	20.6	26.0	0.95T-0.09SK_2O	0.95T-0.10SK_2O – 0.12 RR_K_2O

T, target yield equation (q/ha); S, soil test value of the respective nutrient (kg/ha); RR, rice residue.

Table 3 Ready reckoner for wheat under NPK alone and NPK + rice residue at 6 t/ha

Soil test value N: P_2O_5:K_2O	NPK alone			NPK + rice residue		
	45 q/ha	50 q/ha	55 q/ha	45 q/ha	50 q/ha	55 q/ha
40:20:100	132:65:33	151:73:38	170:80:42	101:53:28	120:61:33	139:68:38
70:30:120	103:62:31	122:70:36	141:78:40	72:50:26	122:58:31	110:66:34
100:40:140	74:60:29	93:68:34	112:76:38	43:48:24	93:56:29	81:64:36

(Madhavi *et al.* 2020, Singh *et al* 2021). Thanh *et al.* (2016) also expressed improved soil *p*H, SOC, and nutrient content with rice residue incorporation compared to removed residue.

Based on the above findings, it can be concluded that targeted yield-based prescription technology not only ensures sustainable wheat yield, but is also helpful in cutting the costlier fertilizer inputs while considering the contribution of soil and other IPNS components. The fertilizer prescriptions using the developed models can effectively support 50 and 55 q/ha yield targets with IPNS in the wheat crop. The fertilizer prescription equations established using this model may hold good for the efficient and economic use of fertilizers in Indo Gangetic plains of northwestern India and can be recommended as an effective tool for balanced fertilization.

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