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Soil Science

Soil Test Based Fertilizer Recommendation of Nitrogen, Phosphorus and Sulphur in Wheat (*Triticum aestivum* L.) in an Alluvial Soil

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Abstract

Soil test crop response correlation involving integrated plant nutrition system (STCR-IPNS) studies on nitrogen (N), phosphorus (P) and sulphur (S) in wheat on an Inceptisol, New Delhi, India were carried out following Ramamoorthy's 'inductive cum targeted yield model'. After establishment of marked fertility gradient with respect to soil available N, P and S, four levels of fertilizer N, P, S and three levels of farmyard manure (FYM) were randomized in three fertility strips each having twenty four plots. Soil and plant analysis data were further used to compute basic parameters required for development of nutrient prescription equation. The nutrient requirement for producing one quintal of wheat grain yield was worked out as 2.26 kg of N, 0.40 kg of P and 0.54 kg of S. Soil available pool contributed 26.15, 50.06 and 52.55 % to total N, P and S uptake, respectively; contribution from applied fertilizer were 42.31, 25.12 and 46.39% and contribution from applied FYM were 27.95, 11.21 and 17.66% to total N, P and S uptake by wheat. Using basic data, fertilizer prescription equations and ready reckoner were developed for range of soil test values and desired yield targets for NPS alone and IPNS (NPS with FYM).

Highlights

- Basic parameters - nutrient requirement, contribution from soil, fertilizer and farmyard manure in wheat computed.
- Fertilizer prescription equation and ready reckonerfor N,P and S recommendations developed

Keywords: Fertilizer prescription equations, *Triticum aestivum* L., soil test crop response, targeted yield approach

Introduction

Wheat is one of the most important cereal crops grown in India. India ranks second in global acreage (28.52 million hectares) and grain production (80.71 million tonnes) (FAOSTAT, 2012). The average wheat productivity of India is 2.83 t/ha. Analysis of long term experiments have generated very valuable information on yield trends of wheat. Analysis of 33 long term experiments in Indo-Gangetic Plains of South Asia, non-IGP in India and China have showed that, yields in treatments receiving recommended rates of

N, P and K stagnated in 85% and declined significantly (p<0.05) in 6% of long term experiments (Ladha *et al.,* 2003). Analysis experiment conducted at six locations across the country revealed that, per cent yield gaps observed between potential and on-farm yield, on-station and on-farm yield, and potential and on-station yield were 35.4-60%, -0.07-39.1% and 34.3-49.2%, respectively (Agarwal *et al.,* 2000; Ladha *et al.,* 2003). Such yield gaps provides ample scope to improve yield levels in irrigated wheat through adoption of techniques prescribing fertilizer nutrient based on soil test values and desired yield targets.

Over past few decades fertilizer consumption in India has increased appreciably. But, it is important to note that Indian agriculture is running at 'net negative nutrient balance' of staggering 8-10 Million tonnes per year (Tandon, 2004) which is set to reach around 15 million tonnes by 2025. Application fertilizer nutrients by the farmer without information on soil fertility status and nutrient requirement by crop affect soil and crop adversely (Ray *et al.,* 2000). Intensive cropping and imbalanced fertilizer application are major causes of depletion macronutrients like N, P, K and S. Soil analysis of number of samples across the country revealed that, 57-64 Mha of soils in India are S deficient (TSI, 2012). Considering high costs of fertilizers and adverse effect of its overuse on environment and soil health, proper organic manure-fertilizer recommendations on the basis of soil test values, residual effect and yield targets becomes vital. At such point of time, unique 'inductive cum targeted yield model' of Ramamoorthy *et al.,* (1967) to develop proper manure-fertilizer prescription becomes very useful (Santhi *et al.,* 2011-12). Majority of such experiments consider three major nutrients N, P and K; however, studies on recommendation of S considering soil test value of S and target yield in wheat crop are completely missing. Considering importance of S to plant nutrition and its wide spread deficiency in India soils, it is important to explore this kind of research area to develop of S recommendation in wheat and others crops.

'Targeted yield model' is one of the practical approach for efficient use fertilizers. Theory of formulating optimum fertilizer recommendations for targeted yields was first given by Troug (1960) which was further modified by Ramamoorthy *et al., (*1967) as 'Inductive-cum targeted yield model'. Addition of Integrated Plant Nutrition System (IPNS) to this concept ensures balanced fertilization by application of inorganic and organic sources of nutrients. Use of moong straw to improve nutrient status and soil properties in rice-wheat cropping system (Gangola *et al.,* 2012), farmyard manure to enhance nutrient recovery and productivity of wheat (Bhaduri and Gautam, 2012) and higher rice productivity and optimum biological activities (Bhatt *et al*., 2012) has been successfully demonstrated in recent literature. Such recommendations are helpful in maintenance and enhancing soil fertility simultaneously with improving crop production and nutrient use efficiencies. Moreover, the computer simulation models being used for fertilizer recommendation are precise but require huge database and are often complex. They are generally computer based programmes, which limits their use to rich farmers and researchers and remains beyond reach of poor farmers. This necessitates formulation of comparatively simple and easy-to-use approaches of fertilizer recommendations. So, soil test crop response correlation study involving integrated plant nutrition system (STCR-IPNS) was undertaken to develop balanced manure-fertilizer N, P and S schedule for wheat crop. This study aims (1) to develop basic data of nutrient requirement and contribution of nutrients to total uptake from different sources and (2) to develop fertilizer N, P and S prescription equations and farmer friendly ready reckoner to prescribe fertilizers in wheat crop.

Materials and methods

Field experiments were carried out during regular wheat growing season of 2010-11 and 2011-12 at research farm of Indian Agricultural Research Institute, New Delhi, India, (latitude 28.4^{0}N, longitude 77.1^{0}E) at 250 meters above mean sea level. Climate of Delhi region is semi-arid and subtropical characterized by dry summers and cold winters.

Physical and chemical properties of experimental soil

The soil of the experimental site was sandy loam in texture with predominance of illitic type of clay minerals which taxonomically categorized under the great group *Typic Haplustepts* (old alluvium). Soil of experimental field had 166 kg/ha alkaline permanganate oxidizable N (Subbiah and Asija, 1956), 14 kg/ha 0.5 *N* sodium bicarbonate-extractable P (Olsen *et al.,* 1954), 146 kg/ha neutral *N* ammonium acetate exchangeable K (Hanway and Heidel, 1934), 22 kg/ha 0.15 % $CaCl_2$ extractable-S (William and Steinberg, 1959), 0.43% organic carbon (Walkley and Black, 1934), pH of 8.0 and electrical conductivity of 0.43 dS/m in 1:2.5 soil to water (Jackson, 1973). DTPA-extractable Fe, Mn, Zn and Cu were present soil in sufficiency range.

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Fertility gradient experiment

Prior to test crop experimentation, fertility gradient experiment was conducted to create soil fertility gradient using 'inductive methodology' developed by Ramamoorthy *et al.,* (1967). For this purpose, field was divided into three equal rectangular strips and graded doses of fertilizer N, P and S were applied as $N_0P_0S_0$, $N_{1/2}P_{1/2}S_{1/2}$ and $N_1P_1S_1$ ($N_1P_1S_1$ represents 400, 300, 150 kg/ha of N, P_2O_5 and S, respectively) in strip I, strip II and strip III, respectively. K was applied at a static rate of 100 K_2O kg/ha. Soil fertility gradient with respect to farmyard manure (FYM) was developed by applying FYM @ 0, 5 and 10 tonnes/ha in three strips across the fertilizer applied strips. This created distinct nine blocks (3 in each strip) in field receiving different nutrient doses. During summer 2010-11, preliminary exhaustive fodder maize crop (variety: African tall) was grown to stabilize soil fertility and it was then harvested as a fodder. Twenty-four soil samples (0-15 cm) from each strip were collected after harvest of exhaustive fodder crop and analyzed for alkaline $KMnO_4$-N, Olsen's-P and 0.15% $CaCl_2$ extractable-S.

Test crop experimentation

After fertility gradient experiment, each strip was divided into 24 plots to accommodate 24 treatments (21 treatments + 3 controls) making total of 72 plots. Three blocks (comprising 8 treatments) were made within each strip. The experiment was laid out in fractional factorial randomized block design. The treatments comprised of selected combinations of four levels of nitrogen (0, 60, 120 and 180 kg N/ha), phosphorus (0, 30, 60 and 90 kg P_2O_5/ha) and sulphur (0, 15, 30 and 45 kg S/ha) and three levels of FYM (0, 5, 10 tonnes FYM/ha) (Table 1). Treatments were randomized in each strip and replicated thrice. N was applied in three equal splits as basal and two top dressings at crown root initiation and maximum tillering; however, full basal dose of P and S was applied at the time of sowing. Test crop 'HD-2851' was grown during 2010-11 and 2011-12. Wheat crop was grown as a component crop in rice wheat cropping system. Similar set of experiment using hybrid rice 'Pusa Rice Hybrid-10' was carried out in wet season of 2010-11 and 2011-12 (except N levels as 0, 70, 140 and 210 kg N/ha) applied in three equal splits at transplanting and two top dressings at tillering and panicle initiation an flowering.

Twenty-four soil samples (0-15 cm) were collected from each strip before and after sowing of test crop wheat and analyzed for alkaline $KMnO_4$-N, Olsen's-P, 0.15% $CaCl_2$-S. Grain and straw was separated by threshing. Grain and straw samples collected from each plot were oven dried at 60±2^{0}C till a constant weight. Oven dried samples were digested for chemical analysis in di-acid mixture (HNO_3:$HClO_4$ in the ratio of 9:4 v/v) for phosphorus and sulphur (Jackson, 1973). Total phosphorus content in the digest was determined by vanado-molybdate phosphoric acid yellow colour method (Jackson, 1973) and total sulphur was measured turbidimetrically (Tabatabai and Bremer, 1970). Total nitrogen content in grain and straw was analysed using modified micro-kjeldahls' method (Jackson, 1973).

Basic parameters

Total uptake of N, P and S were computed using grain and straw yield and total nutrient content in the grain and straw. Using data on nutrient uptake, root yield, pre-sowing soil available nutrients and applied fertilizer doses, basic parameters *viz.*, nutrient requirement (NR), contribution of nutrients from soil (C_S) and fertilizer (C_F) were calculated as described by Ramamoorthy *et al., (*1967). Contribution of FYM (C_{FYM}) was estimated using data from FYM treated and non-treated plots.

$$\text{kg of N, P or S/q of grain} = \frac{\text{Total uptake of N, P or S (grain + straw) (kg/ha)}}{\text{Rice grain yield (q/ha)}}$$

Contribution of nutrients from soil to total uptake (%)

$$\text{Contribution of N, P or S from soil } (C_S) = \frac{\text{Total uptake of N, P or S in control plot (kg/ha)}}{\text{Soil test values of available N, P or S in control plots (kg/ha)}} \times 100$$

Contribution of nutrients from fertilizer to total uptake (%)

$$\text{Contribution of N, P or S from fertilizer } (C_F) = \frac{\text{Total uptake of N, P or S in fertilized plot (kg/ha) - \{Soil test value of N, P or S in fertilized plot (kg/ha) x mean } C_S\}}{\text{Fertilizer N, P and S applied (kg/ha)}} \times 100$$

Contribution of farmyard manure to total uptake (%)

$$\text{Contribution of N, P or S from farmyard manure } (C_{FYM}) = \frac{\text{Total uptake of N, P or S in farmyard manure treated plot (kg/ha) - \{Soil test value of N, P or S in farmyard treated plot (kg/ha) x mean } C_S\}}{\text{N, P and S applied through farmyard manure (kg/ha)}} \times 100$$

Fertilizer prescription equations

Using data of basic parameters fertilizer prescription equations were developed for wheat.

Fertilizer nitrogen (FN)

$$FN = \frac{NR}{CF/100} T - \frac{C_S}{C_F} STVN$$

...without farmyard manure

$$FN = \frac{NR}{CF/100} T - \frac{C_S}{C_F} STVN - \frac{C_{FYM}}{C_F} FYMN$$

...with farmyard manure

Fertilizer phosphorus (FP)

$$FP = \frac{NR}{CF/100} T - \frac{C_S}{C_F} STVP$$

...without farmyard manure

$$FP = \frac{NR}{CF/100} T - \frac{C_S}{C_F} STVP - \frac{C_{FYM}}{C_F} FYMP$$

...with farmyard manure

Fertilizer sulphur (FS)

$$FS = \frac{NR}{CF/100} T - \frac{C_S}{C_F} STVS$$

...without farmyard manure

$$FS = \frac{NR}{CF/100} T - \frac{C_S}{C_F} STVS - \frac{C_{FYM}}{C_F} FYMP$$

...with farmyard manure

Where, FN, FP and FS - fertilizer N, P and S (kg/ha), respectively; NR - nutrient requirement of N, P and S (kg/q); C_S, C_F and C_{FYM} - percentage contribution of nutrients from soil, fertilizer and farmyard manure, respectively; STVN, STVP and STVS - soil test value for available N, P and S (kg/ha); FYMN, FYMP and FYMS - amount of N, P and S applied through farmyard manure, T - target yield (kg/ha) of crop.

The above explained fertilizer prescription equations help in calculation of fertilizer quantities for variable soil test values of N, P and S and desired target yield. Furthermore, ready reckoner of fertilizer doses for range of soil test values and target yields under NPS alone and IPNS (NPS with FYM) was generated.

Results

Establishment of fertility gradient

Descriptive statistics of pre-sowing available soil nutrients in surface soil is presented in Table 2. Mean alkaline $KMnO_4$-N of 168.6, 213.1 and 237.1 kg/ha in 2010-11 and 160.1, 205.8 and 226.5 kg/ha in 2011-12 were observed in strip I, II and III, respectively. Mean Olsen's-P values in strip I, strip II and strip III were 18.7, 26.1 and 32.1 kg/ha in 2010-11 and 17.7, 24.9 and 30.4 kg/ha in 2011-12, respectively. Mean 0.15% $CaCl_2$ extractable-S of 22.2, 29.9 and 40.4 kg/ha in 2010-11 and 21.5, 29.2 and 39.5 kg/ha in 2011-12 were recorded in strip I, II and III, respectively. From the data, it is obvious that mean value of the alkaline $KMnO_4$-N, Olsen's-P and 0.15% $CaCl_2$ extractable-S was highest in strip III, followed by strip II and it was lowest in strip I. Within strip variation with respect to soil available nutrients can be explained by coefficient of variation. Variations in soil available N was lesser compared to soil available P and S during both the years of experimentation (Table 2). A marked fertility gradient was built up by application of graded levels of fertilizer and FYM. This indicates that, adequate variability with respect to soil available N, P and S was developed before start of test crop experiment.

Grain yield and nutrient uptake

Year wise descriptive statistics of wheat grain yield and nutrient uptake is presented in Table 3. During both the years of experimentation, highest grain yields were obtained in strip III being fertile strip followed by strip II and the lowest in unfertilized strip I. Mean grain yields of overall plots were 3.82, 4.20 and 4.50 t/ha in 2010-11 and 4.25, 4.46 and 4.76 t/ha in 2011-12 in strip I, strip II and strip III, respectively. Grain yield of wheat increased with the increase in application of fertilizer N, P and S and FYM. The highest grain yield of 5.34 and 5.19 t/ha in 2010-11 and 2011-12 was observed in the second strip with application of 120, 60 and 30 kg/ha of N, P_2O_5 and S in conjunction with 10 t FYM/ha. Like soil available nutrients, N, P and S uptake was observed to be the highest in strip III followed by strip II and it was the least in strip I. Variability in wheat grain yield, N, P and S uptake was higher compared to variability in soil available nutrients which is conspicuous from comparatively higher values of coefficient of variation for grain yield, N, P and S uptake (Table 2 and 3).

Development of basic parameters

In present set of experiment, data of grain yield, nutrient uptake, pre-sowing soil available nutrients, applied doses of N, P and S through fertilizer and FYM were used to compute basic data *viz.* (1) nutrient requirement (NR) in

Table 1: Detailed N, P and S treatment combinations used for test crop experimentation

Sr. No.	Treatment combinations			Amount of nutrients (kg/ha)		
	N	P	S	N	P	S
1.	0	0	0	0	0	0
2.	0	0	0	0	0	0
3.	0	0	0	0	0	0
4.	0	2	2	0	60	30
5.	1	1	1	60	30	15
6.	1	1	2	60	30	30
7.	1	2	1	60	60	15
8.	1	2	2	60	60	30
9.	2	1	1	120	30	15
10.	2	0	2	120	0	30
11.	2	1	2	120	30	30
12.	2	2	0	120	60	0
13.	2	2	1	120	60	15
14.	2	2	2	120	60	30
15.	2	2	3	120	60	45
16.	2	3	2	120	90	30
17.	2	3	3	120	90	45
18.	3	1	1	180	30	15
19.	3	2	1	180	60	15
20.	3	2	2	180	60	30
21.	3	3	1	180	90	15
22.	3	3	2	180	90	30
23.	3	2	3	180	60	45
24.	3	3	3	180	90	45

Table 2: Descriptive statistics of available soil (0-15 cm) nutrients after soil fertility gradient experiment.

Nutrients	Strip I		Strip II		Strip III	
	Range	Mean ± SD[a] (CV[b])	Range	Mean ± SD (CV)	Range	Mean ± SD (CV)
			2010			
Alkaline $KMnO_4$-N (kg/ha)	141.0-195.5	168.6 ± 14.04 (8.32)	173.6-232.5	213.1 ± 17.01 (7.98)	206.4-261.8	237.1 ± 16.73 (7.05)
Olsen's-P (kg/ha)	12.3-25.0	18.7 ± 4.05 (21.65)	20.4-31.6	26.1 ± 3.02 (11.57)	22.8-42.8	32.4 ± 6.09 (18.79)
0.15% $CaCl_2$ (kg/ha)	18.4-26.8	22.2 ± 2.68 (12.07)	22.3-36.4	29.9 ± 4.23 (14.14)	33.2-49.7	40.4 ± 5.08 (12.57)
			2011			
Alkaline $KMnO_4$-N (kg/ha)	130.2-189.6	160.1 ± 16.96 (10.59)	158.8-237.8	205.8 ± 22.17 (10.77)	183.9-257.4	226.5 ± 24.34 (10.74)
Olsen's-P (kg/ha)	10.8-31.7	17.7 ± 5.58 (31.52)	17.4-32.2	24.9 ± 4.07 (16.34)	17.9-44.7	30.4 ± 7.82 (25.72)
0.15% $CaCl_2$ (kg/ha)	16.1-31.3	21.5 ± 3.71 (17.25)	19.2-38.3	29.2 ± 5.36 (18.35)	29.5-50.0	39.5 ± 6.90 (17.46)

[a]: Standard Deviation,
[b]: Coefficient of variation (Standard Deviation/Mean x 100) in %.

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Table 3: Descriptive statistics of wheat grain yield and nutrient uptake.

Parameters	Strip I		Strip II		Strip III	
	Range	Mean ± SD[a] (CV)[b]	Range	Mean ± SD[a] (CV)[b]	Range	Mean ± SD[a] (CV)[b]
2010-11						
Grain yield (t/ha)	1.54-5.44	3.82 ± 1.18 (30.89)	2.01-5.34	4.20 ± 1.10 (26.19)	2.23-5.38	4.50 ± 1.13 (25.11)
N uptake (kg/ha)	21.2-148.0	90.7 ± 39.27 (43.29)	31-140.5	92.3 ± 38.38 (41.58)	35-147.5	108.8 ± 39.06 (35.9)
P uptake (kg/ha)	3.3-27.5	16.1 ±7.38 (45.83)	4.6-24.5	16.3 ± 6.88 (42.20)	5.4-26.5	18.2 ± 7.26 (39.89)
S uptake (kg/ha)	8.6-29.1	21.9 ± 6.50 (29.68)	10.7-28.7	22.3 ± 6.13 (27.48)	12.0-29.1	23.5 ± 5.83 (24.80)
2011-12						
Grain yield (t/ha)	1.91-5.29	4.24 ± 1.06 (25.00)	2.27-5.68	4.44 ± 0.99 (22.29)	2.28-5.36	4.68 ± 0.97 (20.72)
N uptake (kg/ha)	37.0-148.8	104.8 ± 35.95 (34.30)	42.9-148.2	105.5 ± 34.75 (32.93)	41.81-149.7	112.8 ± 34.77 (30.82)
P uptake (kg/ha)	8.7-21.6	16.3 ± 3.87 (23.72)	9.4-28.3	18.1 ± 4.52 (24.97)	7.7-20.8	22.24 ± 3.53 (15.87)
S uptake (kg/ha)	9.3-30.8	22.0 ± 6.49 (29.5)	10.6-30.1	22.5 ± 5.70 (25.33)	11.463-28.718	24.7 ± 6.03 (24.41)

[a]: Standard Deviation,
[b]: Coefficient of variation (Standard Deviation/Mean x 100) in %.

kg per quintal of wheat grain yield, (2) percentage contribution from soil available nutrients (C_S), (3) percentage contribution from fertilizer nutrients (C_F) and (4) percentage contribution from FYM (C_{FYM}) to the total nutrient uptake. Basic parameters are required for developing fertilizer N, P and S prescription equations with or without FYM for targeted yield of wheat.

Nutrient requirement (NR)

During 2010-11, 2.17 kg N, 0.41 kg P and 0.56 kg S were required for producing one quintal of wheat grain and the corresponding amounts of N, P and S in 2011-12 were 2.34, 0.38 and 0.51 kg, respectively. Average of two years data of nutrient requirement of N, P and S was 2.26, 0.40 and 0.54 kg per quintal of wheat grain. The order of nutrient requirement in the present experiment was N>S>P.

Percentage contribution of nutrients from soil (C_S), fertilizers (C_F) and FYM (C_{FYM})

Mean percentage contribution of nutrients from soil available N, P and S (C_s) to the total uptake was 26.15, 50.06 and 52.55%, respectively. The percentage contribution of nutrient from soil to the total uptake of nutrient was calculated from absolute control. Using data from fertilizer

Table 4: Nutrient requirement and per cent contributions of nutrients from soil, fertilizer and farmyard manure in wheat.

Basic parameters or data	Nutrients								
	N	P 2010	S	N	P 2011	S	N	P Mean	S
Nutrient requirement (NR) of grain yield (kg/q)	2.17	0.41	0.56	2.34	0.38	0.51	2.26	0.40	0.54
Per cent contribution from available soil nutrients (C_S)	23.57	45.51	53.10	28.72	54.50	52.00	26.15	50.06	52.55
Per cent contribution from fertilizer nutrients (C_F)	40.67	27.27	43.62	43.94	22.97	49.15	42.31	25.12	46.39
Per cent contribution from farmyard manure (C_{FYM})	26.02	12.54	16.14	29.87	9.87	19.17	27.95	11.21	17.66

treated plots, mean contribution of fertilizer nutrients to the total uptake for N, P and S was observed as 42.31, 25.12 and 46.39%, respectively. As a component of IPNS, 27.92, 11.21 and 17.66% of the total nutrient uptake was contributed by farm yard manure N, P and S.

Fertilizer prescription equations and ready reckoner for target yield of wheat

Using basic parameters, year-wise and mean soil test based fertilizer prescription equations were developed for desired target yield of wheat (Table 5). For range of soil test values and target grain yield of 5 t/ha, ready reckoner or nomogram was prepared for NPS alone and NPS with FYM. For targeted wheat grain yield of 5 t/ha with soil test values of $KMnO_4$-N, Olsen's-P and 0.15% $CaCl_2$ extractable-S as 200:15:25 kg ha^{-1}, amounts of fertilizer N, P_2O_5 and S to be applied are 144 kg N/ha, 106 kg P_2O_5/ha and 25 kg S/ha, respectively. When 10 t/ha of FYM (moisture content - 38% and 0.53, 0.22 and 0.21% of N, P and S, respectively) was applied along with NPS, amount of fertilizer N, P_2O_5 and S were reduced to 137 kg N/ha, 96 kg P_2O_5/ha and 25 kg S/ha, respectively (Table 6).

Discussion

Fertility gradient experiment

In the present investigation, presence of adequate variability in wheat grain yield and N, P and S uptake was observed due to operational range of soil test values. Variation in soil fertility is major pre-requisite and underlying principle for development of soil test based fertilizer recommendations. Alkaline $KMnO_4$-N, Olsen's-P and 0.15% $CaCl_2$ extractable-S were found to be the highest in strip III followed by strip II and the least in strip I. The marked fertility gradient built up was reflected in terms of grain yield and nutrient uptake. Similar kind of trend for mean nutrient uptake was observed in both the year of experimentation. Sharma and Singh (2005) reported existence of operational range of soil test values after fertility gradient experiment with preliminary crop pearlmillet for development of soil test based fertilizer recommendation to obtain economic yield of wheat crop. Such types of marked fertility gradient build up by preliminary fertility gradient experiment have been reported by Gayathri *et al.,* (2008, 2009), Santhi *et al.,* (2005).

Basic parameters

Mean nutrient requirement for producing one quintal of wheat grain was 2.17 kg of N, 0.41 kg of P and 0.56 kg of S. Nutrient requirement of N was found to be highest among three nutrients studied followed by S and it was least for P. The requirement of N was 5.29 times that of P and 3.87 times that of S. The percentage contribution of soil to the total nutrient uptake for S was highest among three nutrients followed by P and least for N. Order of percentage contribution of fertilizer nutrient to total nutrient uptake was observed as: S>N>P. Percentage contribution from fertilizer N was higher than that from soil; on the contrary, the percentage contribution from soil was higher than that from fertilizer for P and S. Higher contribution of soil P and S to the total nutrient uptake can be attributed to the residual effect of P and S from preceding crop rice. The

Table 5: Soil test based fertilizer prescription equations for targeted yield of wheat.

Fertilization programme	Fertilizer prescription equation		
	2010	2011	Mean
NPS alone	FN = 5.34 T – 0.58 SN	FN = 5.33 T – 0.65 SN	FN = 5.34 T – 0.62 SN
	FP = 1.50 T – 1.67 SN	FP = 1.65 T – 2.37 SP	FP = 1.58 T – 2.02 SP
	FS = 1.27 T – 1.22 SS	FS = 1.04 T – 1.06 SS	FS = 1.16 T – 1.14 SS
NPS + FYM	FN = 5.34 T – 0.58 SN – 0.64 FYMN	FN = 5.33 T – 0.65 SN – 0.68 FYMN	FN = 5.54 T – 0.62 SN– 0.66FYMN
	FP = 1.50 T – 1.67 SN – 0.46 FYMP	FP = 1.65 T – 2.37 SP – 0.43 FYMP	FP = 1.58 T – 2.02 SP– 0.45 FYMP
	FS = 1.27 T – 1.22 SS – 0.37 FYMS	FS = 1.04 T – 1.06 SS – 0.39 FYMS	FS = 1.16 T – 1.14 SS– 0.38FYMS

FN, FP and FS – fertilizer N, P and S in kg/ha, respectively; T- target yield in q/ha; SN, SP and SS – Alkaline $KMnO_4$ – N, Olsen's-P and 0.15% $CaCl_2$ extractable S in kg/ha, respectively; FYMN, FYMP and FYMS – applied N, P and S in kg/ha through farmyard manure, respectively.

Table 6: Ready reckoner of soil test based fertilizer recommendations of N, P and S for 5 t/ha of wheat grain yield.

$KMnO_4$-N (kg ha^{-1})	NPS alone	NPS + 10 t FYM ha^{-1}	% Reduction e over NPS alon	Olsens-P (kg ha^{-1})	NPS alone	NPS + 10 t FYM ha^{-1}	% Reduction over NPS alone	0.15% $CaCl_2$ extractable S (kg ha^{-1})	NPS alone	NPS + 10 t FYM ha^{-1}	% Red uction over NPS alone
100	206	199	3.2	10	134	124	7.7	10	46	42	8.4
125	191	184	3.5	13	120	110	8.6	15	41	37	9.6
150	175	168	3.8	16	106	96	9.7	20	35	31	11.2
175	160	153	4.1	19	92	82	11.1	25	29	25	13.3
200	144	137	4.6	22	79	68	13.1	30	24	20	16.6
225	129	122	5.1	25	65	54	15.9	35	18	14	21.8
250	113	106	5.8	28	51	41	20.3	40	12	8	32.1
275	98	91	6.8	31	37	27	27.9	45	6	3	60.5
300	82	75	8.0	34	23	13	44.7	50	1	0	0
325	67	60	9.9	37	9	0	0	55	0	0	0
350	51	44	12.9	40	0	0	0	60	0	0	0
375	36	29	18.6	43	0	0	0				
400	20	13	33.0	46	0	0	0				

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percentage contribution from FYM to the total nutrient uptake followed order as: N>S>P. Higher contribution of N from FYM than any other nutrient in wheat crop is concordant with Sharma and Singh (2007).

Fertilizer prescription equations

Majority of research in this frontline area has focused on development of fertilizer prescription equations for three major nutrients N, P and K for different crops. But, information on recommendation of secondary macronutrient like S is completely missing. Under such circumstances STCR-IPNS studies for S recommendation becomes important in areas where K is not a limiting factor for crop production. Fertilizer prescription equations were developed in the present study for N, P and S recommendation in wheat. Such kind of fertilizer (NPK) prescription equations for different crops (rice, wheat, maize, mustard, rapeseed) have been documented by Milap-Chand *et al.,* (2006), Sharma and Singh (2005, 2007), Verma *et al.,* (2002). Inclusion of IPNS component FYM in the present investigation resulted in reduction requirement of fertilizer nutrient. Fertilizer requirement computed for initial soil test values of 200:15:25 kg/ha of $KMnO_4$-N, Olsen's-P and 0.15% $CaCl_2$ extractable-S using IPNS showed saving of 9 kg N, 10 kg P_2O_5 and 4 kg of S for yield target of 5 t/ha (Table 6).

Conclusion

In the present investigation, use of fertilizer prescription equations considering nutrient requirement (2.26 kg of N, 0.40 kg of P and 0.54 kg of S); percentage contribution from soil (26.15, 50.06 and 52.55 for N, P and S), fertilizer (42.31, 25.12 and 46.39 for N, P and S) and FYM (27.95, 11.21 and 17.66 for N, P and S) to total uptake ensured balanced nutrient supply to wheat crop. Use of integrated plant nutrition system resulted in saving of fertilizer nutrients in wheat crop. Target yield equations generated from STCR-IPNS technology ensures not only sustainable crop production but also economise use of costly fertilizer inputs. Practice of fertilizing crops using fertilizer prescription equations needs to be popularized among farmers to achieve higher productivity, nutrient use efficiencies and profitability.

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