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SOIL TEST BASED FERTILIZER PRESCRIPTIONS THROUGH INDUCTIVE CUM TARGETED YIELD APPROACH FOR WHEAT IN ALLUVIAL SOILS OF NORTHWEST INDIA

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ABSTRACT
Fertilizer is one of the costlier inputs in agriculture and for attaining higher crop yields farmers tend to use excessive chemical fertilizers. Considerable economy in fertilizer use can be achieved by gathering knowledge of crop response to applied fertilizer, inherent supply of nutrients by the soil and its short or long term effects in the system. Therefore, a study was undertaken with the objective of developing soil test based fertilizer calibrations with desired yield targets for wheat following Rama moorthy's "Inductive cum Targeted yield approach". This approach showed that the nutrient requirement for producing one tonne of wheat was 1.46, 0.78 and 1.82 kg q^{-1} of N, P_2O_5 and K_2O, respectively. The percent contribution of nutrients from soil and fertilizer were found to be 42 and 24 for nitrogen, 14 and 42 for phosphorus and 13 and 21 for potassium, respectively. Similarly, the percent contribution of nutrients from fertilizers in presence of farmyard manure (FYM) was 56 for nitrogen, 19 for phosphorus and 39 for potassium. Increased contribution of nutrients in FYM plots was due to higher soil microbial activity. In addition, farmers field experiments to check the fertilizer adjustment equations of wheat showed superiority of target yield concept over the other practices.

INTRODUCTION

Wheat (*Triticum aestivum* L) is the most widely grown cereal grain, occupying 17 percent of the total cultivated land area in the world. In India, it is the staple food for a large population, next only to rice and contributes about 30% towards total grain production of the country. By 2025, India will need 29 million tonnes of food grains as against a provisional production of 264 million tonnes in 2013-2014 (Parvathi and Arulselvam, 2013). Thus, an additional food grain production of 64 million tonnes has to be achieved from the same or even lesser land area.

Fertilizer is one of the costliest inputs in agriculture for attaining higher crop yields; thus farmers tend to use excessive chemical fertilizers. However, 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 effects (Dobermann *et al*., 2003). Therefore, for achieving higher farm profitability and minimizing environmental protection it is necessary to have information on optimum use of fertilizer for crops (Kapoor *et al*., 2008; Kimetu *et al*., 2004). Soil testing is recognized as an important tool for judicious use of fertilizers which takes care of unbalanced application of nutrients (Singh *et al.,* 2015). Several approaches in the past have been advocated to recommend fertilizer doses to the farming community based on the soil and plant analysis made through the All India Coordinated Research project for Investigation on Soil test crop response correlation (STCRC). Out of these, the three namely: 1) state level generalized fertilizer recommendation dose (GRD); 2) soil test based fertilizer recommendation (STRD) and; 3) target yield approach needs special attention. The GRD are made only for medium fertility soils and do not account for variation in soil fertility which varies in the Punjab state widely While the STRD is based on grouping of soils in different classes *viz*. low, medium and high in respect of the status of nutrient in question. In this approach, soils testing low or high, the fertilizer recommendation is increased or decreased by 25% respectively of the GRD. This approach suffers from the constraint that it recommends the same fertilizer dose for extremely deficient and marginally deficient soils. Similarly extremely high and moderately high nutrient status soils receive the same amount of fertilizers. However, considerable economy in fertilizer use can be achieved if site specific soil test values for pre-set yield targets are used for recommending fertilizers (Ramamoorthy and Velayutham, 1971). This approach takes into consideration the effects of soil heterogeneity, management practices and climatic conditions on the response of crops to applied (organic and inorganic sources) and native nutrients.Thus, application of N, P and K based on soil test yield target may enhance wheat productivity while maintaining soil health in the region (Singh *et al*., 2014).

Keeping the above facts in view and non-availability of STCR data for wheat crop in the region, the present investigation was contemplated in alluvial soils so as to elucidate the significant relationship between soil test values and crop response to fertilizers and to develop fertilizer prescription equations under IPNS for desired yield target of wheat crop

MATERIALS AND METHODS

In the present study, the recommended procedure as outlined by Truog (1960) and later modified by Ramamoorthy *et al.* (1967) as "Inductive cum Targeted yield model" was used. It provides a scientific basis for balanced fertilization by taking into account the balance between applied nutrients and soil available nutrients forms. A field experiment involving three fertility gradient strips (S_0, $S_{1/2}$, and S_1) created by applying graded amounts of fertilizer nutrients and farmyard manure (FYM was conducted at the Soil Science Research Farm, PAU , Ludhiana on a sandy loam soil (*Typic Ustochrepts)*. In order to stabilize the fertility gradients in the field, basmati and wheat crops were grown with different amounts of N (30, 40, and 50 kg N ha^{-1} for Basmati and 90, 120, and 150 kg N ha^{-1} for wheat), P (20, 30 and 40 kg P_2O_5 ha^{-1} for Basmati and 50, 60, and 75 kg P_2O_5 ha^{-1} for wheat) and K (20, 30 and 40 kg K_2O ha^{-} for both basmati and wheat) and with three rates of FYM (0, 2.5 and 5 t ha^{-1}) during 2011 through 2013. A control plot was also kept with each rate of FYM application. Each fertility strip accommodated all the treatments in the Latin square design.

For the present, study area was the same as in case of fertilizer gradient experiment and was started in November 2013 with wheat (var. HD 2967) as the test crop (with three rates of NPK fertilizer and FYM as given above) and harvested in April 2014. Each of these 3 strips (S_0, $S_{1/2}$, and S_1) were sub-divided into 24 plots of which 21 plots in each strips received fertilizer treatments with various selected combinations while, other three were kept as unfertilized (control). For generating the soil test based integrated recommendations, each strip was divided in three equal size blocks (I, II and III). Block II and III were treated with organic manure *viz.*, farmyard manure (FYM) two weeks before sowing. Quantity of organic manure (5 t ha-1) in block III was doubled to that block II (2.5 t ha^{-1}). The remaining three plots in each strip were kept as control. The fertilizer materials used were urea, single superphosphate and muriate of potash. Full dose of P, K and half dose of N was applied at the time of sowing and half dose of N was top-dressed 4 weeks after sowing of wheat crop.The test verification trials with same wheat cultivar were conducted at farmers' field during November 2014 to April 2015.

Surface (0-15 cm) soil samples were drawn from each plot (72) before sowing and after the harvest of the crop. The initial soil fertility status showed that the experimental field had pH of 7.8, EC of 0.12 dS m^{-1}(1: 2 soil: water), organic carbon 0.21% (Walkley and Black, 1934), $KMnO_4$-N of 82 kg ha^{-1} (Subbiah and Asija, 1965), $NaHCO_3$ extractable P of 28.0 kg ha^{-1} (Olsen *et al*., 1954) and neutral normal ammonium acetate extractable K (Jackson, 1973) of 131.0 kg ha^{-1}. At harvest of wheat, grain and straw samples from each plot were taken and analyzed for total N, P and K using standard methods (Anderson and Ingram, 1993). Site-specific fertilizer adjustment equations for targeted yields of wheat were computed by making use of data on the grain yield, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P_2O_5 and K_2O applied, the basic parameters *viz*., nutrient requirement (NR), contribution of nutrients from soil (CS), fertilizer (CF) and farmyard manure (Cfym) were calculated as outlined by Ramamoorthy *et al*. (1967). The basic data, in turn, was transformed into simple workable fertilizer adjustment equations for calculating fertilizers N, P and K doses for yield targets based on initial soil test values. The detailed methodology has been outlined earlier by Rao and Srivastava, (2001).

RESULTS AND DISCUSSION

Status of soil available nutrients

Strip wise range and mean values of soil available nutrients in plots receiving NPK alone or NPK+FYM showed that $KMnO_4$-N values increased from 43.9 kg ha^{-1} in strip I to 144.3 kg ha^{-1} in strip III with mean values of 71.1, 95.9 and 121.1 kg ha^{-1} respectively in strip I, II and III (Table 1). Likewise, Olsen- P increased from 16.5 to 59.5 kg ha^{-1} in strip I to strip III with

Table 1: Pre-sowing soil available NPK, wheat yield and NPK uptake by wheat (kg ha^{-1})

Particulars	Strip I		Strip II		Strip III		Control	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
$KMnO_4$ –N	43.9-112.9	71.1	72.1-124.0	95.9	94.1-144.3	121.1	40.8-91.3	62
Olsen–P	16.5-40.7	28.1	20.4-48.2	39.1	23.0-59.5	38.3	27.0-48.5	40.5
NH_4OAc-K	115.3-155.9	139.2	138.2-165.5	150.6	112.5-175.2	145.9	112.5-175.0	141.2
Wheat grain yield	1360-4410	3380	1580-4670	3570	2000-4670	3860	1160-2100	1700
N uptake	11.8-59.4	43.1	14.6-68.6	50.5	11.4-79.8	56.6	11.5-28.0	18.3
P uptake	3.2-14.8	10	3.8-18.6	11.4	4.2-20.7	13.3	13.3-27.2	19.1
K uptake	14.3-57.1	45.2	17.4-70.5	51.4	13.3-77.9	57.1	14.3-77.9	55.8

Table 2 : Nutrient requirement, per cent contribution of nutrients from soil, fertilizer and farmyard manure for wheat

Parameters	Basic data		
	N	P_2O_5	K_2O
Nutrient requirement (kg q^{-1})	1.46	0.78	1.82
Per cent contribution from soil (CS)	42	14	13
Per cent contribution from fertilizer (CF)	24	42	21
Per cent contribution from FYM (cfym)	56	19	39

Table 3 : Fertilizer adjustment equations for wheat (HD 2967) in alluvial soils

Nutrient	Fertilizer adjustment equation
NPK alone	
N	5.96T-1.71SN
P	1.85T-0.32S P_2O_5
K	0.87T-0.06 SK_2O
NPK+FYM	
N	3.63T-1.05SN-1.40 FYM_N
P	1.80T-0.31SP_2O_5 –0.43 FYM_P_2O_5
K	1.00T-0.06SK_2O-0.19 FYM_K_2O

Where, 'T' stands for target yield equation (q ha^{-1}), S'' represents soil test value of the respective nutrient (kg ha^{-1}), and 'FYM' represents total respective nutrient addition (kg ha^{-1}) through FYM.

efficiency were reported by Kudu and Bulbule, (2007) for finger millet and Singh *et al.* (2015) on maize crop. Likewise, the per cent contribution of N from FYM was 56 whereas for P_2O_5 and K_2O it was 19 and 39, respectively. The high N uptake suggest increased supplemented nutrient N availability by residual FYM (Regar and Singh, 2014 and Singh *et al.*, 2015)

Fertilizer prescriptions for desired targets of wheat crop

Using basic parameters, fertilizer prescription equations for desired yield targets of wheat under NPK alone as well as NPK + FYM were formulated (Table 3).n the basis of above equations, ready reckoner for requirement of fertilizers doses were computed for a range of soil test values and desired yield

Table 4 : Soil test based fertilizer prescription for yield target of wheat under NPK alone and NPK + FYM

Soil test values	NPK alone			NPK +FYM (5t ha^{-1})		
N:P_2O_5:K_2O	45 q ha^{-1}	50 q ha^{-1}	55 q ha^{-1}	45 q ha^{-1}	50 q ha^{-1}	55 q ha^{-1}
80:50:100	131:67:33	161:76:37	190:86:41	52:51:28	70:60:33	88:69:37
100:60:120	97:64:32	126:73:36	156:82:40	31:48:27	49:57:31	67:66:36
120:70:140	62:61:30	92:70:35	122:79:39	10:45:26	28:54:30	46:63:35

Table 5 : Results of test verification trials of wheat (mean of three trials)

Treatments	Fertilizer dose N-P_2O_5-K_2O	Mean Yield (kg ha^{-1})	Additional yield (kg ha^{-1})	Value of additional yield (Rs)	Cost of fertilizer (Rs)	Net benefit	Benefit cost ratio(Rs)
Control	0-0-0	1620	-	-	-	-	-
FP	170-50-0	4130	2510	36395	4540	31855	7
GRD	120-60-30	4320	2700	39150	5250	33900	6.5
STRD	120-45-0	4570	2950	42775	3690	39085	10.6
TG $_{4500\ kg\ ha^{-1}}$	170-0-30	4180	2560	37120	2850	34270	12
TG $_{5500\ kg\ ha^{-1}}$	217-0-39	4870	3250	47125	3093	44032	14.2
LSD	-	270	-	-	-	-	-

Rate wheat grain Rs 14.5/kg; N 12.0, P_2O_5 50.0 and K_2O 27.0 Rs/kg

mean value of 28.1, 39.1 and 38.3 kg ha^{-1} and NH_4OAc-K from 115.3 in strip I to 175.2 kg ha^{-1} in strip III with mean value of 139.2, 150.6 and 145.9 kg ha^{-1} respectively in strip I, II and III. In control plots of three fertility strips, the magnitude of $KMnO_4$-N ranged from 40.8 to 91.3 kg ha^{-1} with a mean of 62.0 kg ha^{-1}; Olsen-P status ranged from 27.0 to 48.5 kg ha^{-1} with a mean value of 40.5 kg ha^{-1}; NH_4OAc-K varied from 112.5 to 175.0 kg ha^{-1} with a mean value of 141.2 kg ha^{-1}. Higher available NPK in strip III followed by strip II and I was probably due to addition of graded dose of fertilizer application which resulted in creating fertility gradient in the same field (Chatterjee *et al.*, 2010) and further application of FYM along with inorganic fertilizer accelerated the soil microbial activity that resulted in more mineralization there by increasing nutrient availability (Jadhav *et al.*,2 013)

Wheat grain yield and nutrient uptake

The wheat yield in treated plots ranged from 1360 to 4670 kg ha^{-1} with mean value of 3380, 3570 and 3860 kg ha^{-1} respectively in strip I, II and III whereas in control plots, the wheat yield varied from 1160 to 2100 kg ha^{-1} with a average of 1700 kg ha^{-1} (Table 1). Similarly, maximum average nutrient uptake was in the order: Strip III >II > I. The above results indicated a wide variability existed in the soil test values of nutrients and wheat yields of treated and control plots, which is required for calculating the basic parameters and developing fertilizer prescription equations for specific yield targets of wheat crop (Basumatary *et al.*, 2015). In addition, higher yield under FYM treatments may have been due to direct contribution of plant nutrients from FYM to the crop growth as well as its indirect effect in improving the physical, chemical and biological properties of the soil (Singh *et al.*, 2014; Das *et al.*, 2016)

Basic parameters

The basic parameters, viz. nutrient requirement (NR) for producing one quintal grain of wheat, per cent contribution of nutrients from soil (%CS), fertilizer contribution (%CF) and farmyard contribution (%CFYM) were also calculated. These parameters were used for developing fertilizer prescription equations using NPK alone and NPK+FYM. The results showed that for producing one quintal of wheat grain, fertilizer needed was 1.46 kg N, 0.78 kg P_2O_5 and 1.82 kg K_2O (Table 2). The per cent contribution from soil (CS) and fertilizer (CF) were found to be 42.0 and 24.0 for N, 14 and 42 for P_2O_5 and 13 and 21 for K_2O, respectively. The foregoing results indicated that the contribution of P and K were higher for applied fertilizer than soil. Higher P contribution was probably due to originally high residual P in soils followed by fertilizer P application. Borrow and Debnath, (2014) reported that when soil becomes saturated with applied P, the residual P becomes more available for plant uptake and thus results in increased P concentration in the soil. The high K contribution may be due to interactive effect of high doses of N, P and priming effect of initially applied K_2O dose, which caused release of more soil K from fixed to available form. Similar results of higher K fertilizer target of 45, 50 and 55 q ha^{-1} of wheat (Table 4). The estimates showed that for attaining a yield target of 50 q ha^{-1}, fertilizer N recommendation was found in the range of 35 to 161 kg ha^{-1}, fertilizer P_2O_5 from 70 to 76 kg ha^{-1} and fertilizer K_2O from 35 to 37 kg ha^{-1}. In FYM amended plots (5 t ha^{-1}) along with NPK fertilizers, the required fertilizer doses of N, P_2O_5 and K_2O ranges from 28 to 70 kg ha^{-1}, 54 to 60 kg ha^{-1} and 30 to 33 kg ha^{-1} respectively. Generally, application of FYM over a period of time, increase the carbon content of soil which is a source of energy for microflora. Therefore, reduced amount of fertilizer doses under integrated nutrient management system in the present study may have been due to enhancement of microbial activity causing faster nutrient transformations and thus higher availability of nutrients. . Both Mahajan *et al*. (2013) and Santhi *et al*. (2010) reported similar results in wheat, and onion crops.

Validation Trials

Before recommending the fertilizer prescriptions to farmers and extension agencies, its validity for wheat crop were verified by conducting three trials at farmers' field with five treatments viz., Control, Farmers practice (FP), General recommended dose (GRD), Soil test based recommended dose (STRD), Target 45 and 55 q ha^{-1} (Table 5). The results showed that applying fertilizers on the basis of target yield approach gave significantly higher yield over soil test based recommended (STRD) and the farmers' practice. Among all the treatments, control and farmers practice were least efficient in enhancing wheat grain yield. Highest net benefit and benefit: cost ratio were achieved in TG 55 q ha^{-1} treatment (Table 5). Saxena *et al*. (2008) reported higher benefit: cost ratio through target yield approach in onion and Milapchand *et al*. (2006) in rapeseed and mustard crops. It has been seen that lower yield targets were better achieved than the higher yield levels probably due to more efficient utilization of NPK fertilizers. Results of the present study corroborate the findings of Bera *et al*. (2006) and Katharine *et al*. (2013).

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