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V Goyal
Assistant Soil Chemist, Department of Soil Science, CCS Haryana Agricultural University, Hisar, Haryana, India

KK Bhardwaj
Department of Soil Science, CCS Haryana Agricultural University, Hisar, Haryana, India

Pradip Dey
PC STCR, ICAR, IISS, Bhopal, Madhya Pradesh, India

Corresponding Author:
V Goyal
Assistant Soil Chemist, Department of Soil Science, CCS Haryana Agricultural University, Hisar, Haryana, India

Validation of soil test based fertilizer prescription models for specific yield target of wheat on an Inceptisols of Haryana

V Goyal, KK Bhardwaj and Pradip Dey

Abstract

The studies on STCR-IPNS for desired yield targets were conducted on wheat crop at 12 farmers' field during *rabi* 2016-17 to 2018-19 in semiarid sub humid climate on an Inceptispols of Haryana to verify the fertilizer prescription models over the available technology and to analyze the economics of the adoption of these models to enhance the productivity and profitability of the crop. Seven fertilizer treatments were implemented which included control; farmers practice (FP); generalized recommendations dose (GRD), STCR recommendations for 5.5 & 6.0 t ha^{-1} (TY 5.5 & TY 6.0) grain yield target with fertilizers alone; and with fertilizer and FYM (TY 5.5FYM & TY 6.0FYM. The results of the experiment revealed that the treatments based on the targeted yield precision model with and without IPNS component ensured higher grain yield, per cent increase in the yield, higher response to fertilizers and FYM, additional benefits from higher produce and higher benefit/ cost ratio over the farmers' practice. The grain yield from the pre-fixed targets of 5.5 and 6.0 t ha^{-1} of wheat were achieved within ± 10 % deviation at almost all the locations which further validate the fertilizer prescription model for wheat. The IPNS treatments guaranteed better benefit/cost ratio vis-s-vis without IPNS. The targeted yield precision model for fertilizer recommendations was more precise to achieve the targeted yield which additionally led to higher profits.

Keywords: Wheat, target yield equation, validation, Inceptisols, Haryana

Introduction

Degradation of soil health has also been reported due to long-term imbalanced use of fertilizer nutrients. For Indian soil, the ideal overall nutrient use of N:P_2O_5 :K_2O is 4:2:1 but the imbalanced use ratio of nutrient of 6.8:2.8:1 has led to wide gap between crop removal and fertilizer application. The partial factor productivity of fertilizers during the last three and half decades showed a declining trend from 48 kg food grains/kg NPK fertilizer in 1970-71 to 10 kg food grains/ kg NPK fertilizer in 2007-08 (Aulakh and Benbi, 2008; SubbaRao and Reddy, 2009) [5, 29]. Multi-nutrient deficiencies have led to the concept of Site-Specific Nutrient Management (SSNM). Due to inadequate knowledge about soil and crop requirement, costly inputs like fertilizers, chemicals, water and other inputs go waste, resulting in monetary loss and adverse effect on environment. The current status of nutrient use efficiency is quite low in case of P (15-20%), N (30-50%), S (8-12%), Zn (2-5%), Fe (1-2%) and Cu (1-2%). Declining soil fertility and mismanagement of plant nutrients have made this task more difficult. Balanced NPK fertilization has received considerable attention in India (Gosh *et al*., 2004; Hegde *et al*., 2004 and Prasad *et al*., 2004) [9, 13, 20]. Soil testing helps the farmers to use fertilizers according to needs of crop. Fertilizer use for targeted yield based on Ramamoorthy *et al*., 1967 is an approach, which takes into account the crop needs and nutrients present in the soil. In the intensive agriculture system integrated fertilizer recommendation is an urgent need since, it balance soil and applied nutrients from inorganic as well as organic sources to balance nutrition of crops and maintenance of soil health.

Wheat is an important global crop and has very high nutritional value containing 40-45 % protein and 18-22% oil. India produces about 70 million tonnes of wheat per year and is second in production in the world. India being the second largest in population is also the second largest in wheat consumption after China. In India, wheat is grown in an area of 30.79 million hectare with an annual production of about 98.51 million tonnes and productivity of 3200 kg ha^{-1} (Agricultural Statistics at a Glance 2018) [1]. Also, wheat contributes 13.3 % towards national production from 9 % area of the country (Kumar *et al*., 2012) [16].

The productivity of any crop depends upon various factors viz. climatic conditions, soil properties seed quality and variety, irrigation facilities, insect-pest and disease management etc.

but most important is the optimum and balanced use of inorganic fertilizer nutrients especially macro and micro nutrients. It is very essential to encourage the application of mineral nutrients at optimum dose for sustainable management and maintaining soil health. To get maximum benefit and reduce nutrient losses from the fertilizers, it must be applied in right quantity, sources and combination at right time and in right manner. Application of balanced doses of chemical fertilizer is very crucial for getting maximum yield but application of organic manures before sowing along with the fertilizers gives good results by maintaining sustainability of soil for longer time. Thus, it is very difficult to recommend a general schedule of fertilizers application without initial soil test value. Depending on the initial status of nutrients in the soil and getting desired levels of targets as per the potential of varieties, chemical fertilizers which are costly and energy consuming to be applied judiciously.

Soil test crop response (STCR) is a base for prescription of right amount of fertilizers to the crops. No single dose of plant nutrient applied through inorganic fertilizer, organic manure, crop residue or bio-fertilizers can meet the entire nutrient requirement of a crop in modern intensive agriculture (Gangwar *et al*., 2016; Udayakumar and Santhi, 2017) [8, 32]. Thus there is an urgent need to adopt the integrated plant nutrient supply approach (IPNS) which is practicable, economically viable, socially acceptable and ecologically sound. Adoption of STCR based integrated plant nutrient system (STCR-IPNS) can restore and sustain soil fertility and crop productivity, prevent multi-nutrient deficiency, economize the fertilizer use and improvement in nutrient use efficiency and create favourable physical, chemical and biological condition (Udayakumar and Santhi 2017; Singh *et al*., 2012) [32, 28]. So, STCR approach provides the balanced supply of required quantities of nutrients to the crops thus avoiding the over and under usage of fertilizers. This prevents the environmental hazards and results in higher returns. Crop requirements are satisfied to produce the highest economic yields, ensure the quality of the produce and avoid excessive levels of nutrients (Boldea *et al*., 2015) [6]. To enhance farm productivity under different soil-climatic conditions, it is necessary to generate information on optimum nutrient doses for various crops.

Soil test based application of plant nutrients helps to realize higher response ratio and benefit: cost ratio as the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and the correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization (Rao and Srivastava, 2000) [22]. Hence, the present study was carried out for wheat in an Inceptisols of Hisar (Haryana) which is neutral to slightly alkaline in nature. Extrapolation of the results emanated from the study is possible if it is test verified at farmer's holdings. Therefore, to enhance the production of wheat and to sustain soil health, verification of suitable fertilizer prescription model is highly essential.

Material and Method

Field experiments were conducted on soil test crop response studies under integrated plant nutrient supply system on wheat (WH 711) during 20108-10 at the Research Farm, Department of Soil Science, CCS Haryana Agricultural University, Hisar on Inceptisols (*Typic Haplusteps*). The experiments were conducted in two phases following the inductive approach in which fertility gradients were created by dividing the field of 0.56 ha in to three strips of equal size and applying no fertilizers in strip I; 150, 75 and 75 kg ha^{-1} of N, P_2O_5 and K_2O, respectively, in strip II; and 300, 150 and 150 kg ha^{-1} of N, P_2O_5 and K_2O, respectively, in strip III. The pearl millet was sown as an exhaustive crop upto the maturity so that the applied nutrients got transformed into the soil. The purpose of creating the fertility gradients w.r.t. available N, P and K was to obtain variable soil test values in one and the same field and to eliminate the influence of climate and management practices on crop yield instead of conducting experiments in different fields with variable nutrients at different sites.

After the harvest of the pearl millet crop, wheat (WH 711) was sown as a test crop to investigate soil test crop response coorelations, each strip was sub divided into 24 plots of 10 x 5 m^2. Twenty four selected fertilizer combinations of four levels each of N (0, 75, 150 and 225 kg ha^{-1}), P_2O_5 (0, 30, 60 and 90 kg ha^{-1}) and K_2O (0, 30, 60 and 75 kg ha^{-1}) were applied in wheat. Three levels of FYM i.e. 0, 7.5 and 15.0 t ha^{-1} were also applied across the width of strip making three blocks of FYM. The different treatments were randomized in such a way that each FYM block fertility strip had the same 24 treatment combinations. Each strip comprised of one absolute control, two FYM levels, seven treatments of selected combinations of fertilizer nutrients alone and fourteen treatments in which both fertilizer and FYM were applied jointly. The crop was raised upto maturity by following standard agronomic practices for two years (2008-09 and 2009-10) in two adjacent fields. In each year, fertility gradients were created in the preceding season before sowing of wheat. The nitrogen, phosphorous and potassium were applied through urea, single super phosphate and muriate of potash, respectively. Full dose of P_2O_5 and K_2O were applied at the time of sowing along with one-half of N as a basal dose, whereas one-half N was applied after 25 days of sowing. The grain yield and dry matter yield of the crop was recorded, plant samples were collected and analyzed for their N, P and K contents. The total uptake of N, P and K of wheat grain and straw were calculated. The data on grain yield yield; available N, P and K; uptake of N, P and K; and fertilizer and FYM nutrient doses for N, P_2O_5 and K_2O were used to compute the basic data i.e.

i) Nutrient requirement in kg q^{-1} of wheat (NR)

$$\text{NR (kg q}^{-1}) = \frac{\text{Total uptake of N or P}_2\text{O}_5 \text{ or K}_2\text{O (kg ha}^{-1})}{\text{Seed cotton yield (q ha}^{-1})} \quad (1)$$

ii) The per cent contribution from soil available nutrient to its total uptake (CS)

$$\text{CS} = \frac{\text{Total uptake of N or P}_2\text{O}_5 \text{ or K}_2\text{O in control plots (kg ha}^{-1})}{\text{Soil test value for available N or P}_2\text{O}_5 \text{ or K}_2\text{O in control plots (kg ha}^{-1})} \times 100 \quad (2)$$

iii) Per cent contribution from applied fertilizer to its total uptake (CF)

$$CF = \frac{\text{Total uptake of N or } P_2O_5 \text{ or } K_2O \text{ in treated plots } \left(\text{kg ha}^{-1}\right) - \text{Soil test value for available N or } P_2O_5 \text{ or } K_2O \text{ in treated plots } \left(\text{kg ha}^{-1}\right) \text{ x } \frac{CS}{100}}{\text{Fertilizer nutrient } \left(\text{kg ha}^{-1}\right)} \text{ x } 100 \quad (3)$$

iv) per cent contribution from applied FYM (CFYM)

$$CFYM = \frac{\text{Total uptake of N or } P_2O_5 \text{ or } K_2O \text{ in FYM treated plots } \left(\text{kg ha}^{-1}\right) - \text{Soil test value for available N or } P_2O_5 \text{ or } K_2O \text{ in FYM treated plots} \left(\text{kg ha}^{-1}\right) \text{ x} \frac{CS}{100}}{\text{FYM nutrient } \left(\text{kg ha}^{-1}\right)} \text{ x } 100 \quad (4)$$

These basic data were used to formulate soil test based fertilizer adjustment equations for targeted yield of wheat. The doses of fertilizers N, P_2O_5 and K_2O for different yield targets were calculated by using soil test crop response based fertilizer prescription equations under integrated nutrient supply (STCR-IPNS) for targeted yield of wheat as given below:

FN = 5.22 T – 1.04 SN -0.12 FYM (N)
FP_2O_5 = 2.38 T – 4.06 SP -0.14 FYM (P_2O_5)

Where, FN and FP_2O_5 are fertilizer N and P_2O in kg ha^{-1} respectively. T is the yield targeted in q ha^{-1}; SN and SP are soil available N and P in kg ha^{-1} respectively. FYM (N) and FYM (P_2O_5) are the N and P_2O_5 through FYM (Kg ha^{-1}), respectively.

After the development of fertilizer prescription models, field experiments were conducted at total of 12 farmers' field 4 each during *rabi* 2016-17, 2017-18 and 2018-19 on an Inceptisols of Hisar district, Haryana. Before validating the soil test based fertilizer prescription equations for targeted yield of wheat under integrated plant nutrient supply, composite surface (0-15 cm) soil samples were taken from the fields of farmers, processed in the laboratory and analyzed for texture, pH and electrical conductivity using standard procedure. The soil samples were also analyzed for organic carbon (Walkley and Black, 1934) [33], alkaline $KMNO_4$-N (Subbiah and Asija, 1956) [30], Olsen-P (Olsen *et al.*, 1954) [19] and NH_4OAc-K (Hanway and Heidal, 1952) [12].

Seven fertilizers and FYM treatments were applied in each field comprising of control, farmers' practice (FP), general recommendation dose of fertilizers (GRD), soil test based fertilizer dose for yield target of 55 and 60 q ha^{-1} (TY 5.5 and TY 6.0) without FYM. In addition, the two treatments in which fertilizers along with 15 t ha^{-1} were applied for yield target of 5.5 and 6.0 t ha^{-1} (TY 5.5FYM and TY 6.0FYM), respectively. Initial determination of native soil fertility revealed that, soils across all locations were neutral to slightly alkaline in reaction and non-saline in nature. Organic carbon was low at all the location. Available N, P_2O_5 and K_2O were low, medium to high and high in status ranging from 98 to 154, 12 to 25 and 215 to 325 kg ha^{-1}, respectively (Table 1). The cultivation practices were carried out periodically and the seed and straw yield was recorded at harvest.

The range of N, P_2O_5 and K_2O application rates under different treatments across all the locations indicated that, N, P_2O_5 and K_2O recommendations by farmers practice were lower at some locations while higher at other location than STCR-IPNS recommendations (Table 2) which showed the precise application of mineral fertilizers in STCR-IPNS approach.

The crop was raised up to the maturity adopting standard agronomic practices and seed and straw yield was recorded treatment-wise. The response (t ha^{-1}) of added nutrients was calculated by subtracting the yield of control from that of the fertilizers/and FYM treatments. The net profit due to fertilizer application was calculated by subtracting the price of fertilizers applied from the total benefit from response. The marginal B:C ratio was worked out by dividing the price of additional produce with the price of fertilizers.

Result and discussion

Test Verifications of Fertilizer Prescription Equations (FPEs)

The data on pooled mean grain yield (Table 3) showed that the highest grain yield was recorded in STCR-IPNS TY6.0FYM (6.22 t ha^{-1}) followed by STCR TY 6.0 (6.03 t ha^{-1}), STCR-IPNS TY 5.5FYM (5.68 t ha^{-1}), STCR TY 5.5 (5.48 t ha^{-1}), general recommended dose of fertilizers GRD (5.36 t ha^{-1}), farmers' practice (5.17 t ha^{-1}) and least in control (3.19 t ha^{-1}) indicating the STCR-IPNS treatments at same targeted yield recorded relatively higher yield over STCR fertilizer alone treatments. STCR-IPNS TY 6.0FYM treatment recorded the yield increase of 20.45 % over the farmer's practice while an increase of 16.74 % in grain yield was observed in TY 6.0 STCR treatment. Also, an increase of 10.02 and 6.17 % was observed in TY 5.5FYM and TY 5.5 treatments. A perusal of data on STV (Table 1) and increase in crop yield (Table 3) revealed that the yield varied in accordance to the inherent soil fertility status of the experimental sites of wheat at farmers' field. Integrating FYM along with fertilizers on the basis of STV produced significantly higher yield as compared to GRD and farmers' practice. The higher yield in integrated treatment is due to the fact that FYM releases organic acids that bind the soil particles thus forming stable soil aggregates which in-turn will provide better favorable conditions for the crop to achieve higher targets. The higher grain yield in STCR and STCR-IPNS at both targets than GRD and FP might be due to balanced fertilization in the former which is necessary for maintaining soil fertility and productivity. Shah *et al.* (2013) reported that application of FYM in conjunction with mineral fertilizers helps in increasing the wheat grain yield due to faster release of nutrients.

The grain yield of wheat obtained in various treatments at different locations in all the years ranged widely (Table 3). The grain yield of all the sites in different villages in control varied from 3.00 to 3.35 t ha^{-1} during all the years of study. The yield in FP treatment ranged from 4.95 to 5.37 t ha^{-1} during the period of study (pooled mean 5.17 t ha^{-1}). This increase in yield from control (62%) in FP was due to application of 150 kg N and 50 kg P_2O_5 /ha by the farmers' at various location of Hisar district, Haryana. The response to fertilizer application over control ranged from 2.15 to 2.66 t ha^{-1} (mean 2.29 t ha^{-1}) in TY 5.5 treatment at farmers' field. However, it ranged from 2.28 to 2.95 t ha^{-1} (pooled mean 2.49 t ha^{-1}) in TY 5.5FYM. The response to fertilizers in TY 6.0 and TY 6.0FYM ranged from 2.61 to 3.13 and 2.87 to 3.23 t ha^{-1} (pooled mean of 2.84 and 3.03 t ha^{-1}), respectively. The higher response to fertilizers was observed in higher targeted yield treatments both in STCR and STCR-IPNS due to higher application of fertilizers as compared to lower targeted treatments (Table 2). Also, the higher responses to fertilizers in targeted yield treatments was due to more precise/balanced application of fertilizers as compared to imbalanced fertilization in FP and GRD. The NPK consumption ratio is highly skewed towards N resulting in imbalanced and inadequate use of fertilizers particularly that of K resulting in mining of soils posing question mark to yield sustainability in wheat. Antil *et al.* (2015) [4] reported that the area under low to medium category in available K in soils of Haryana was widespread to about 73 % which require K application through fertilizers for better crop yields and sustaining productivity and fertility of soils. The increase in yield due to application of higher levels of nutrients in balanced proportion was also reported by Antil and Singh 2007; [2] Hoshmani *et al.*, (2013) [14]. The mean response to fertilizers in STCR-IPNS (TY 6.0FYM and TY 5.5 FYM) treatments was higher as compared to STCR (TY 6.0 and TY 5.5) treatments. This might be due to FYM which besides providing organic nutrients also helps the crop in utilizing the appropriate amount of nutrients at critical growth stages of crops.

The application of N and P_2O_5 in TY 5.5 and TY 5.5.FYM treatments in most of the locations were lower than that in FP/GRD/TY6.0/TY6.0FYM treatments. Thus, balanced application of these major nutrients resulted in higher yields in this treatment in comparison to FP & GRD treatment under irrigated conditions. In PR treatment, blanket application of 150 and 60 kg N and P_2O_5 were applied in all the fields irrespective of the soil test values, whereas the application of these nutrients varied considerably for targeted yield treatments in different fields depending upon the soil test values of a specific field. Not only higher yield and response were obtained under STCR approach for 6.0 t ha^{-1} yield target but the precious fertilizer nutrients could also be saved in some fields. These results are in line with those reported by Gudadhe *et al.* (2013) [11], Manjunatha *et al.* (2014) [17] and Katharine *et al*. (2013) [15], who reported the superiority of STCR based fertilizer recommendations over farmer's practices and blanket recommendations. Milap-chand *et al.* (2006) [18] validated the fertilizers prescription equation for mustard and rapeseed and observed the higher yield under fertilizer application based targeted yield treatments. Sellamuthu *et al*., 2015 [24] showed the highest mean yield of wheat in STCR-IPNS 4t ha^{-1} with an increase of 62.1 % over blanket recommendation. Sharma *et al*., (2015) [26] also observed an increase of 196 and 193 % of wheat grain and straw yield in STCR based integrated fertilizer recommendation in *Typic Haplustepts* under long term study on pearl millet-wheat cropping system. It is pertinent to mention that the doses of fertilizer nutrients were reduced on an average by 22 kg N and 15 kg P_2O_5 /ha in treatments TY-6.0FYM and TY-5.5FYM, where 15 t FYM/ha was also applied, in comparison to TY-6.0 and TY-5.5 treatments. In general, the yields under STCR-IPNS were higher than STCR fertilizer alone which might be due to favourable environment in rhizosphere of the crop due to improvement in soil conditions. Antil and Narwal (2007) [3] indicated that FYM is the store house of nutrients supplying micro and secondary nutrients in addition to major nutrients and its continuous application resulted in sustainable crop productivity and improvement in soil health. The pooled data of the three years revealed that the highest mean grain yield of wheat was recorded in TY 6.0FYM treatment which decreased in the following order: TY 6.0FYM > TY 6.0 > TY5.5FYM > TY5.5 > GRD > FP of Hisar district, Haryana.

Per cent deviation of yield targets

The variation / deviation of yield from targets of 5.5 and 6.0 t ha^{-1} of wheat were fully to marginally achieved at different locations during the period of study. The deviation of the yield targets of 5.5 and 6.0 t ha^{-1} under STCR-IPNS treatments ranged from -2.0 to +11.8 and +0.4 to +5.7 per cent, respectively. However, the wide variation in yield targets of 5.5 and 6.0 t ha-1 under STCR treatment was observed ranging from -2.1 to +5.1 and -3.2 to +4.3 per cent, respectively. In all the verification experiments, the per cent deviation of the targeted yield was within ± 10 % variation proving the validity of equation for prescribing integrated fertilizer dose for wheat. Suresh and Santhi (2018) [31] validated STCR equations for hybrid maize and reported that STCR based fertilizers recommendation with targeted yield has been achieved within ± 10 % variation proving the validity of fertilizer prescription equations of STCR. Similar results were reported by Sharma *et al*., (2015) [26] for pearl millet, Singh *et al*., (2017) [27] for rice and Dhinesh *et al*., 2017 [7] for brinjal. Alternatively, Reddy *et al*., (2018) [23] in their validation experiment on Soybean, observed above 10 per cent (72-91 %) deviation in yields from the desired targets at all the locations of Telangana State proving that the targets were not achieved for soybean crop.

Economics of the experiment

The economics of fertilizer and FYM applied and resultant yield of crop was worked out for each treatment and field by considering the prices of nutrients and produce prevailing in respective years (Table 5). There was a wide variation in the benefit from additional yield (response) in different treatments and locations. The mean benefit pooled for different locations for three years was Rs 37304/-, 46311/-, 40543/- and 49400/- per hectare in, TY 5.5, TY 6.0, TY 5.5 FYM and TY 6.0FYM treatment, respectively. Thus, the net profit after subtracting the cost of fertilizers and FYM from the total benefit was also highest in TY 6.0FYM (Rs. 43539/-) which was followed by TY-6.0 (Rs. 40431/-), TY 5.5FYM (Rs. 35572/-) and TY 5.5 (Rs. 32316/-) per hectare. The higher profit in yield target of 6.0 t ha^{-1} was due to higher yield obtained in the treatment. The B:C varied from 8.10 to 8.68 in different locations and years under different STCR and STCR-IPNS treatments in wheat. The B:C under different treatments are viable and remunerative. The farmers, therefore, should go for STCR-IPNS approach for 6.0 t ha^{-1} yield target owing to higher productivity, benefit from additional produce, total profit and higher marginl B:C. The net profit in TY 6.0 / TY 6.0FYM was Rs 40431/- and Rs 43539/- with higher productivity of about 3.03 to 2.84 t ha^{-1} in former treatments. The farmers' may opt for STCR approach for lower yield targets of 5.5 t ha^{-1} under resource constraints. These results clearly revealed the superiority of STCR based fertilizer recommendations over farmers' practices and general package recommendations. Sharma *et al*. (2015) [26]; Milap-chand *et al.* (2006) [18] and Goyal and Singh (2018) [10] also observed the superiority of STCR based integrated fertilizer recommendations in terms of getting max returns and higher B:C over control in pearl millet-wheat, mustard-wheat cropping and Cotton based cropping system.

Table 1: Physico-chemical properties of the soils of the farmers' fields

S. No.	Village	Texture	pH (1:2)	EC (dS m^{-1}) (1:2)	Organic Carbon (%)	Available Nutrients (kg ha^{-1})		
						N	P	K
Rabi 2016-17								
1	Kirori	SL	8.6	0.28	0.42	133	20	254
2	Shyamsukh	SL	8.3	0.49	0.45	147	15	301
3	Sadalpur	L	8.10	0.40	0.42	126	17	280
4	Khara Barwala	SL	7.7	0.48	0.21	98	10	228
Rabi 2017 -18								
1	Bhadawad	L	7.8	0.48	0.72	154	25	255
2	Gyanpura	L	7.5	0.38	0.45	126	14	250
3	Asrawan	SL	7.6	0.45	0.39	112	16	265
4	Kabraeil	SL	7.5	0.47	0.48	133	23	285
Rabi 2018-19								
1	Bhiwani Rohilla	SL	7.8	0.38	0.42	119	18	305
2.	Kaimiri	SL	8.0	0.31	0.63	154	16	225
3.	Gangwa	SL	8.2	0.28	0.36	112	20	215
4.	Devan	SL	7.3	0.33	0.27	105	12	325

Table 2: Fertilizer doses ranges in different treatments in wheat (WH 1105) at farmer's field in different years

S. No.	Treatment	Fertilizer nutrients (kg ha^{-1})	
		N	P_2O_5
Rabi 2016-17			
1	Control	0	0
2	F.P.	150	50
3	P.R.	150	60
4	TY-55	134-171	21-70
5	TY-60	160-197	33-82
6	TY-55FYM	112-149	6-55
7	TY-60FYM	138-175	18-67
Rabi 2017-18			
1	Control	0	0
2	F.P.	150	50
3	P.R.	150	60
4	TY-55	127-171	29-74
5	TY-60	153-197	41-86
6	TY-55FYM	105-149	14-59
7	TY-60FYM	131-175	26-71
Rabi 2018-19			
1	Control	0	0
2	F.P.	150	50
3	P.R.	150	60
4	TY-55	150-166	66-90
5	TY-60	176-193	78-102
6	TY-55 FYM	128-144	51-75
7	TY-60 FYM	154-170	63-87

Table 3: Seed yield (q ha^{-1}) of wheat under different treatment of STCR approach

S. No.	Location		Fertilizer practice		STCR recommendation		STCR-IPNS recommendation		Variation in targeted yield from farmers practice (%)			
		Control	FP	GRD	TY 55	TY60	TY55FYM	TY60FYM	TY55	TY60	TY55FYM	TY60FYM
Rabi 2016-17												
1	Khara Barwala	30.00	50.45	54.15	53.85	58.45	55.60	60.45	6.74	15.86	10.21	19.82
2	Sadalpur	32.00	53.51	53.73	54.48	59.55	61.49	63.43	1.81	11.29	14.91	18.54
3	Shyamsukh	32.00	50.86	51.47	53.82	58.09	56.62	61.91	5.82	14.22	11.33	21.73
4	Kirori	30.50	51.75	53.94	52.50	59.58	55.56	62.80	1.45	10.87	3.39	16.86
Rabi 2017-18												
1	Bhadawad	32.50	49.60	53.12	56.10	61.50	57.80	62.94	13.10	23.99	16.53	26.90
2	Gyanpura	31.22	52.10	54.80	57.80	62.55	57.85	63.05	10.94	20.06	11.04	21.02

3	Asrawan	32.51	53.64	55.10	57.45	61.20	56.62	61.50	5.24	14.09	5.56	14.65
4	Kabreil	32.41	53.20	55.90	55.60	61.21	56.90	62.54	4.51	15.06	6.95	17.56
Rabi 2018-19												
1	Bhiwani Rohilla	32.10	4952	5213	5410	6087	55.48	62.45	9.25	22.92	12.04	26.11
2	Kaimiri	33.45	52.10	54.25	54.97	61.25	57.80	62.80	5.51	17.56	10.94	20.54
3	Gangwa	33.10	50.90	53.64	54.75	59.75	55.90	61.80	7.56	17.39	9.82	21.41
4	Devan	30.45	50.12	51.28	52.10	58.94	53.90	60.25	3.95	17.60	7.54	20.21
Pooled mean (2016-19)		31.85	51.65	53.63	54.79	60.25	56.79	62.16	6.17	16.74	10.02	20.45

Table 4: Response, per cent deviation of targeted yield and economics of wheat under different treatments of STCR approach

S. No.	Location	Response to fertilizers and FYM (t ha^{-1})						Per cent deviation/variation from targeted yield			
		FP	GRD	TY 5.5	TY 6.0	TY5.5FYM	TY 6.0FYM	TY 5.5	TY 6.0	TY5.5FYM	TY 6.0FYM
	Rabi 2016-17										
1	Khara Barwala	2.05	2.42	2.39	2.85	2.56	3.05	-2.1	-2.6	+1.1	+0.8
2	Sadalpur	2.15	2.17	2.25	2.76	2.95	3.14	-0.9	-0.8	+11.8	+5.7
3	Shyamsukh	1.89	1.95	2.18	2.61	2.46	2.99	-2.1	-3.2	+2.9	+3.2
4	Kirori	2.13	2.34	2.20	2.91	2.51	3.23	-4.5	-0.7	+1.0	+4.7
	Rabi 2017-18										
1	Bhadawad	1.71	2.06	2.36	2.90	2.53	3.04	+2.0	+2.5	+5.1	+4.9
2	Gyanpura	2.09	2.36	2.66	3.13	2.66	3.18	+5.1	+4.3	+5.2	+5.1
3	Asrawan	2.11	2.26	2.39	2.87	2.41	2.90	+2.6	+2.0	+2.9	+2.5
4	Kabreil	2.08	2.35	2.32	2.88	2.45	3.01	+1.1	+2.0	+3.5	+4.2
	Rabi 2018-19										
1	Bhiwani Rohilla	1.74	2.00	2.20	2.88	2.39	3.04	-1.6	+1.5	+0.9	+4.1
2	Kaimiri	1.87	2.08	2.15	2.78	2.44	2.94	-0.1	+2.1	+5.1	+4.7
3	Gangwa	1.78	2.05	2.17	2.67	2.28	2.87	-0.5	-0.4	+1.6	+3.0
4	Devan	1.97	2.08	2.17	2.85	2.35	2.98	-5.3	-1.8	-2.0	+0.4
Pooled mean (2016-19)		1.98	2.18	2.30	2.84	2.49	3.03				

Table 5: Economics of the targeted yield of wheat under different treatments of STCR over the farmers' practice

S. No.	Location	Cost of fertilizers (Rs)					Benefit (Rs)					Marginal B/C ratio (Rs/Re)				
		FP	TY 55	TY 60	TY55 FYM	TY 60 FYM	FP	TY 55	TY 60	TY55 FYM	TY 60 FYM	FP	TY 55	TY 60	TY55 FYM	TY 60 FYM
	Rabi 2016-17															
1	Khara Barwala	4138	3760	4584	4304	5128	30675	35775	42675	38400	45675	7.41	9.51	9.31	8.92	8.91
2	Sadalpur	4138	2617	3487	3161	4030	32265	33720	41325	44235	47145	7.80	12.88	11.85	13.99	11.70
3	Shyamsukh	4138	6109	6978	6653	7522	28290	32730	39135	36930	44865	6.84	5.36	5.61	5.55	5.96
4	Kirori	4593	5645	6514	5289	6158	31875	33000	43620	37590	48450	6.94	5.85	6.70	7.11	7.87
	Rabi 2017-18															
1	Bhadawad	4138	2895	3764	3439	4308	25650	35400	43500	37950	45660	6.20	12.23	11.56	11.03	10.60
2	Gyanpura	4138	5306	6175	5849	6719	31320	39870	46995	39945	47745	7.57	7.51	7.61	6.83	7.11
3	Asrawan	4138	5127	5996	5671	6540	31695	35910	43035	36165	43485	7.66	7.00	7.18	6.38	6.65
4	Kabreil	4138	3578	4402	4122	4945	31185	34785	43200	36735	45195	7.54	9.72	9.81	8.91	9.14
	Rabi 2018-19															
1	Bhiwani Rohilla	4620	7027	8024	5926	6910	33098	41800	54663	44422	57665	7.16	5.95	6.81	7.50	8.34
2	Kaimiri	4620	6535	7520	5434	6419	35435	40888	52820	46265	55765	7.67	6.26	7.02	8.51	8.69
3	Gangwa	4620	5503	6488	4402	5387	33820	41135	50635	43320	54530	7.32	7.47	7.80	9.84	10.12
4	Devan	4593	5757	6626	5401	6270	37373	41135	54131	44555	56620	8.14	7.15	8.17	8.25	9.03
Pooled mean (2016-19)		4334	4988	5880	4971	5861	37304	37304	46311	40543	49400	7.41	8.10	8.29	8.57	8.68

Price of N = Rs.12.39 /kg, P_2O_5= Rs. 45.58 /kg, K_2O= Rs. 26.66 /kg, Wheat seed = Rs. 15 /kg, FYM = Rs. 100 /t

Conclusion

The soil test fertilizer prescription models under STCR and STCR-IPNS for wheat developed at Research farm of the University was well validated at 12 different locations of farmers' field. The result of the present study clearly demonstrated that balanced nutrient application only through fertilizers (GRD) without the knowledge of soil fertility is undermined by the actual balanced nutrients application to bridge the gap between the total crop requirement of nutrients and those supplied by the soil. The STCR approach serve this purpose recommending site specific nutrient application considering the crop requirement and replenishment of nutrients from soil. The targeted yield based fertilizer prescription models for wheat are dynamic in nature as it can be increased or decreased for each unit decrease or increase in soil available nutrients. The fertilizer nutrients application for 6.0 t ha^{-1} grain yield target of wheat based on soil test under IPNS was found superior over the farmers' practice and GRD owing to increase in yield, higher response to fertilizers and FYM, productivity benefit and viable marginal benefit/cost ratio.

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