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Affirmation of technology of soil test crop response based fertilizer recommendations for different targeted yields of *Bt* cotton in inceptisols of Haryana

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Abstract : The suitability of soil test crop response (STCR) based fertilizer prescription equations under integrated plant nutrient supply (IPNS) for targeted yields of *Bt* cotton were affirmed at Research Farm of CCS HAU, Hisar during 2018 and 2019. Treatment included were STCR recommendations for 28 and 32 q/ha (TY-28 and TY-32) seed cotton yield target with fertilizers alone; and with fertilizer and FYM (TY-28 FYM and TY32 FYM) which were super imposed on two different *Bt* cotton hybrids (RCH 773 and RCH 776). The highest mean seed cotton yield was recorded in TY-32 FYM which decreased in the following order: TY-32 FYM > TY-32 >> TY-28 FYM > TY-28 under both varieties for both years. The experiment was laid out on sandy loam soil with medium organic carbon, low in nitrogen while, medium in phosphorous and potassium.). For *Bt* cotton hybrid of RCH 773, the yield varied from 2695 to 3050 kg/ha and 2710 to 3025 kg/ha under target yield of 28 and 32 q/ha with and without IPNS during *kharif* 2018 and 2019. The corresponding seed cotton yield for *Bt* cotton hybrid of RCH 776 ranged from 2612 to 2985 during *kharif* 2018 and 2740 to 3120 kg/ha during *kharif* 2019 under targeted yield of 28 and 32 q/ha. The yield targets of 28 and 32 q/ha with fertilizers alone (TY-28 and TY-32) was achieved within deviations of -6.7 to -3.8 and -7.8 to -6.6 per cent, respectively during *kharif* 2018 average across the *Bt* cotton hybrids. Similarly, 28 and 32 q/ha yield targets under IPNS (TY-28 IPNS and TY-32 IPNS) were achieved within deviations of -2.0 to - 5.4 and -4.7 to – 6.7 per cent, respectively. The increase in 35 and 18 per cent in nitrogen uptake was observed with increase in application of fertilizer nitrogen from 104 kg/ha to 164 kg/ha (mean of the two years) and 85 to 150 kg/ha (mean of the two years), respectively. The results of present study clearly demonstrated that balanced nutrients application only through fertilizers without knowledge of soil fertility is undermined by the actual balance nutrients application to bridge the gap between the total crop requirement of nutrients and those supplied by the soil.

Key words: *Bt* cotton, integrated nutrient management, nutrient uptake, STCR, targeted yield

In the modern period of crop cultivation, application of fertilizers based on soil testing is an essential tool to prescribe nutrient doses for crops besides assessing soil health. Further, the escalation in fertilizer prices has caused a serious set back for balanced fertilization. At present, an annual net negative balance of about 8-10 million tons of nutrients per annum is reported in India (Sherene *et al.*, 2019). Introduction of high yielding varieties and imbalanced fertilization due to over or under use of fertilizers had led to affect the soil health negatively. The soil health can be maintained by proper and balanced use of fertilizers which can be achieved by adopting the right practices and following the proper approach of soil fertility evaluation for achieving the desired yield especially in inceptisols of Haryana.

Cotton (*Gossypium* spp) the important fibre and cash crop playing key role in agrarian and industrial economy. Cotton accounts for 70 per cent of total fibre consumption in textile industry, 11 per cent to industrial production, 14 per cent to manufacturing sector, 4 per cent to GDP and 38 per cent of the country export. The area under cotton has increased by 1.47 times

from 87.3 lakh ha in 2001-2002 to 128.2 lakh ha during 2014-2015 (Cotton Corporation of India, 2016) and about 95 per cent of the area is under *Bt* cotton which was evenly distributed among the major cotton growing states (Chaudhary and Gaur, 2014; Goyal and Singh, 2018). During this period, the production of cotton has increased by about 2.40 times from 158 lakh bales (170 kg/bale) in 2001-2002 to 380 lakh bales in 2014-2015. However, the current productivity of 504 kg/ha of lint of India and 538 kg/ha of lint of Haryana is much lower than the seed cotton yield of 2803 kg/ha (about 930 kg/ha lint) and 3392 kg/ha (about 1130 kg ha/lint) obtained under experimental research stations (Katherine *et al.* 2013 and Manjunatha *et al.* 2014).

The sustainability of cotton productivity has been hampered and the production of cotton has been adversely affected mainly due its high cost of production because of heavy infestation of whitefly and indiscriminate use of insecticides as well as imbalanced use of fertilizers. The fertilizer prices have escalated steeply in recent past and necessity of judicious application of appropriate quantity of nutrients through fertilizers and manures based on soil test and crop requirement is fundamental to sustain farm productivity and to improve economy of the farmers. Several approaches of fertilizer recommendations have been followed world over of which soil test crop response based fertilizer recommendation for specific yield target of crops is unique as it not only indicates soil test based balanced fertilizer recommendations but also the level of the yield which farmers' can obtain with optimum crop management under favourable climatic conditions. Under STCR approach, the fertilizer dose varies for each unit change in soil test value and higher doses are recommended for higher targets.

The study on the effect of soil test crop response based fertilizer recommendations for specific yield targets of *Bt* cotton in Haryana is lacking. The present study was under taken to affirm the technology of soil test based fertilizer prescription equations for targeted yields under integrated nutrient supply for *Bt* cotton for different varieties under irrigated conditions in Inceptisols of Hisar district, Haryana.

MATERIALS AND METHODS

Study site and experimental treatments

The experiment was conducted at Research Farm of Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Hisar, Haryana state of India (Lat. 29o16' N, Lon. 75o7' E, 215 m above mean sea level). The study site was located at south western part of Haryana and north western part of India. This region belongs to semi arid and sub tropical which is hot and dry in summers and cold and arid in winter. The mean annual temperature of the study site is 24.8oC ranging from 48oC in June to 1.5oC in January. The annual precipitation is approximately 443 mm with 80 per cent received during the months of rainy season from July to September. About 90 per cent of the study region is covered with the plains of fluvial alluvium of recent to sub recent age blanketing almost the entire sub-surface geology (Goyal *et al.*, 2009). The soils of the region are typically Inceptisols (classified as *Typic Haplustepts*).

The fertilizer prescription equations based on STCR technology for targeted yield of Bt. cotton under integrated plant nutrient supply were tested at Research Farm of Department of Soil Science, CCS HAU, Hisar during *kharif* 2018 and 2019. Before laying out the experiment, composite surface (0-15 cm) soil samples were drawn from the field; processed in the laboratory and analyzed for texture, pH and electrical conductivity using standard methods. The samples were also analysed for organic carbon and available nitrogen, phosphorous and potassium using standard methods.

Nitrogen content (%) in in grain and straw sample was determined by Nessler's Reagent

method (Jackson, 1973) (Oven dried grain and straw samples of *Bt* cotton from each plot were well digested in Tri Acid-mixture, separately for P determination (Jackson, 1973), Vanado-Molybdo-Phosphoric yellow colour method was followed. The colour intersity was read with "Spectronic-20" at 470 mu (μ) photometer. Thereafter, a standard curve was prepared with a series of standard solutions. Phosphorus content (%) was worked- out from the standard curve. Potassium (K) content (%) was determined by Jackson 1973 using flame photometer. Total uptake of nutrients was calculated by the following equation:-

$$\text{Nutrients Uptake (kg/ha)} = \frac{\text{Nutrient conc. in grain/straw (\%) x grain/straw yield (kg/ha)}}{100}$$

Two *Bt* cotton hybrids (RCH 773 and RCH 776) were tested for affirming of fertilizer prescription equation of N, P_2O_5 and K_2O during two consecutive years in 2018 and 2019. Four fertilizers and FYM treatments were applied in each field comprising of soil test based fertilizer dose for 28 q/ha (TY-28) and 32 q/ha (TY-32) seed cotton yield with and without 15 t FYM/ ha for 28 q/ha (TY-28 FYM) ad 32 q/ha (TY-32FYM) seed cotton yield targets. The doses of fertilizer N, P_2O_5 and K_2O (Table 2) 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 *Bt* cotton (MRC 6304) developed during 2011-2013 by the Hisar centre of AICRP on "Soil Test Crop Response Correlations" which are given below :-

$FN = 14.93\ T - 2.48\ SN - 0.46\ FYM\ (N)$

$F(P_2O_5) = 3.83\ T - 4.98\ SP - 0.31\ FYM\ (P_2O5)$

$F(K_2O) = 2.43\ T - 0.20\ SK - 0.18\ FYM\ (K_2O)$

where FN, F (P_2O_5) and F (K_2O) are fertilizer N, P_2O_5 and K_2O (kg/ha), respectively. T is seed cotton yield target (q/ha). SN, SP and SK are the soil available N, P and K (kg/ha), respectively. FYM (N), FYM (P_2O_5) and FYM (K_2O) are the N, P_2O^5 and K_2O in FYM (kg/ ha), respectively.

The doses of K2O was kept constant *i.e.* 15 kg/ha which is applied as a starter dose as the soils of the study region are high in K content and the responses to fertilizers are very little due to presence of Illite clay minerals in the soil (Goyal and Jhorar, 2007). The doses of fertilizer N, P_2O_5 and K_2O were reduced in TY 28 FYM and TY 32 FYM in comparison to TY 28 and TY-32 treatments depending upon the contents of nutrients and their efficiencies in FYM. The crop was sown using standard agronomic practices with 67.5 x 60.0 cm spacing in the month of May. The crop was raised up to maturity and seed cotton yield was recorded treatment wise.

RESULTS AND DISCUSSION

The soils of the experimental fields (Table 1) were normal and alkaline in reaction, non saline and the soil texture is sandy loam. The soils were found medium in organic carbon (0.58 %), low in available N, medium in available P and medium in available K (Table 1).

Table 1. Physicochemical properties of the soil of the experimental field

Sr. No.	Parameter	Value	Fertility status	Methodology
1.	pH (1:2:: soil:water)	7.68	Alkaline	Jackson (1973)
2.	EC (1:2:: soil:water)	0.75	Non-saline	Jackson (1973)
3.	Texture	Sandy loam	-	International Pipette MethodDay, R.P. (1965)
4.	Organic carbon (%)	0.58	Medium	Walkley and Black (1934)
5.	Available nitrogen (kg/ha)	125.0	Low	Subbiah and Asija (1956)
6.	Available Phosphorous (kg/ha)	12.0	medium	Olsen *et al.*, (1954)
7.	Available potassium (kg/ha)	278	medium	Jackson (1973)

Seed cotton yield

The seed cotton yield obtained in various treatments in sandy loam soils during both the years (2018 and 2019) for cotton hybrids of RCH 773 and RCH 776 at yield targets of 28 and 32 q/ha with and without IPNS ranged widely (Tables 3 and 4). For *Bt* cotton hybrid of RCH 773, the yield varied from 2695 to 3050 kg/ha under target yield of 28 and 32 q/ha with and without IPNS during *kharif* 2018 while it varied from 2710 to 3025 kg/ha during *kharif* 2019. The corresponding seed cotton yield for Bt cotton hybrid of RCH 776 ranged from 2612 to 2985 during *kharif* 2018 and 2740 to 3120 kg/ha during *kharif* 2019 under targeted yield of 28 and 32 q/ha. This indicates that both the hybrids of *Bt* cotton were equally good in producing the desired yield targets. The higher seed cotton yields were obtained in TY 32 and TY 32 IPNS during both *kharif* 2018 and 2019 in both the *Bt* cotton hybrids. The improvement in yield over TY 28 and TY 28 IPNS was due to higher application of fertilizers in TY 32 and TY 32 IPNS, thereby making strong case of balanced fertilizer application not only at lower yield targets (TY 28) but also at higher yield targets (TY 32). 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 cotton. There are reports that the area under low to medium category in available K in soils of Haryana was widespread to about 73 per cent which require K application through fertilizers for better crop yields and sustaining productivity and fertility of soils. The increase in yield of *Bt* cotton due to application of higher levels of nutrients in balanced proposition was also reported. The higher yield was obtained in IPNS treatments during both years of study

Table 2. Fertilizer nutrient applied in an experiment during *kharif* 2018 and *kharif* 2019

Sr. No.	Treatments	Initial Soil Test values (kg/ha)			Fertilizer nutrients (kg/ha)		
		SN	SP	SK	FN	F P_2O_5	F K_2O
			Kharif 2018				
1	TY 28	125	12	280	108	47	15*
2	TY 32				168	63	15*
3	TY 28 IPNS				88	35	15*
4	TY 32 IPNS				148	51	15*
			Kharif 2019				
5	TY 28	128	13	285	101	43	15*
6	TY 32				160	58	15*
7	TY 28 IPNS				81	31	15*
8	TY 32 IPNS				140	46	15*

Table 3. Seed cotton, per cent deviation and uptake of NPK in *Bt* cotton during k*harif* 2018

Plot No.	Treatment	*Bt* cotton hybrids	Yield		Per cent deviation (Grain)	Total Uptake (kg/ha)		
			Seed cotton (kg/ha)	Straw (kg/ha)		N	P	K
1	TY 28	RCH 776	2612	5008	-6.7	63	14	79
2	TY 32	RCH 776	2950	5808	-7.8	91	16	88
3	TY 28	RCH 773	2695	4841	-3.8	65	15	76
4	TY 32	RCH 773	2990	5929	-6.6	87	17	96
5	TY 28 + FYM	RCH 773	2745	5457	-2.0	73	16	91
6	TY 32 + FYM	RCH 773	3050	6001	-4.7	85	18	89
7	TY 28 + FYM	RCH 776	2650	5573	-5.4	76	15	91
8	TY 32 + FYM	RCH 776	2985	6338	-6.7	86	19	97

Table 4. Yield, per cent deviation and uptake of NPK in *Bt* cotton during *kharif* 2019

Plot No.	Treatment	*Bt* cotton hybrids	Yield		Per cent deviation (Grain)	Total Uptake (kg/ha)		
			Seed cotton (kg/ha)	Straw (kg/ha)		N	P	K
1	TY 28	RCH 776	2740	5080	-2.1	67	15	85
2	TY 32	RCH 776	3005	6050	-6.1	85	17	92
3	TY 28	RCH 773	2710	4952	-3.2	69	14	82
4	TY 32	RCH 773	3010	6021	-5.9	91	19	105
5	TY 28 + FYM	RCH 773	2850	5590	1.8	75	18	98
6	TY 32 + FYM	RCH 773	3025	6080	-5.5	89	21	97
7	TY 28 + FYM	RCH 776	2950	5680	5.4	81	18	101
8	TY 32 + FYM	RCH 776	3120	6452	-2.5	89	21	107

with RCH 773 and RCH 776 *Bt* cotton hybrids. This could be due to the addition of C sources through FYM and greater root biomass that results in more aggregation of the soil particles and helps in sustaining the structure of soil (Zhe E *et al.*, 2012, Kumar *et al.*, 2021). Organic manures also increase the activity of microbes which converts the organically bound nutrient into more readily available inorganic form resulting in increased yield of *Bt* cotton.

The straw yield also varied with different treatments under TY 28 and 32 q/ha during both the year of study (Table 3 and 4). Highest straw yield was obtained under IPNS treatments as compared to without IPNS treatments. Application of higher amounts of fertilizers in TY 32 and TY 32 IPNS treatments compared to TY 28 and TY 28 IPNS would led to increase the biomass yield of the crop, thus the straw yield increased. Chauhan *et al.*, (2014) also reported the increase in straw yield of wheat with increase in N (kg/ha) application from 0 to 50 to 100 to 150 kg/ha. Higher amounts of N, P and K fertilizers would increase the lint and seed of the cotton that might have extracted more nutrients from the soil.

Per cent achievement of yield targets

The perusual of data presented in Table 3 and 4 indicated that the yield targets of cotton were fully to marginally achieve under different treatments in both the years for both the hybrids. The yield targets of 28 and 32 q/ha with fertilizers alone (TY 28 and TY 32) was achieved within deviations of -6.7 to -3.8 and -7.8 to -6.6 per cent, respectively during *kharif* 2018 average across the *Bt* cotton hybrids. Similarly, 28 and 32 q/ha yield targets under IPNS (TY 28 IPNS and TY 32 IPNS) were achieved within deviations of -2.0 to -5.4 and -4.7 to – 6.7 per cent, respectively. The deviations from yield targets of 28 and 32 q/ha were less under IPNS treatments due to improvement in soil structure with addition of FYM along with fertilizers, that may provide the congenial environment for increasing the yield and thus decreasing the deviations from the targets. Similar per cent deviation from the yield targets were obtained from *kharif* 2019. These results clearly revealed the validity of soil test based fertilizer prescriptions for targeted yields of *Bt* cotton under STCR/STCR-IPNS as all the targets were achieved within acceptable limit of ± 10 per cent (Saranya *et al.*, 2012). Various studies on achieving the targeted yield with application of nutrients in balanced proportion as per STCR basis have been reported for various crops (Goyal *et al.*, 2017; Goyal *et al.* 2020; Kumar *et al.*, 2020; Kumar *et al.* 2021). The farmers' may opt for STCR approach for lower yield targets of 28 q/ha under resource constraints. These results clearly revealed the superiority of STCR based fertilizer recommendations over farmers' practices and general package recommendations.

Nutrient N, P and K uptake

Nitrogen uptake

Average across the years, application of higher doses of nitrogen for achieving the target yield of *Bt*. cotton from 28 to 32 q/ha increased the maximum total uptake of N by 35 per cent whereas in TY IPNS treatments of 28 and 32 q/ha yield targets, this increase was observed to be maximum 18 per cent. The increase in 35 and 18 per cent in nitrogen uptake was observed with increase in application of fertilizer nitrogen from 104 to 164 kg/ha (mean of the two years) and 85 to 150 kg/ha (mean of the two years), respectively (Table 2). Chauhan *et al.*, 2014 also observed the higher N uptake with application of fertilizer N @ 150 kg/ha as compared to N application @75kg/ha in wheat. They recorded that N application @ 150 kg/ha increased the N uptake by 10.5, 23.4 and 41.4 per cent through grain and 14.7, 22.3 and 41 per cent through straw over 100, 50 and 0 kg N /ha, respectively

Phosphorous uptake

The pooled data of the P uptake from Table 3 and 4 showed the maximum increase in P uptake of 24 per cent and 21 per cent from TY 28 to TY 32 and TY 28 IPNS to TY 32 IPNS. This increase of 24 per cent in P uptake may be due to increase in application of fertilizer P from 45 to 61 kg/ha (mean of two years; Table 2) for TY 28 to TY 32 treatments. However, the increase of 21 per cent in P uptake under IPNS treatments was due to increased application of fertilizer P from 33 to 49 kg /ha. Also the increased application of N fertilizers would increase the P uptake by the crop. Chauhan *et al.*, 2014 also observed the higher uptake with higher P application rates and accounted for 3.1, 7.8 and 13.6 per cent more P uptake by grain and 23.7, 30.5 and 58.2 per cent through straw over 50, 25 and 0 kg P /ha. Singh *et al.*, 2004 also reported the similar results of increase in P uptake with increased application of nitrogenous fertilizers.

Potassium uptake

Potassium was applied in soil in different treatments @ 15 kg/ha as a starter dose since the area lithology is dominated by illitic clay minerals. Inspite of this, the variation in K uptake was observed in TY 28 and TY 32 with and without IPNS. The average data for the two year on K uptake showed the increase of 27 per cent and 6 per cent from TY 28 to TY 32 without and with IPNS, respectively. This variation in K uptake might be due to variation in nitrogen and P uptake.

CONCLUSION

Soil test crop response based fertilizer prescription equations under IPNS developed at Research Farm were found to hold good when validated on other site. The results of present study clearly demonstrated that balanced nutrients application only through fertilizers without knowledge of soil fertility is undermined by the actual balance nutrients application to bridge the gap between the total crop rquirement 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 recommendations are dynamic in nature as it can be increased or decreased for each unit decrease or increase in soil available nutrients. The target yield equations are validated irrespective of variety but have increased the yield with increase in target yield.

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