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Soil Test Crop Response Based Nutrient Management Modules for Enhancing Growth, Productivity, Profitability and Nutrient Uptake of Maize in an Acid Alfisol of North-Western Himalayas

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***Abstract*:** Soil test crop response based nutrient management modules could be extremely useful for prescribing fertilizer doses to achieve desired productivity and better soil health. The present Soil Test Crop Response (STCR) study was carried out on hybrid maize where in seven approaches of fertilization were evaluated in RBD. The experiment was conducted at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India during *kharif*, 2019. The maize growth, yield, nutrient uptake, and economics was computed. The maize growth, yield and its attributes, nutrient uptake, profit, and grain quality improved under the influence of different treatments and maximum value for measured variables was recorded in STCR based IPNS treatment of 40 q ha^{-1} and minimum in control. It was concluded from the current study that IPNS-STCR approach improved maize productivity and profitability in the western Himalayan region. This will immensely help resource poor farmers not only increasing yield but also reduce the cost of cultivation by increasing fertilizer use efficiency and saving costly fertilizers.

Keywords: Soil test crop response, Growth, Productivity, Profitability, Nutrient uptake, Maize

Rapidly increasing population and emerging production vulnerabilities spell out an urgent need for enhancing and sustaining productivity of land through cereal food production systems (Pooniya et al 2015). Under such situation, maize appears to be a potential cereal crop because of its highest genetic yield potential over other cereals and its suitability to diverse climates and management practices that is why it is known as queen of cereals (Kumar et al 2015). Maize is a major a *kharif* crop of Himachal Pradesh with an average yield of 25.5 q ha^{-1} (Choudhary et al 2013a) and Shivalik and Himalayan foothill region constitute main conventional maize production areas. Although the maize productivity is quite higher than the national and state averages, but still there is a scope to increase its yield to desired level, which may be achieved by the adoption of recommended farm technology (Choudhary et al 2015). Fertilization of crops based on generalized recommendation not only leads to under fertilization or over fertilization, but also before results in lower productivity, profitability with after along environmental pollution. Under these circumstances, the need of the day is to sustain agriculture without harming the delicate balance of soil ecology, soil fertility as well as unlocking the mystery of biota influencing plant growth by integration of fertilizers and organic manure (Chaterjee et al 2005). Among the various scientific methods of fertilizer recommendation, soil test based nutrient management approach has been found most effective to develop recommendations for potential productivity of crops and maintaining soil health. It provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients (Ramamoorthy and Velayutham 2011). Use of soil test-based fertilizer adjustment equations could be extremely useful for prescribing fertilizer doses to achieve desired productivity and improving soil health. Based on this concept, soil test crop response correlation studies were undertaken in different parts of India and fertilizer prescriptions have been derived for desired yield targets of various major field and horticultural crops on different soil types and agro-climatic zones (Dey and Bhogal 2016). However, such studies have not yet been carried out for maize in most of the soil types, particularly in acid alfisols.

MATERIAL AND METHODS

Experimental site: The present study was undertaken as a part of an ongoing long-term fertilizer experiment initiated from *kharif* 2007 in a maize-wheat sequence at the Experimental Farm of Department of Soil Science, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experiment was conducted on maize for one year during *kharif* 2019. The experimental farm is situated at 32° 6' N latitude and 76° 3' E longitude at an elevation of 1290 m above mean sea level.

Climate and weather: The experimental site represents the mid-hill wet temperate agro-climatic zone of Himachal

Pradesh. The region receives an average annual rainfall of 2500 mm to 3000 mm per annum with 75% of the showers occuring mainly during monsoon months (June to September). The study area received a total rainfall of 200.2 mm with a mean maximum temperature of 27.6 °C in the month of June 2019 and minimum temperature of 17.9°C during October 2019.

Soil characteristics: The soil of the experimental site belonged taxonomically to the order alfisol under the sub-group *Typic Hapludalf*. Initially, the soils under study were acidic in nature with silty clay loam texture, low in available nitrogen, high in available phosphorus and medium in available potassium and organic carbon and had sufficient micronutrients.

Field experimentation and operations: The field experiment was laid out in a RBD comprising different treatment combinations (Table 1). Each treatment was replicated thrice. Sowing of maize crop was done on June 20, 2019 and the recommended seed rate of 20 kg ha^{-1} was used. The row to row and plant to plant spacing was kept as 40 cm and 60 cm, respectively. Full doses of P_2O_5 and K_2O along with 1/3rd dose of N as per treatments was applied at the time of sowing as a basal dose. The remaining 2/3rd dose of nitrogen was applied in two equal splits (1/3rd at knee height and 1/3rd at tasseling stage). All the recommended cultural practices were followed during the entire crop growth. After attaining the physiological maturity, maize was harvested on October 22, 2019 and grain as well as stover yield was recorded. FYM was applied @ 5 t ha^{-1} (dry weight basis) in STCR treatment with IPNS. Fertilizer doses in case of yield targeted treatments were worked out using following equations given by Verma et al. (2007):

$FN = 5.88\,T - 0.23\,SN – 0.9\,ON$ $FP_2O_5 = 4.87\,T – 1.22\,SP – 0.81\,OP$ $FK_2O = 3.66\,T – 0.49\,SK – 0.51\,OK$

In above equations, FN, FP_2O_5, FK_2O are doses of N, P_2O_5 and K_2O, respectively in kg ha^{-1}. T is yield target (q ha^{-1}), SN, SP and SK are soil available N, P and K, respectively in kg ha^{-1}. ON, OP and OK are N, P and K that were supplied through FYM (kg ha^{-1}), respectively.

Table 1. Treatment details of the experiment

Sr. No.	Treatments
T_1	Control
T_2	Farmers' practice (25% recommended dose of fertilizers + 5t ha^{-1} FYM)
T_3	General recommended dose of fertilizers (GRD)
T_4	Soil test-based fertilizer application (STB)
T_5	Target yield 30q ha^{-1} without FYM (T_{30})
T_6	Target yield 30q ha^{-1} with FYM @ 5t ha^{-1} (T_{30} IPNS)
T_7	Target yield 40q ha^{-1} without FYM (T_{40})
T_8	Target yield 40q ha^{-1} with FYM @ 5t ha^{-1} (T_{40} IPNS)

Field studies: Five randomly selected plants in each plot were tagged for various periodic observations such as growth and yield attributing characters The grain yield from each plot was recorded separately and then converted to q ha^{-1}. After removal of the cobs, the stalks were weighed to determine the stover yield (q ha^{-1}) on dry weight basis.

Laboratory studies: Representative grain and stover samples collected after maize harvest were air dried and later kept in the hot air oven at 60-70°C for eight hours. The oven dried grain and stover samples were powdered separately with Wiley milling machine and stored in paper bags and were subjected to wet digestion for further analysis as per standard procedures. The nutrient uptake was calculated by multiplying per cent concentration of a nutrient with grain and stover yield (dry weight basis) as per following formula:

Uptake (kg ha^{-1}) = [% nutrient concentration x yield in q ha^{-1} (dry weight basis)]

The uptake of the nutrients obtained in respect of grain and stover was summed up to compute the amount of total nutrients removed by the crop.

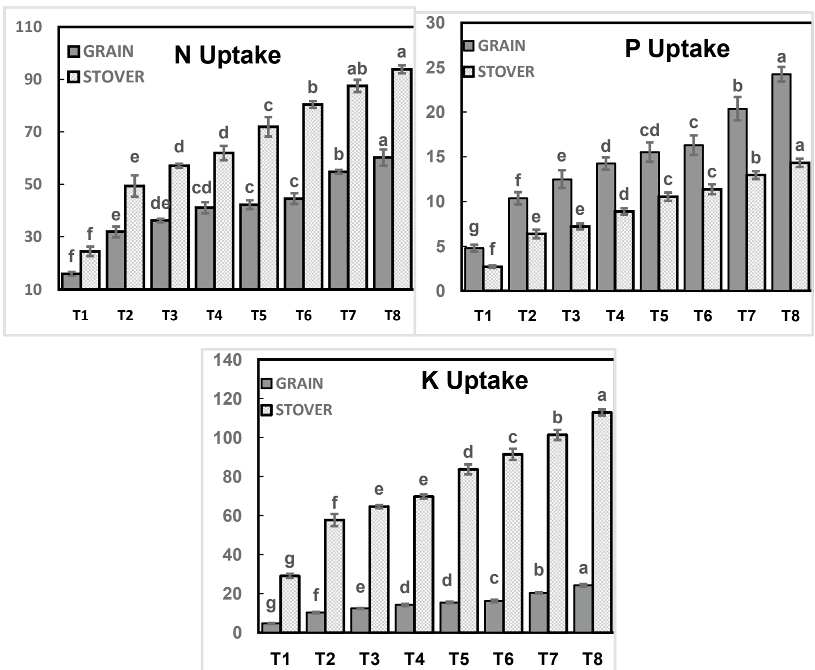
Total uptake = stover uptake + uptake by grains

Economic analysis: The economic analysis of the experiment in terms of net returns and B:C ratio was carried out by taking into consideration the prevailing prices of the inputs and outputs in the market during the study. Gross returns were calculated by multiplying the maize grain yield (q ha^{-1}) by price of maize grains and expressed in (₹ ha^{-1}). The net returns (₹ ha^{-1}) were calculated by deducting the cost of cultivation from gross returns (₹ ha^{-1}). The benefit–cost ratio was calculated by dividing gross returns with cost of cultivation.

RESULTS AND DISCUSSION

Growth parameters: In general, all the growth parameters were significantly influenced due to IPNS treatments as compared to non-IPNS treatments (Table 2). The tallest plants, maximum number of rows per cob, number of grains in a single cob, maximum 100 grain weight, longest cob length existed in the treatment corresponding to target yield of 40 q ha^{-1} with FYM (T_8), whereas least values of these parameters prevailed in T_1 (control). Application of organic and inorganic nutrient sources improved synergism and synchronization between nutrient release and plant recovery thus resulted in better crop growth (Huang et al. 2010). The increase in plant height might be since nitrogen being an essential constituent of plant tissue favours rapid cell division and its enlargement, which together with the adequate quantity of phosphorus and potassium helps in the rapid cell division and better development of the cell size ultimately produced taller plants (Meena et al 2013). These findings are in conformity with and Singh et al (2017). The maximum number of grains per row might be due to availability of N at proper time, which was required for better growth and development of plants, improved moisture retention and soil structure by organic manures. The increase in hundred grain weights could be due to balanced supply of food nutrients both from inorganic and organic manure throughout the grain filling and development period of plant (Khaliq 2004).

Uptake of major (N, P, K) and secondary nutrients (Ca, Mg, S): The uptake of major nutrients was significantly higher in all the treatments as compared to control (Fig. 1). The maximum N, P and K uptake by maize grains was recorded under T_8 (STCR based IPNS treatment for target yield of 40 q ha^{-1} and minimum in T_1(Control). Similarly, N, P and K uptake by maize stover followed the same trend and as depicted by grains, which was minimum in T_1(Control)and maximum in T_8 (target yield of 40 q ha^{-1} with FYM). Likewise, the Ca, Mg and S uptake by maize grain and stover was recorded highest in T_8 and minimum in control (T_1) (Fig. 2). The reason for



Error bars denote ± 1SE. Bars with similar lowercase letters are not significantly different with respect to least significant difference (LSD) values at p=0.05

Fig. 1. Effect of IPNS-STCR module on nitrogen, phosphorus and potassium uptake (kg ha^{-1})

Table 2. Effect of IPNS-STCR module on maize growth

Treatments	Plant height (m)		No. of rows/cob	No. of grains/row	No. of grains/cob	100 Seed weight (g)	Cob length (cm)	Cob diameter (cm)
	Tasseling	Harvest						
T1	1.1e±0.10	1.4d±0.16	12.8f±0.38	22.9f±0.78	294.6g±17.15	19.0c±1.15	11.4c±1.66	3.4g±0.03
T2	1.7d±0.08	2.2c±0.04	13.4e±0.26	37.0e±1.31	498.5f±9.32	26.6b±1.66	13.8b±0.62	3.7f±0.06
T3	1.8cd±0.05	2.3c±0.08	13.6de±0.08	38.4de±1.76	523.6ef±25.26	27.1b±0.48	14.2b±0.22	3.8ef±0.08
T4	1.9bcd±0.10	2.4bc±0.21	13.9cde±0.15	40.2cd±1.05	559.5de±20.0	27.6b±1.57	14.6b±0.11	3.9de±0.11
T5	2.0bc±0.03	2.5abc±0.12	14.1bcd±0.08	41.7bc±0.96	591.3cd±16.1	28.4ab±1.13	15.1ab±0.7	4.0cd±0.08
T6	2.1abc±0.09	2.7abc±0.14	14.3abc±0.06	43.2ab±0.63	619.7bc±10.66	29.3ab±0.33	15.5ab±0.36	4.1bc±0.04
T7	2.1ab±0.03	2.8ab±0.14	14.6ab±0.15	43.3ab±0.97	633.4ab±20.2	29.6ab±0.54	16.0ab±0.35	4.2ab±0.01
T8	2.3a±0.07	2.9a±0.04	14.8a±0.08	45.1a±0.30	668.9a±6.03	31.0a±0.57	17.2a±1.01	4.4a±0.08

Treatments with similar lowercase letters within a column are not significantly different with respect to least significant difference (LSD) values at p=0.05. The results are presented as mean ± SE increased N uptake could be ascribed to slow and continued supply of the nutrients, coupled with reduced N losses through denitrification or leaching, resulting in improved synchrony between plant N demand and supply from the soil (Haile et al 2012, Tilahun et al 2013). The form of orthophosphate ion might have converted from PO_4^{3-} to HPO_4^{2-} or even $H_2PO_4^-$ for short periods, resulting higher concentration of P in the various parts of maize plants (Siddaram et al 2011).The increased K-uptake in maize crop might be attributed to improved grain yield, better availability of potassium from organic sources and to solubility action of organic acids produced during degradation of organic materials that resulted into more release of native P and K in soil (Srinivas et al 2010). Thirunavukkarasu and Kousalya (2015) revealed that the nitrogen application through organic and inorganic sources increased the magnesium uptake indicating the synergistic effect of nitrogen on Ca and Mg. Increase in the uptake of sulphur, calcium and magnesium might also be attributed to the fact that organics are excellent sources of these nutrients and due to decomposition, mineralization and solubulization might have accelerated their availability and uptake by maize plants (Eghball et al 2002).

Uptake of micronutrients (Fe, Mn, Zn, Cu): Different treatments manifested a significant productive effect on uptake of micronutrients by maize over control (Fig. 3). The value of micronutrients uptake in grain and stover, respectively stretched from a minimum value in T_1 (control) to a maximum in T_8 (target yield of 40 q ha^{-1} with FYM). Organic manures play a dual role by adding the micronutrients to soil and increase the availability of native nutrients due to chelation, complex formation. etc. FYM is a good source of nutrients and growth promoting substances and higher uptake of these micronutrients in treatments supplied with FYM might be attributed to higher content of these micronutrients present in FYM, presence of higher microbial and enzymatic activity which stimulated the root growth and resulted in higher uptake Laxminarayana and Patiram (2006).

Productivity and profitability: The highest grain yield of 44.6 q ha^{-1} was observed in T_8 (IPNS based treatment for target yield 40 q ha^{-1}) and minimum (14.1 q ha^{-1}) in T_1 (Control) (Table 3). Among the STCR treatments, target yield of 40 q ha^{-1} with and without FYM established themselves as the superior most treatments when compared with their corresponding IPNS and non IPNS treatment with target yield of 30 q ha^{-1}, respectively. It was certainly perceptible from the data that like grain yield, stover yield also followed a similar trend with minimum value in T_1 (control) and maximum inT_8 (target yield 40 q ha^{-1} with FYM). The highest net returns of Rs. 63831 ha^{-1} were manifested by T_8 (target yield of 40 q ha^{-1} with FYM) as compared to other treatments. With respect to the benefit drawn per unit rupee invested on input, the highest B:C ratio (2.98) was perceived in the T_7 treatment (target yield of 40 q ha^{-1} without FYM), followed by the same treatment (T_8) with FYM (2.83) (Table 2). Many researchers described increased yield levels of different crops including maize in STRCR-IPNS approach due to their effect on root growth, nutrient uptake, simulation of many different enzymes related photosynthesis, efficient response to plant nutrient requirement, integrated supply of nutrients from different sources and improved nutrient supply (Suresh and Santhi 2018). The net returns and B:C ratio increased when FYM was included in the fertilizer prescription, which might be due to better use efficiency of applied NPK fertilizers at low yield target levels (Bera et al 2006). The

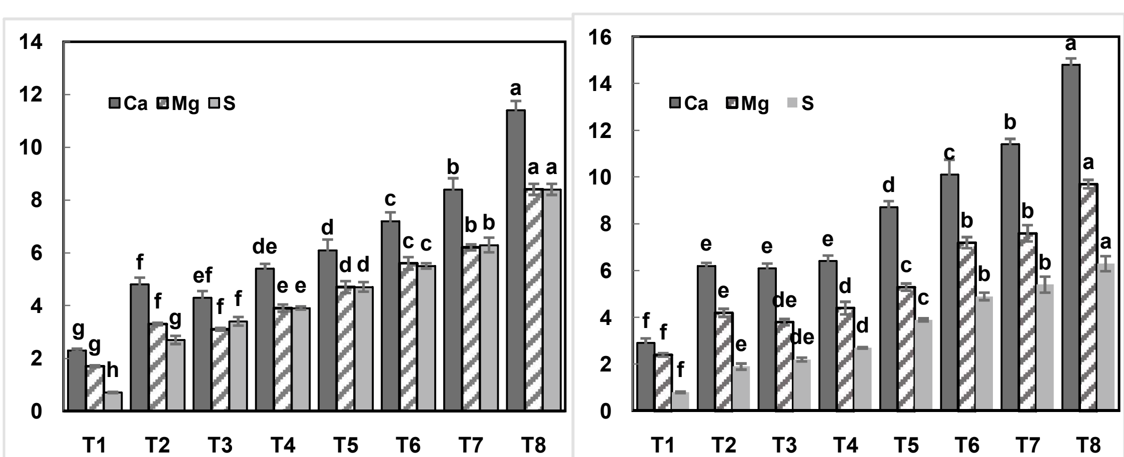


Fig. 2. Effect of IPNS-STCR module on Calcium, Magnesium and Sulphur uptake. Error bars denote ± 1SE. Bars with similar lowercase letters are not significantly different with respect to least significant difference (LSD) values at p=0.05

Table 3. Effect of IPNS-STCR module on productivity and profitability of maize

Treatments	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Net returns (Rs ha^{-1})	B:C Ratio
T1	13.6f±0.59	23.0f±1.26	7859e	1.38e±0.05
T2	25.7e±0.98	42.2e±2.29	24801d	1.87d±0.07
T3	28.8d±0.56	47.2d±0.92	32547c	2.20c±0.05
T4	31.6c±0.69	50.3d±1.15	38565b	2.46c±0.05
T5	32.4c±1.08	57.9c±1.74	41337b	2.50b±0.03
T6	32.9c±1.24	61.2c±1.55	39214b	2.24b±0.04
T7	39.7b±0.45	69.4b±1.25	53199a	2.74ab±0.03
T8	42.7a±0.64	76.2a±0.8	55854a	2.60a±0.02

Treatments with similar lowercase letters within a column are not significantly different with respect to least significant difference (LSD) values at p=0.05. The results are presented as mean ± SE

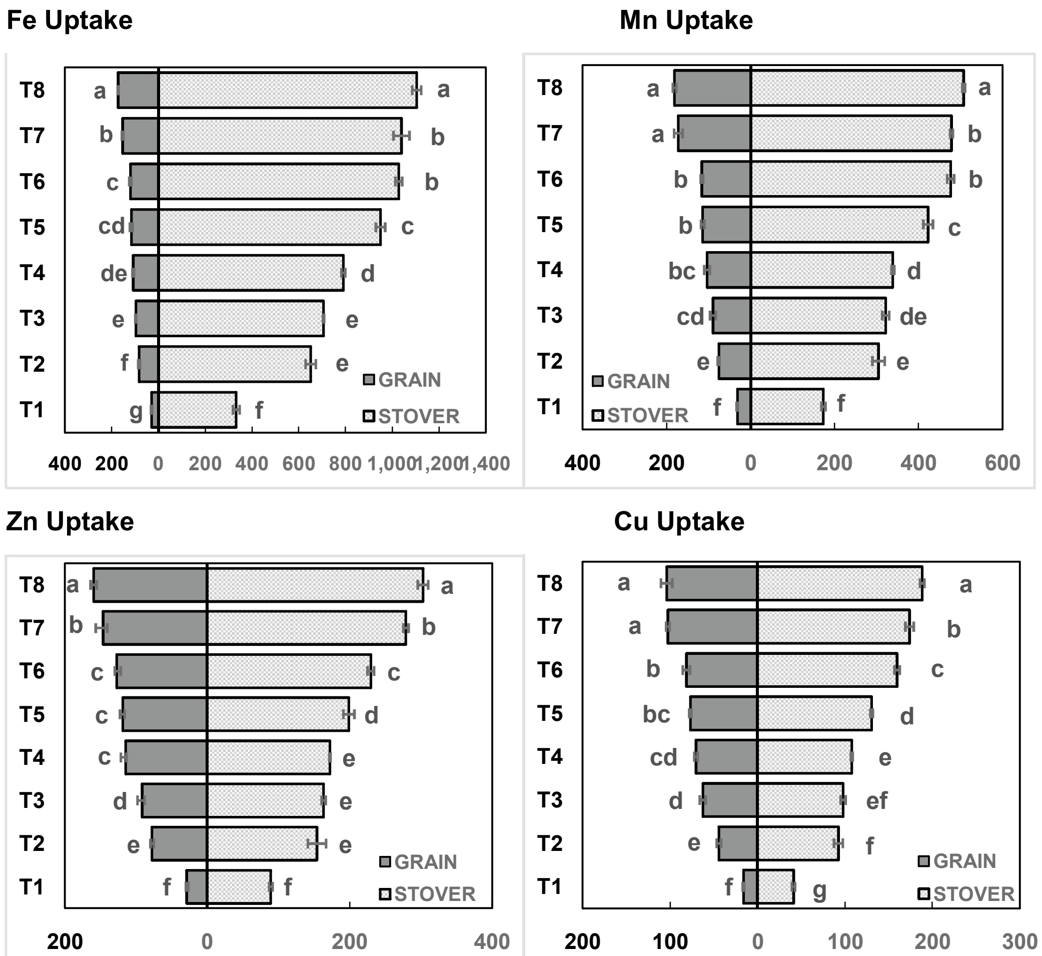


Fig. 3. Effect of IPNS-STCR module on Iron, Manganese, Zinc and Copper uptake (g ha^{-1}). Error bars denote ± 1SE.Bars with similar lowercase letters are not significantly different with respect to (LSD) least significant difference values at p=0.05

current findings are in conformity with the results obtained for different crops (Majumdar et al 2018, Choudhary 2019).

CONCLUSIONS

IPNS-STCR approach discussed in the present study will improve maize productivity and profitability in the Western Himalayan region. This will immensely help resource poor farmers not only increasing yield but also reduce the cost of cultivation by increasing fertilizer use efficiency and saving costly fertilizers.

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