



Development of Soil Test Crop Response (STCR) and STCR-Integrated Plant Nutrition Supply (IPNS) Models to Achieve Targeted Yields of Maize (*Zea mays* L.) in *Vertisols* of Northern Karnataka

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ABSTRACT

Background: Soil test crop response (STCR) approach assists in determining the appropriate amount of fertilizer to use for particular season and location based on the initial soil fertility status and crop response in terms of nutrient uptake and yield. A field experiment was conducted during 2020-21 at Dharwad, by adopting the Inductive Cum Targeted Yield Model to develop soil test-based fertilizer prescriptions under STCR and STCR-IPNS approach to achieve desired target yields of maize in *vertisols* of Northern Karnataka, India.

Methods: In the experiment's first phase, an exhaust crop fodder maize was grown in three different fertility strips. After the harvest of fodder maize, the soil fertility levels varied significantly among the strips, indicating the creation of fertility gradients. In the second phase of the experiment, a test crop (hybrid maize) was grown and the response of maize to four levels of N, P and K and three levels of FYM under different fertility gradients was studied. The basic parameters *viz*, nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizers (Cf) and FYM (Cfym) were computed using the data from test crop experiment. The basic parameters *viz*, nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizers (Cf) and FYM (Cfym) were computed using the data from test crop experiment.

Result: Using the basic parameters, fertilizer prescription equations for desired yield targets of maize under NPK fertilizers alone and under STCR-IPNS (with FYM) were derived based on initial soil test values. Results of the validation experiment in *kharif* 2021 revealed that the grain yield was significantly higher under STCR-IPNS equation with a target yield of 100 q ha⁻¹ as compared to other treatments. STCR-IPNS equation with the application of FYM to achieve 100 q ha⁻¹ target yield resulted in savings of 11, 10 and 15 percent of N, P₂O₅ and K₂O as compared to STCR-NPK alone equation.

Key words: Maize, Nutrient requirement, Soil test crop response, STCR-IPNS approach, Target yield.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most versatile crop showing wider adaptability under varied agro-climatic conditions and is grown all-round the year in India. Globally, maize is also known as "Queen of cereals" because of its highest genetic yield potential among cereals. Maize is third most important cereal crop after rice and wheat in India, accounting for about 10 per cent of total food grain production. During 2020-21, the area under maize in India has reached 9.8 M ha, with a production of 31.1 M t (Anonymous, 2021). Among Indian states, Karnataka is the state with the largest maize area (1.68 M ha) and production (4.5 M t), with a productivity of 3092 kg ha⁻¹.

STCR approach takes into account the effectiveness of nutrient absorption from both the soil and fertilizers, considers the quantity of nutrients extracted by the crops. STCR-IPNS considers the contribution of nutrients from organic manures in addition to the nutrient contribution from soil and fertilizers while determining fertilizer prescription equations, thus STCR-IPNS approach plays a vital role in guaranteeing balanced nutrition of crops. Greater economy in fertilizer use can be made, if fertilizers are applied under integrated plant nutrition system (IPNS) on the basis of

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soil test. Despite the availability of STCR target yield equations various regions of Karnataka, STCR-IPNS studies for maize in Northern Karnataka vertisols have yet to be conducted. Hence an effort was made to develop the soil test crop response (STCR) and STCR-integrated plant nutrition supply (IPNS) models to achieve targeted yields of maize (*Zea mays* L.) in *vertisols* of Northern Karnataka for nutrient management in maize.

MATERIALS AND METHODS

A field experiment was conducted on maize during the year 2020-21 at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, Karnataka by adopting "Inductive cum Targeted Yield Model" as outlined by Ramamoorthy *et al.* (1967). The approved treatment structure and layout design was followed as per procedure outlined by All India Coordinated Research Project for Investigations on Soil Test Crop Response Correlation (AICRP-STCR).

Fertility gradient experiment (Phase I)

Prior to the main experimentation, fertility gradient experiment was conducted by dividing the field into three equal strips, to achieve the operational range of soil fertility by purposefully creating wide differences in soil fertility on the same experimental field. Thus, in the gradient experiment, graded doses of NPK fertilizers were applied in three different strips and fodder maize (*var.* South African tall) was grown as the gradient crop on 30.03.2020 and was harvested on 08.06.2020. During the gradient experiment, which was carried out in *summer* 2020, a total rainfall of 137.3 mm was received during the cropping season. Five irrigations were scheduled to meet the water requirement with the help of sprinklers at 12 days interval. Among the three strips, the low fertility strip received no fertiliser ($N_0P_0K_0$). Whereas, medium and high fertility strips received 100 per cent ($N_{150}P_{100}K_{50}$) and 200 per cent ($N_{300}P_{200}K_{100}$) of the recommended dose of N, P_2O_5 and K_2O kg ha⁻¹. Pre-sowing and post-harvest soil samples were collected from each fertility strip and analyzed for soil available N, P_2O_5 and K_2O status.

Test crop experiment (Phase II)

After confirming the establishment of fertility gradient, test crop experiment was conducted. Each strip was divided into 24 plots (21 treatments+3 controls). Treatments comprising four levels each of N (0, 75, 150 and 225 kg ha⁻¹), P_2O_5 (0, 31.25, 62.5 and 93.75 kg ha⁻¹), K_2O (0, 31.25, 62.5 and 93.75 kg ha⁻¹) and three levels of FYM (0, 5 and 10 t ha⁻¹) were randomized in each of the three strips. The layout of the test crop experiment is given in Fig 1. The IPNS treatments *viz.*, NPK alone (No FYM), NPK + FYM @ 5 t ha⁻¹ and NPK+FYM @ 10 t ha⁻¹ were superimposed across the strips in such a way that all treatments occurred in both the directions.

Maize hybrid var. NK-6240 was sown as test crop during *kharif* (2020) at a seed rate of 22.5 kg ha⁻¹ with a spacing of 60 cm x 20 cm. The crop was sown on 22.07.2020 and was harvested on 27.11.2020. The total rainfall received during the crop growing period was 737.2 mm, which was higher than the normal rainfall. Higher rainfall was received during the month of august, september and october (323.6 mm, 186 mm and 202 mm, respectively). Half the dose nitrogen and entire dose of phosphorus and potassium were applied as basal. Remaining dose of nitrogen was applied through top dressing at 25 and 45 DAS in equal doses. Representative soil samples from individual plots were collected before sowing and also at the harvest of the test crop and analysed for available NPK status. Composite soil samples were collected from each strip after harvest of the test crop and these samples were analysed for estimation of pH, EC, organic carbon, available N, P_2O_5 and K_2O by using standard methods.

With the help of data on nutrient uptake, crop yield, fertilizers applied and soil test values before sowing of maize, the basic parameters such as nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and FYM (Cfym) were derived by formulae given below and used for calculating fertilizer prescription equations.

Calculation of basic parameters

Nutrient requirement (NR)

$$\text{Nutrient requirement per quintal grain production (NR) (kg q}^{-1}\text{)} = \frac{\text{Total uptake of N/P/K (kg ha}^{-1}\text{)}}{\text{Grain yield (q ha}^{-1}\text{)}}$$

Per cent contribution of nutrients from soil to total nutrient uptake (Cs)

$$\% \text{ Contribution from soil (CS)} =$$

$$\frac{\text{Total uptake of N/P/K, kg ha}^{-1} \text{ in control plots}}{\text{Available soil test values for N/P/K, kg ha}^{-1} \text{ in control plots}}$$

Per cent contribution of nutrients from fertilizer to total nutrient uptake (Cf)

$$\% \text{ Contribution to nutrient uptake from fertilizer (Cf)} =$$

$$\frac{\left\{ \text{Total uptake of N/P/K (kg ha}^{-1}\text{) in treated plot} \right\} - \left\{ \text{Available soil test value for N/P/K (kg ha}^{-1}\text{)} \right\}}{\text{Fertilizer N/P/K applied, kg ha}^{-1}} \times \left\{ \text{Per cent contribution of N/P/K from soil/100} \right\}$$

Per cent contribution of nutrients from FYM (Cfym)

$$\% \text{ Contribution to nutrient uptake from FYM (Cfym)} =$$

$$\frac{\left\{ \text{Total uptake of N/P/K (kg ha}^{-1}\text{) in fertilizer and FYM} \right\} - \left\{ \text{Soil test values of N/P/K (kg ha}^{-1}\text{) in FYM treated plots (Cs / 100)} \right\}}{\text{Nutrient N/P/K added through FYM (kg ha}^{-1}\text{)}} \times 100$$

These parameters were used for developing fertilizer prescription equations for deriving fertilizers doses and the soil test based fertilizer recommendations were prescribed for desired yield target of Maize under NPK alone as well as under NPK - IPNS.

Fertilizer prescription equations

i) Fertilizer nutrient under STCR-NPK alone

$$FN/FP/FK = \left\{ \frac{NR}{Cf/100} \right\} \times T - \left\{ \frac{Cs}{Cf} \right\} \times SN$$

ii) Fertilizer nutrient under STCR-IPNS

$$FN = \left\{ \frac{NR}{Cf/100} \right\} \times T - \left\{ \frac{Cs}{Cf} \right\} \times SN - \left\{ \frac{Cfym}{Cf} \right\} \times FYMN$$

Where,

FN= Fertilizer N or P_2O_5 or K_2O in $kg\ ha^{-1}$, respectively.

NR= Nutrient requirement in $kg\ q^{-1}$.

Cs= Per cent contribution of nutrients from soil.

Cf= Per cent contribution of nutrients from fertilizer.

Cfym= Per cent contribution of nutrients from FYM.

T= Targeted yield in $q\ ha^{-1}$.

SN= Soil N or P or K in $kg\ ha^{-1}$.

FYMN= Quantities of N/ P/ K supplied through FYM in $kg\ ha^{-1}$.

These equations serve as a basis for predicting fertilizer doses for specific yield targets (T) of maize for varied soil available nutrient levels.

Validation experiment (Phase III)

Validation experiments were conducted during *kharif* 2021-22 in at MARS, Dharwad which belongs to North transitional zone of Karnataka to evaluate the effectiveness of developed STCR and STCR-IPNS equations. Hybrid maize var. NK-6420 was sown on 25.06.2021 and was harvested on 08.11.2021. A total rainfall of 584.1 mm was received during the crop growth period which was higher than the normal rainfall. The highest rainfall received was in the month of July (187.4 mm). The treatment details pertaining to validation experiment and the fertilizer doses administered are given in Table 1.

RESULTS AND DISCUSSION

Fertility gradient experiment

The green fodder yield of maize obtained was 20700, 33475 and 42375 $kg\ ha^{-1}$ in low, medium and high fertility strips. High fertility strip recorded an increase in maize fodder yield of 26 % and 104 % over medium and low fertility strips, which was attributed to gradual increase in fertilizer doses from low to high fertility strip (Table 2). The difference in yield between the strips was due to improved nutrient availability in synchrony with crop nutrient needs in high fertility strip, resulting in improved nutrient uptake by fodder maize. Roopa, (2019) and Saranya *et al.* (2012) also reported the purposeful production of fertility gradients by the application of graded quantities of N, P_2O_5 and K_2O fertilizers in *vertisols* and *inceptisols* at Dharwad and Coimbatore, respectively.

Table 1: Dosages of fertilizers administered ($kg\ ha^{-1}$) based on fertilizer prescription equations at Dharwad.

Tr. no	Treatments	N	P_2O_5	K_2O
T ₁	STCR-NPK alone T.Y. 60 $q\ ha^{-1}$	184.6	68.5	72.1
T ₂	STCR-NPK alone T.Y. 80 $q\ ha^{-1}$	273.5	104.7	113.5
T ₃	STCR-NPK alone T.Y. 100 $q\ ha^{-1}$	362.4	140.9	154.8
T ₄	STCR-IPNS T.Y. 60 $q\ ha^{-1}$	144.5	54.8	49.2
T ₅	STCR-IPNS T.Y. 80 $q\ ha^{-1}$	233.3	91.0	90.5
T ₆	STCR-IPNS T.Y. 100 $q\ ha^{-1}$	322.2	127.2	131.9
T ₇	Jabalpur STCR equation T.Y. 60 $q\ ha^{-1}$	208.3	95.2	96.5
T ₈	Jabalpur STCR equation T.Y. 80 $q\ ha^{-1}$	296.3	142.8	137.9
T ₉	Jabalpur STCR equation T.Y. 100 $q\ ha^{-1}$	384.3	190.4	179.3
T ₁₀	R.D.F+10 t FYM ha^{-1}	150.0	62.5	62.5
T ₁₁	Absolute control	0	0	0

*T.Y indicates target yield.

Table 2: Effect of application of graded levels of N, P_2O_5 and K_2O on post -harvest soil fertility status of gradient experiment ($kg\ ha^{-1}$).

Fertility strips	Fertilizer doses applied ($kg\ ha^{-1}$)			Post-harvest soil test values ($kg\ ha^{-1}$)			Fodder yield ($kg\ ha^{-1}$)	Nutrient uptake ($kg\ ha^{-1}$)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O		N	P_2O_5	K_2O
Low	0	0	0	127.1 ^c	26.8 ^c	297.3 ^c	20700 ^c	86.3 ^c	15.4 ^c	96.3 ^c
Medium	150	100	50	173.5 ^b	35.8 ^b	342.6 ^b	33475 ^b	166.8 ^b	34.4 ^b	189.2 ^b
High	300	200	100	293.1 ^a	38.2 ^a	406.5 ^a	42325 ^a	223.3 ^a	46.9 ^a	250.0 ^a
S.Em. ($\pm$)				10.1	0.71	6.47	1534	8.11	1.87	9.12

Higher nutrient uptake and available soil nutrients were recorded on High fertility strip followed by medium and low (Table 2). The higher post-harvest available N levels in high fertility strip was due to the better adsorption of NH_4^+ ions by organic and inorganic colloids of the soil (Havlin *et al.*, 2009). The increased availability of P_2O_5 was attributed to the application of phosphatic fertilizer at graded levels either on par with or over and above the P fixing capacity of the experimental field, more of P would have remained in the soil solution (Dibb *et al.*, 1990). Higher soil K_2O in high fertility strip was due to the application of graded levels of potassic fertilizers either on par with or over and above the K fixing capacity of the soil and the probable retention of the added K by the soil colloids in the exchangeable form (Subba Rao and Brar, 2002).

Test crop experiment

Nutrient requirement

The data emanated from the present investigation revealed that the nutrient requirement to produce one quintal of maize was 2.89 kg of N, 0.77 kg of P_2O_5 and 1.92 kg K_2O (Table 3). The Nutrient requirement of N was higher, followed by K_2O and P_2O_5 . The requirement of N was 3.75 times higher than P_2O_5 and 1.50 times higher than K_2O . Similar results of higher N requirement followed by higher K_2O and P_2O_5 requirement were reported by Madhavi *et al.* (2020) and Udayakumar and Santhi (2017) for sesamum and pearl millet, respectively.

Per cent contribution of nutrients from soil (Cs) and fertilizers (Cf) to total uptake of maize

The contribution of nutrients from soil to maize was higher for P (50.10%) followed by N (22.08%) and K (14.27%) (Table 3). With regard to N and K, comparatively lower Cs was recorded which might be due to preferential nature of maize towards applied N and K_2O than the native N and K. This was in accordance with the findings of Muralidharudu *et al.* (2007) on hybrid maize.

The contribution from fertilizer nutrients (Cf) towards the total uptake by maize was 65.03, 42.58 and 92.91 per cent, respectively for N, P_2O_5 and K_2O (Table 3). The estimated per cent contribution of nutrients from fertilizers (Cf) to total uptake clearly revealed the fact that the magnitude of contribution by fertilizer K_2O was 2.18 times higher than P_2O_5 and 1.43 times as that of N. The contribution of nutrients towards the total uptake by maize was higher from fertilizers than that from soil for all the three nutrients viz., N, P_2O_5 and K_2O . Anonymous (2012) also reported similar trend for hybrid maize on black soil.

Muralidharudu *et al.* (2007) and Kashyap *et al.* (2018) observed similar trend of results for jute in West Bengal and rice on Alluvial soils in Assam.

Contribution of nutrients from FYM to the total uptake of maize

The estimated per cent contribution of N, P_2O_5 and K_2O from FYM (Cfym) were 50.54, 26.43 and 47.71, respectively for maize which indicates that relatively higher contribution was observed for N followed by K_2O and P_2O_5 (Table 3). Higher contribution of N from FYM than any other nutrient in wheat crop was concordant with the findings of Santhi *et al.* (2002) and Saranya *et al.* (2012).

Fertilizer prescription equations for maize

Soil test based fertilizer prescription equations for desired yield target of maize were formulated using the basic parameters and are furnished below:

Fertilizer prescription equations under STCR-NPK alone and STCR-IPNS approach

STCR-NPK alone target yield equations

$$\begin{aligned}\text{FN} &= (4.44 \times T) - (0.34 \times \text{SN}) \\ \text{FP}_{2\text{O}_5} &= (1.81 \times T) - (1.18 \times \text{SP}_{2\text{O}_5}) \\ \text{FK}_{2\text{O}} &= (2.07 \times T) - (0.15 \times \text{SK}_{2\text{O}})\end{aligned}$$

STCR-IPNS target yield equations

$$\begin{aligned}\text{FN} &= (4.44 \times T) - (0.34 \times \text{SN}) - (0.78 \times \text{FYM N}) \\ \text{FP}_{2\text{O}_5} &= (1.81 \times T) - (1.18 \times \text{SP}_{2\text{O}_5}) - (0.62 \times \text{FYM } \text{P}_{2\text{O}_5}) \\ \text{FK}_{2\text{O}} &= (2.07 \times T) - (0.15 \times \text{SK}_{2\text{O}}) - (0.51 \times \text{FYM } \text{K}_{2\text{O}})\end{aligned}$$

Where,

FN, FP and FK= Fertilizer N, P_2O_5 and K_2O in kg ha⁻¹.

Here T= Target yield in q ha⁻¹,

SN, SP and SK= Soil available N, P and K in kg ha⁻¹,

FYMN, FYMP and FYMK= N, P and K through FYM in kg ha⁻¹.

Economy of fertilizer use

Fertilizer doses for achieved desired target yield of maize were calculated (Table 4). The extent of saving of inorganic fertilizers for maize under STCR-IPNS approach was 40.1, 13.7 and 22.9 kg fertilizer N, P_2O_5 and K_2O respectively. The per cent of fertilizer saved was higher for 60 q ha⁻¹ target yield as compared to 80 and 100 q ha⁻¹ target yield. This is mainly due to the increase in fertilizers with increasing target yield at fixed supply of FYM and soil available nutrients. Increase in soil fertility levels, lead to decrease in fertilizer doses to be applied resulting in higher percentage saving of fertilizers. On the other hand, increase in target yields lead to increase in fertilizer doses to be applied. Similar trend of results were reported by Santhi *et al.* (2011) in beetroot on *alfisols*, Anon

Table 3: Basic parameters derived from the test crop experiment and targeted yield equation developed for hybrid maize.

Particulars	N	P_2O_5	K_2O
Nutrient requirement (kg q ⁻¹)	2.89	0.77	1.92
Contribution of nutrients from the soil (%)	22.08	50.10	14.27
Contribution of nutrients from fertilizer (%)	65.03	37.63	92.91
Contribution of nutrients from FYM (%)	50.54	30.62	47.71

Table 4: Soil test based fertilizer doses for desired yield targets of maize under STCR-NPK alone (kg ha⁻¹) and STCR-IPNS (NPK+FYM @ 10 t ha⁻¹).

Target yield	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)
NPK alone			
60 q ha ⁻¹	184.6	68.5	72.1
80 q ha ⁻¹	273.5	104.7	113.5
100 q ha ⁻¹	362.4	140.9	154.8
IPNS (NPK + FYM @ 10 t ha⁻¹)			
60 q ha ⁻¹	144.5	54.8	49.2
80 q ha ⁻¹	233.3	91.0	90.5
100 q ha ⁻¹	322.2	127.2	131.9

Initial soil fertility status-242 N, 34.1 P₂O₅ and 346 K₂O kg ha⁻¹.

Table 5: Grain yield of maize as influenced by nutrient management through STCR and STCR-IPNS approach at different target yields at Dharwad and Belavatgi.

Tr. no	Treatments	Grain yield (q ha ⁻¹)
T ₁	STCR-NPK alone T.Y. 60 q ha ⁻¹	61.7 ^c
T ₂	STCR-NPK alone T.Y. 80 q ha ⁻¹	82.0 ^b
T ₃	STCR-NPK alone T.Y. 100 q ha ⁻¹	101.5 ^a
T ₄	STCR-IPNS T.Y. 60 q ha ⁻¹	63.7 ^c
T ₅	STCR-IPNS T.Y. 80 q ha ⁻¹	85.7 ^b
T ₆	STCR-IPNS T.Y. 100 q ha ⁻¹	104.8 ^a
T ₇	Jabalpur STCR equation T.Y. 60 q ha ⁻¹	62.6 ^c
T ₈	Jabalpur STCR equation T.Y. 80 q ha ⁻¹	83.6 ^b
T ₉	Jabalpur STCR equation T.Y. 100 q ha ⁻¹	102.9 ^a
T ₁₀	RDF+10 t FYM ha ⁻¹	62.8 ^c
T ₁₁	Absolute control	26.2 ^d
	S.Em.±	2.07

NOTE: Means followed by the same alphabet (s) within a column are not significantly differed by DMRT (P=0.05)

(2012) in maize on *vertisols* and Coumaravel (2012) in maize on *alfisols*.

Results of validation trail

The perusal data on grain yield revealed that STCR-IPNS equation with 100 q ha⁻¹ target yield recorded superior grain yield than other treatments and was on par with Jabalpur STCR equation with 100 q ha⁻¹ target yield and the STCR-NPK alone equation with 100 q ha⁻¹ target yield (Table 5). The STCR-IPNS equation with a target yield of 100 q ha⁻¹ increased grain yield by 67% above the recommended package of practises.

CONCLUSION

Nutrient application under STCR-IPNS approach with target yield of 100 q ha⁻¹ not only led to increased yields and profitability but also increased soil fertility. The fertilizer application rates were reduced with conjoint use of NPK fertilizer with FYM. Thus, STCR fertilizer prescription equations developed under NPK alone and IPNS (NPK+FYM) could be used in *vertisols* of Northern

Karnataka as an effective guide for achieving the desired target yields of maize and maintenance of soil fertility.

Conflict of interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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