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# Effect of Soil Test Crop Response (STCR) and STCR –Integrated Plant Nutrition System (IPNS) Based Fertilizer Prescription Equations on Maize Productivity, Economics and Soil Fertility Status in *Vertisols* of Northern Karnataka

**K. Jaisimha Reddy [a++*], C. P. Chandrashekara [b#], D. P. Biradar [c†], G. R. Rajakumar [d‡] and P. S. Kanannavar [e^]**

*[a] University of Agricultural Sciences, Dharwad, India.*
*[b] AICRP on IFS OFR, University of Agricultural Sciences, Dharwad, India.*
*[c] Department of Agronomy, University of Agricultural Sciences, Dharwad, India.*
*[d] KVK, Hanumanmatti, University of Agricultural Sciences, Dharwad, India.*
*[e] IWMRC, Belavatgi, University of Agricultural Sciences, Dharwad, India.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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[++] *Ph.D. Scholar;*
[#] *Principal Scientist (Agronomy);*
[†] *Professor and Head (Retired);*
[‡] *Scientist (Soil Science);*
[^] *Associate Professor (Agri. Engineering);*
**Corresponding author: E-mail: kjaisimhareddy66@gmail.com;*

## ABSTRACT

A study on Soil Test Crop Response based Integrated Plant Nutrition System (STCR - IPNS) was conducted adopting an Inductive cum Targeted yield model in *vertisols* of Northern Karnataka at Main Agricultural Research Station (MARS), UAS, Dharwad, Karnataka during *kharif* 2020-21 in order to develop STCR and STCR-IPNS fertilizer prescription equations (FPEs) for achieving desired yield targets of maize. Fertilizer doses at varying soil test values, for attaining 60, 80 and 100 q $ha^{-1}$ target grain yield of maize have been worked out based on the initial soil test values of available N, P and K and the quantities of N, P and K added through farm yard manure (FYM). Using these equations, validation trials were conducted during *kharif* 2021-22 at MARS, Dharwad and Irrigation Water Management Research Centre (IWMRC), Belavatgi. The results of the experiment indicated that at both the locations, the per cent achievement of the targeted yield was within ± 10 % variation proving the validity of the equations for prescribing integrated fertilizer doses for maize. The highest grain yield was recorded in STCR-IPNS equation with 100 q $ha^{-1}$ target yield (Dharwad -104.8 q $ha^{-1}$, Belavatgi – 102.3 q $ha^{-1}$) recording an increase of 67 and 69 per cent over recommended package of practices at Dharwad and Belavatgi, respectively. However, it was found to be on par with Jabalpur STCR equation with 100 q $ha^{-1}$ target yield and STCR-NPK alone equation with 100 q $ha^{-1}$ target yield. Higher gross returns were recorded under STCR-IPNS equation with 100 q $ha^{-1}$ target yield owing to higher grain and stover yields. While STCR equation developed at Jabalpur with 100 q $ha^{-1}$ target yield recorded higher net returns. The post-harvest soil available NPK indicated better build-up and maintenance of soil fertility by the soil test based fertilizer recommendation under IPNS. Targeting 100 q $ha^{-1}$ grain yield for maize under STCR approach was found to be ideal in terms of yield, economics and soil fertility maintenance in *vertisols* of Karnataka. The fertilizer prescription equations developed for maize under IPNS can be recommended for *vertisols* of Northern Karnataka for achieving target yield of 100 q $ha^{-1}$ with sustained soil fertility and it can be extrapolated to other agro-climatic zones of Karnataka on similar and allied soil types.


*Keywords: Fertilizer prescription; maize; STCR; STCR-IPNS; target yield; vertisols.*

## 1. INTRODUCTION

Maize (*Zea mays* L.) is a versatile crop that thrives in a variety of agro-climatic situations and is grown all-round the year in India. Maize is renowned as the "Queen of Cereals" because it has higher genetic yield potential among cereals. After rice and wheat, maize is India's third most important cereal crop, accounting for around 10% of total food grain production. During 2020-21, the maize area in India has reached 9.86 million hectares, with a production of 31.51 million tonnes and a productivity of 3195 kg $ha^{-1}$. Among Indian states, Karnataka is the state with the largest maize area (1.68 m ha) and production (5.18 m t), with a productivity of 3092 kg $ha^{-1}$ [1].

In recent years, India's fertilizer demand has shifted toward nitrogen, with phosphorus coming in second. This resulted in a significantly unbalanced NPK utilisation ratio of 7:2.7:1 in 2019–20 as compared to the optimal ratio of 4:2:1. The current condition of nutrient usage efficiency is quite low for N (30-50%), P (15-20%), S (8-12%), Zn (2-5%), Fe (1-2%), and Cu (1-2%) [2]. Because of the imbalanced nutrient utilisation, there is a large gap between crop removal and fertilizer application. As a result, balanced NPK fertilization has attracted considerable attention in India. Soil testing is important to ensure balanced fertilizer application and it helps the farmers to use fertilizers according to crop needs. Targeted yield fertilizer application based on Ramamoorthy et al. [3] 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.

The Soil Test Crop Response (STCR) concept plays an important role as a comprehensive strategy to fertilizer use, in which fertilizer is applied depending on the yield target, site specification, crop specification, and soil test data. The Soil Test Crop Response based Integrated Plant Nutrition System (STCR-IPNS) is critical in ensuring balanced crop nutrition. When determining fertilizer prescriptions, the Soil Test Crop Response based Integrated Plant Nutrition System (STCR-IPNS) considers the

contribution of nutrients from organic manures in addition to the contribution from soil and fertilizers. The use of IPNS components such as farm yard manure (FYM) or vermi compost (VC) reduces the need for fertilizer nutrients. Greater economy in fertilizer use can be made if fertilizers are applied under integrated plant nutrition system (IPNS) on the basis of soil test. The STCR equations developed elsewhere cannot be adopted to Northern transition zone of Karnataka due to its site specificity, soil and climatic conditions. Suitable STCR equations are not developed for *vertisols* of Northern transition zone of Karnataka. Hence an attempt is made to develop STCR-IPNS equations for prescribing the fertilizer recommendations based on soil test values as the Government of India is emphasizing on soil health card, target yield and with the application of FYM. Therefore, the present study was carried out for maize on *vertisols* of Northern Karnataka to test verify the suitability and effectiveness of STCR and STCR-IPNS equations in enhancing the productivity, profitability of maize and to sustain soil health.

## 2. MATERIALS AND METHODS

Field experiments were conducted at two locations during 2021-22 to validate the developed fertilizer prescription equations for maize under STCR and STCR-IPNS approach on *vertisols* in Northern Karnataka. Field trials with maize hybrid NK-6240 were conducted in two locations *viz.,* Dharwad and Belavatgi of Dharwad district. Initial soil samples were collected from each location and analysed for pH, EC, soil N, soil $P_2O_5$ and soil $K_2O$. The pH of the soil was measured in 1:2.5 soil: water suspension using pH meter with glass electrode (ELICO Model) as per the procedure outlined by Jackson (1973). The electrical conductivity (dS $m^{-1}$) of soil was measured using a conductivity metre in a 1:2.5 soil : water extract using the method given by Jackson [4]. The available nitrogen (kg $ha^{-1}$) in soil was determined using the alkaline permanganate method and the Kjeldhal apparatus, as described by Subbiah and Asija [5]. Olsen's extract (0.5 M $NaHCO_3$) was used to extract the soil available phosphorus. The available phosphorus in the extract was determined using the ascorbic acid reductant method using a spectrophotometer with a wavelength of 660 nm. [4] and expressed as kg of $P_2O_5$ $ha^{-1}$. The available potassium was measured using an ELICO CL 361 flame photometer after being extracted using a neutral normal ammonium acetate solution and was expressed by kg of $K_2O$ $ha^{-1}$ [4]. The initial soil fertility status for both the locations is shown in Table 1. STCR and STCR-IPNS equations generated for maize are furnished in Table 2.

The treatments imposed were as follows: STCR-NPK alone equation with a target yield of 60 q $ha^{-1}$, 80 q $ha^{-1}$and 100 q $ha^{-1}$, STCR-IPNS equation with a target yield of 60 q $ha^{-1}$, 80 q $ha^{-1}$and 100 q $ha^{-1}$, Jabalpur STCR equation with a target yield of 60 q $ha^{-1}$, 80 q $ha^{-1}$and 100 q $ha^{-1}$, RDF + 10 t FYM $ha^{-1}$ and Absolute control. Fertilizer dosages were calculated and applied for STCR treatments for various target yields based on the initial soil values of available N, $P_2O_5$, and $K_2O$ and the quantities of N, $P_2O_5$, and $K_2O$ supplied through FYM. Treatments (iv), (v) and (vi) received FYM @ 10 t $ha^{-1}$ and N, P and K fertilizers were administered after the nutrients supplied by FYM were adjusted using STCR-IPNS equations (Table 2). Other STCR treatments received inorganic fertilizers alone based on developed STCR equations and Jabalpur STCR equations. Recommended dose of fertilizers (RDF) were applied @ 150:62.5:62.5 kg N, P2O5 and K2O $ha^{-1}$ along with 10 t FYM $ha^{-1}$ as per the recommendations and no fertilizers and no FYM were applied to Absolute control. The calculated fertilizers as per the different STCR equations are given in Table 4. The crop was harvested after attaining the complete maturity on 12$^{th}$ November 2021 at Dharwad and 21$^{st}$ December 2021 at Belavatgi. Cobs at maturity from net plot were harvested and sun dried. Thereafter, cobs were shelled and the grain yield per net plot recorded and expressed as q $ha^{-1}$. The parameters *viz.,* per cent achievement [(yield obtained/yield target aimed) x 100] was calculated using data on grain yield and fertilizer doses administered and economic parameters *viz.,* gross returns, net returns and benefit cost ratio was calculated using the price of the produce and cost of cultivation. Composite soil samples were collected from each treatment after harvest of maize and these samples were analysed for estimation of soil available N, $P_2O_5$ and $K_2O$. Plant samples from each strip were collected, processed and analysed for total N, P and K contents and N, P and K uptake was computed. Statistical analysis of the data was analysed by using Randomized block design as suggested by Gomez and Gomez [6]. Post-harvest soil samples were collected and analysed to determine the available of N, $P_2O_5$, and $K_2O$ status.

**Table 1. Initial soil fertility of the field experiments**

| Sl. No. | Locations | pH | EC (dS $m^{-1}$) | Soil N (kg $ha^{-1}$) | Soil $P_2O_5$ (kg $ha^{-1}$) | Soil $K_2O$ (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|
| **1.** | Dharwad | 7.10 | 0.30 | 242 | 34.1 | 346 |
| **2.** | Belavatgi | 8.40 | 0.32 | 238 | 29.1 | 585 |

**Table 2. Fertilizer prescription equations under STCR-NPK alone and STCR-IPNS**

| STCR-NPK alone | STCR-IPNS |
|---|---|
| FN = (4.44 x T) – (0.34 x SN) | FN = (4.44 x T) - (0.34 x SN) – (0.78 x FYM N) |
| $FP_2O_5$ = (1.81 x T) – (1.18 x $SP_2O_5$) | $FP_2O_5$ = (1.81 x T) – (1.18 x $SP_2O_5$) – (0.62 x FYM $P_2O_5$) |
| $FK_2O$ = (2.07 x T) – (0.15 x $SK_2O$) | $FK_2O$ = (2.07 x T) – (0.15 x $SK_2O$) – (0.51 x FYM $K_2O$) |

**Table 3. The STCR equations developed for maize at Jabalpur (Madhya Pradesh) is as follows**

| STCR-NPK alone | Soil type | Location |
|---|---|---|
| FN = (4.40 x T) – (0.23 x SN) | Shallow medium and deep | Jabalpur |
| $FP_2O_5$ = (2.06 x T) – (1.39 x $SP_2O_5$) | black soils | (M. P) |
| $FK_2O$ = (2.17 x T) – (0.19 x $SK_2O$) | | |

*Where, FN, $FP_2O_5$ and $FK_2O$ are fertilizers N, $P_2O_5$ and $K_2O$ in kg $ha^{-1}$ respectively; T = Targeted yield in q $ha^{-1}$; SN, $SP_2O_5$ and $SK_2O$ are available N, $P_2O_5$ and $K_2O$ in kg $ha^{-1}$, respectively; FYM N, FYM $P_2O_5$ and FYM $K_2O$ are N, $P_2O_5$ and $K_2O$ supplied through FYM in kg $ha^{-1}$*

**Table 4. Fertilizer doses (kg $ha^{-1}$) imposed at Dharwad and Belavatgi based on fertilizer prescription equations**

| Tr. No | Treatments | Dharwad | | | Belavatgi | | |
|---|---|---|---|---|---|---|---|
| | | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| $T_1$ | STCR-NPK alone T.Y. 60 q $ha^{-1}$ | 184.6 | 68.5 | 72.1 | 186.0 | 74.4 | 36.5 |
| $T_2$ | STCR-NPK alone T.Y. 80 q $ha^{-1}$ | 273.5 | 104.7 | 113.5 | 274.8 | 110.6 | 77.9 |
| $T_3$ | STCR-NPK alone T.Y. 100 q $ha^{-1}$ | 362.4 | 140.9 | 154.8 | 363.7 | 146.8 | 119.3 |
| $T_4$ | STCR-IPNS T.Y. 60 q $ha^{-1}$ | 144.5 | 54.8 | 49.2 | 145.8 | 60.7 | 13.3 |
| $T_5$ | STCR-IPNS T.Y. 80 q $ha^{-1}$ | 233.3 | 91.0 | 90.5 | 234.7 | 96.9 | 54.7 |
| $T_6$ | STCR-IPNS T.Y. 100 q $ha^{-1}$ | 322.2 | 127.2 | 131.9 | 323.6 | 133.1 | 96.0 |
| $T_7$ | Jabalpur STCR equation T.Y. 60 q $ha^{-1}$ | 208.3 | 95.2 | 96.5 | 209.3 | 102.2 | 77.4 |
| $T_8$ | Jabalpur STCR equation T.Y. 80 q $ha^{-1}$ | 296.3 | 142.8 | 137.9 | 297.3 | 149.8 | 118.8 |
| $T_9$ | Jabalpur STCR equation T.Y. 100 q $ha^{-1}$ | 384.3 | 190.4 | 179.3 | 385.3 | 197.4 | 160.2 |
| $T_{10}$ | R.D.F + 10 t FYM $ha^{-1}$ | 150.0 | 62.5 | 62.5 | 208.3 | 95.2 | 96.5 |
| $T_{11}$ | Absolute control | 0 | 0 | 0 | 0 | 0 | 0 |

Fertilizer prescriptions to achieve desired yield targets of 60, 80 and 100 q $ha^{-1}$ of maize was worked out for initial soil test values of Dharwad and Belavatgi and are presented in Table 4. The results indicated that to achieve 60, 80 and 100 q $ha^{-1}$ maize grain yield in Dharwad for a soil test value of 242 kg $ha^{-1}$ of soil N, the fertilizer N doses required were 184.6, 273.5 and 362.4 kg $ha^{-1}$ respectively. With regard to phosphorus, to achieve 60, 80 and 100 q $ha^{-1}$ maize grain yield for soil test value of 34.1 kg $ha^{-1}$ of soil $P_2O_5$, the fertilizer $P_2O_5$ doses required were 68.5, 104.7 and 140.9 kg $ha^{-1}$ respectively. In case of potassium, for a soil test value of 346 kg $ha^{-1}$ of soil $K_2O$, the fertilizer $K_2O$ doses required were 72.1, 113.5 and 154.8 kg $ha^{-1}$, respectively to obtain target yields of 60, 80 and 100 q $ha^{-1}$ of maize. Under IPNS, for same soil test values, to achieve yield target of 60 q $ha^{-1}$, the fertilizer doses required were 144.5 N, 54.8 $P_2O_5$ and 49.2 $K_2O$ kg $ha^{-1}$. To achieve 80 q $ha^{-1}$ target yield the fertilizer doses required were 233.3 N, 91.0 $P_2O_5$ and 90.5 $K_2O$ kg $ha^{-1}$. While to achieve 100 q $ha^{-1}$ target yield the required fertilizer doses were 322.2 N, 127.2 $P_2O_5$ and 131.9 $K_2O$ kg $ha^{-1}$.

Similarly, to produce 60, 80 and 100 q $ha^{-1}$ maize in Belavatgi for soil test value of 238 kg $ha^{-1}$ of soil N, the fertilizer N doses required were 186.0, 274.8 and 363.7 kg $ha^{-1}$ respectively. With regard to P, for soil test value of 29.1 kg $ha^{-1}$ of soil $P_2O_5$, the fertilizer $P_2O_5$ doses required were 74.4, 110.6 and 146.8 kg $ha^{-1}$ to produce 60, 80 and 100 q $ha^{-1}$ maize grain yield respectively. In case of K, for a soil test value of 585 kg $ha^{-1}$ of soil K the fertilizer $K_2O$ doses required were 13.3, 54.7 and 96.0 kg $ha^{-1}$, respectively to obtain target yields of 60, 80 and 100 q $ha^{-1}$ of maize (Table 4). In Belavatgi under IPNS, the required

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

| Tr. No | Treatments | Dharwad | | Belavatgi | |
|---|---|---|---|---|---|
| | | Grain yield (q ha$^{-1}$) | % achievement | Grain yield (q ha$^{-1}$) | % achievement |
| $T_1$ | STCR-NPK alone T.Y. 60 q ha$^{-1}$ | 61.7$^{c}$ | 102.8 | 59.7$^{c}$ | 99.5 |
| $T_2$ | STCR-NPK alone T.Y. 80 q ha$^{-1}$ | 82.0$^{b}$ | 102.5 | 81.1$^{b}$ | 101.4 |
| $T_3$ | STCR-NPK alone T.Y. 100 q ha$^{-1}$ | 101.5$^{a}$ | 101.5 | 98.9$^{a}$ | 98.9 |
| $T_4$ | STCR-IPNS T.Y. 60 q ha$^{-1}$ | 63.7$^{c}$ | 106.2 | 62.7$^{c}$ | 104.5 |
| $T_5$ | STCR-IPNS T.Y. 80 q ha$^{-1}$ | 85.7$^{b}$ | 107.1 | 83.5$^{b}$ | 104.4 |
| $T_6$ | STCR-IPNS T.Y. 100 q ha$^{-1}$ | 104.8$^{a}$ | 104.8 | 102.3$^{a}$ | 102.3 |
| $T_7$ | Jabalpur STCR equation T.Y. 60 q ha$^{-1}$ | 62.6$^{c}$ | 104.4 | 60.3$^{c}$ | 100.5 |
| $T_8$ | Jabalpur STCR equation T.Y. 80 q ha$^{-1}$ | 83.6$^{b}$ | 104.5 | 81.8$^{b}$ | 102.3 |
| $T_9$ | Jabalpur STCR equation T.Y 100 q ha$^{-1}$ | 102.9$^{a}$ | 102.9 | 100.4 $^{a}$ | 100.4 |
| $T_{10}$ | RDF +10 t FYM ha$^{-1}$ | 62.8$^{c}$ | - | 60.5$^{c}$ | - |
| $T_{11}$ | Absolute control | 26.2$^{d}$ | - | 28.2$^{d}$ | - |
| | S.Em.± | 2.07 | - | 2.20 | - |

**Table 6. Economics of maize as influenced by nutrient management through STCR and STCR-IPNS approach at different target yields at Dharwad and Belavatgi**

| Tr. No | Treatments | Dharwad | | | Belavatgi | | |
|---|---|---|---|---|---|---|---|
| | | Gross Returns (Rs. ha$^{-1}$) | Net Returns (Rs. ha$^{-1}$) | B:C ratio | Gross Returns (Rs. ha$^{-1}$) | Net Returns (Rs. ha$^{-1}$) | B:C ratio |
| $T_1$ | STCR-NPK alone T.Y. 60 q ha$^{-1}$ | 117420$^{c}$ | 48409$^{e}$ | 1.70$^{c}$ | 115828$^{c}$ | 47889$^{e}$ | 1.70$^{c}$ |
| $T_2$ | STCR-NPK alone T.Y. 80 q ha$^{-1}$ | 155069$^{b}$ | 80674$^{cd}$ | 2.08$^{b}$ | 153389$^{b}$ | 79902$^{c}$ | 2.09$^{b}$ |
| $T_3$ | STCR-NPK alone T.Y. 100 q ha$^{-1}$ | 190779$^{a}$ | 111125$^{a}$ | 2.40$^{a}$ | 189635$^{a}$ | 111073$^{a}$ | 2.41$^{a}$ |
| $T_4$ | STCR-IPNS T.Y. 60 q ha$^{-1}$ | 121258$^{c}$ | 33631$^{f}$ | 1.38$^{d}$ | 118343$^{c}$ | 31475$^{f}$ | 1.36$^{d}$ |
| $T_5$ | STCR-IPNS T.Y. 80 q ha$^{-1}$ | 162053$^{b}$ | 68741$^{d}$ | 1.74$^{c}$ | 156127$^{b}$ | 64033$^{d}$ | 1.70$^{c}$ |
| $T_6$ | STCR-IPNS T.Y. 100 q ha$^{-1}$ | 197002$^{a}$ | 98498$^{b}$ | 2.00$^{b}$ | 195756$^{a}$ | 98098$^{b}$ | 2.00$^{b}$ |
| $T_7$ | Jabalpur STCR equation T.Y. 60 q ha$^{-1}$ | 119199$^{c}$ | 49143$^{e}$ | 1.70$^{c}$ | 117084$^{c}$ | 47774$^{e}$ | 1.69$^{c}$ |
| $T_8$ | Jabalpur STCR equation T.Y. 80 q ha$^{-1}$ | 158186$^{b}$ | 82565$^{c}$ | 2.09$^{b}$ | 154654$^{b}$ | 79687$^{c}$ | 2.06$^{b}$ |
| $T_9$ | Jabalpur STCR equation T.Y. 100 q ha$^{-1}$ | 193468$^{a}$ | 112575$^{a}$ | 2.39$^{a}$ | 192232$^{a}$ | 111796$^{a}$ | 2.39$^{a}$ |
| $T_{10}$ | R.D.F +10 t FYM ha$^{-1}$ | 119491$^{c}$ | 31583$^{f}$ | 1.36$^{d}$ | 117485$^{c}$ | 29969$^{f}$ | 1.34$^{d}$ |
| $T_{11}$ | Absolute control | 50240$^{d}$ | -6921$^{g}$ | 0.88$^{e}$ | 53855$^{d}$ | -5671$^{g}$ | 0.90$^{e}$ |
| | S.Em.± | 3667 | 3667 | 0.05 | 2976 | 2976 | 0.04 |

fertilizer doses were 145.8 N, 60.7 $P_2O_5$, and 13. $K_2O$ kg $ha^{-1}$ to meet the yield target of 60 q $ha^{-1}$. The fertilizer doses of 234.7 N, 96.9 $P_2O_5$, and 54.7 $K_2O$ kg $ha^{-1}$ were necessary to reach the yield target of 80 q $ha^{-1}$. While the required fertilizer doses to reach the 100 q $ha^{-1}$ target yield were 323.6 N, 133.1 $P_2O_5$, and 96.0 $K_2O$ kg $ha^{-1}$.

## 3. RESULTS AND DISCUSSION

The grain yield of two locations demonstrated that STCR-IPNS equation with 100 q $ha^{-1}$ target yield (Dharwad –104.8 q $ha^{-1}$, Belavatgi– 102.3 q $ha^{-1}$) recorded higher grain yield and was on par with Jabalpur STCR equation with 100 q $ha^{-1}$ target yield (Dharwad –102.9 q $ha^{-1}$, Belavatgi – 100.4 q $ha^{-1}$) and STCR-NPK alone equation with 100 q $ha^{-1}$ target yield (Dharwad –101.5 q $ha^{-1}$, Belavatgi – 98.5 q $ha^{-1}$). RDF + 10 t FYM $ha^{-1}$recorded relatively lower yield (Dharwad – 62.8 q $ha^{-1}$, Belavatgi – 60.5 q $ha^{-1}$) as compared to STCR treatments with 80 and 100 q $ha^{-1}$ target yield (Table 5). STCR-IPNS equation with 100 q $ha^{-1}$ target yield recorded an increase in grain yield to an extent of 67 and 69% over Recommended package of practices at Dharwad and Belavatgi, respectively. The data showed all the STCR equations are equally good because they achieved their respective targeted yields.

The highest per cent achievement of yield targets was observed with STCR-IPNS equation with 80 q $ha^{-1}$ target yield (107.1 %) at Dharwad and STCR-IPNS equation with 60 q $ha^{-1}$ target yield (104.5 %) at Belavatgi. Yield targeting with IPNS treatments resulted in higher percentage achievement of the target yields than the comparable NPK alone treatments. The per cent achievement of the target yield was within ± 10 % deviation of the aimed targeted yields at both locations, demonstrating the validity of the equations for prescribing integrated fertilizer for maize. The target yield equations established by STCR-IPNS technology not only ensured sustainable crop production but also reduced the use of costly fertilizer inputs [7].

Regarding economic parameters, higher gross returns were noticed in STCR-IPNS equation with 100 q $ha^{-1}$ target yield ($T_6$, Dharwad – 197002 Rs. $ha^{-1}$, Belavatgi – 195756 Rs. $ha^{-1}$) and was comparable with Jabalpur STCR equation with 100 q $ha^{-1}$ target yield ($T_9$, Dharwad – 193468 Rs. $ha^{-1}$, Belavatgi – 192232 Rs. $ha^{-1}$) and STCR- NPK alone with 100 q $ha^{-1}$ target yield ($T_3$, Dharwad –190779 Rs. $ha^{-1}$, Belavatgi -189635 Rs. $ha^{-1}$) as compared to rest of the treatments. Higher grain and stover yields in STCR-IPNS equation with 100 q $ha^{-1}$ target yield may have resulted in higher gross returns. While absolute control ($T_{11}$) recorded lower amount of gross returns (Dharwad - Rs. 50240 $ha^{-1}$, Belavatgi - Rs. 53855 $ha^{-1}$) among all the treatments. The higher net returns were recorded in Jabalpur STCR equation with 100 q $ha^{-1}$ target yield ($T_9$, Dharwad –112575 Rs. $ha^{-1}$, Belavatgi– 111796 Rs. $ha^{-1}$) and was on par with STCR-NPK alone equation with 100 q $ha^{-1}$ target yield ($T_3$, Dharwad –111125 Rs. $ha^{-1}$, Belavatgi - 111073 Rs. $ha^{-1}$). Whereas, higher B:C ratio was recorded with STCR-NPK alone equation with 100 q $ha^{-1}$ target yield ($T_3$, Dharwad – 2.40, Belavatgi – 2.41) and was on par with Jabalpur STCR equation with 100 q $ha^{-1}$ target yield ($T_9$, Dharwad – 2.39, Belavatgi – 2.39) (Table 6). Even though higher yields were recorded in STCR IPNS equation with 100 q $ha^{-1}$ target yield, net returns and B:C ratio were lower mainly due to high cost of FYM. These results are in accordance with Basavaraja et al. (2017) who reported higher B:C ratio in STCR inorganic approach over IPNS approach due to high cost of FYM.

The data on soil available N, $P_2O_5$ and $K_2O$ indicated the build-up and maintenance of soil fertility due to soil test based fertilizer recommendation under IPNS. Despite higher removal of nutrients, the fertility status was maintained in STCR-IPNS equation as compared to Jabalpur STCR equation and STCR-NPK alone equation with 100 q $ha^{-1}$ target yields (Table 7). Among the STCR equations, nutrients applied as per STCR-IPNS equation with a target yield of 100 q $ha^{-1}$ ($T_6$) recorded higher available nutrients (Dharwad, 263 N, 38.6 $P_2O_5$ and 369 kg $K_2O$ $ha^{-1}$; Belavatgi - 257 N, 32.5 $P_2O_5$ and 614 $K_2O$ kg $ha^{-}$). However, it was found on par Jabalpur STCR equation with a target yield 100 q $ha^{-1}$ ($T_9$, Dharwad- 261 kg N $ha^{-1}$, 37.7 kg $P_2O_5$ $ha^{-1}$ and 364 kg $K_2O$ $ha^{-1}$; Belavatgi - 254 kg N $ha^{-1}$, 32.3 kg $P_2O_5$ $ha^{-1}$ and 609 kg $K_2O$ $ha^{-1}$) and STCR-NPK alone equation with a target yield 100 q $ha^{-1}$ ($T_3$, Dharwad - 253 kg N $ha^{-1}$, 36.6 kg $P_2O_5$ $ha^{-1}$ and 359 kg $K_2O$ $ha^{-1}$; Belavatgi - 246 kg N $ha^{-1}$, 31.6 kg $P_2O_5$ $ha^{-1}$ and 606 kg $K_2O$ $ha^{-1}$). This might be attributed to the prevention of losses of nutrients under IPNS, even after meeting the crop needs. However, these treatments received relatively higher doses of fertilizers for higher yield targets which could have resulted in increase in available NPK

**Table 7. Available soil nutrient status (kg ha$^{-1}$) after harvest of maize as influenced by nutrient management through STCR and STCR-IPNS approach at different target yields at Dharwad and Belavatgi**

| Tr. No | Treatments | Dharwad | | | Belavatgi | | |
|---|---|---|---|---|---|---|---|
| | | Soil N (kg ha$^{-1}$) | Soil $P_2O_5$ (kg ha$^{-1}$) | Soil $K_2O$ (kg ha$^{-1}$) | Soil N (kg ha$^{-1}$) | Soil $P_2O_5$ (kg ha$^{-1}$) | Soil $K_2O$ (kg ha$^{-1}$) |
| $T_1$ | STCR-NPK alone T.Y. 60 q ha$^{-1}$ | 221$^{e}$ | 31.1$^{f}$ | 307$^{f}$ | 212$^{fg}$ | 27.0$^{d}$ | 549$^{c}$ |
| $T_2$ | STCR-NPK alone T.Y. 80 q ha$^{-1}$ | 237$^{b-e}$ | 33.5$^{c-f}$ | 334$^{c-e}$ | 230$^{b-e}$ | 29.8$^{b}$ | 576$^{bc}$ |
| $T_3$ | STCR-NPK alone T.Y. 100 q ha$^{-1}$ | 253$^{ab}$ | 36.6$^{a-c}$ | 359$^{a-c}$ | 246$^{ab}$ | 31.6$^{ab}$ | 606$^{ab}$ |
| $T_4$ | STCR-IPNS T.Y. 60 q ha$^{-1}$ | 229$^{c-e}$ | 33.1$^{d-f}$ | 319$^{d-f}$ | 227$^{c-f}$ | 28.7$^{cd}$ | 561$^{c}$ |
| $T_5$ | STCR-IPNS T.Y. 80 q ha$^{-1}$ | 246$^{a-c}$ | 35.2$^{a-d}$ | 342$^{b-d}$ | 241$^{a-c}$ | 30.7$^{ab}$ | 583$^{a-c}$ |
| $T_6$ | STCR-IPNS T.Y. 100 q ha$^{-1}$ | 263$^{a}$ | 38.2$^{a}$ | 369$^{a}$ | 257$^{a}$ | 32.5a | 614$^{a}$ |
| $T_7$ | Jabalpur STCR equation T.Y. 60 q ha$^{-1}$ | 226$^{de}$ | 32.2$^{ef}$ | 317$^{d-f}$ | 218$^{ef}$ | 27.5$^{d}$ | 550$^{c}$ |
| $T_8$ | Jabalpur STCR equation T.Y. 80 q ha$^{-1}$ | 241$^{b-d}$ | 34.5$^{b-e}$ | 336$^{c-e}$ | 237$^{b-d}$ | 30.3$^{bc}$ | 578$^{bc}$ |
| $T_9$ | Jabalpur STCR equation T.Y. 100 q ha$^{-1}$ | 261$^{a}$ | 37.7$^{ab}$ | 364$^{ab}$ | 254$^{a}$ | 32.3$^{a}$ | 609$^{ab}$ |
| $T_{10}$ | R.D.F+10 t FYM ha$^{-1}$ | 227$^{de}$ | 34.9$^{b-e}$ | 315$^{ef}$ | 222$^{d-f}$ | 27.9$^{d}$ | 556$^{c}$ |
| $T_{11}$ | Absolute control | 193$^{f}$ | 24.1$^{g}$ | 250$^{g}$ | 199$^{g}$ | 23.7$^{e}$ | 496$^{d}$ |
| | S.Em.± | 5.08 | 0.94 | 7.97 | 5.08 | 0.61 | 10.21 |

status in soil. The effect was further improved with the application of FYM, which had not only increased the build-up of nutrients of the soil but also the ability of the soil to sustain the fertility status over long run. Santhi et al. [9] and Coumaravel [10] established that soil test based fertilizer prescription for maize-tomato sequence was found to be useful in increasing not only the yields but also maintaining soil fertility.

## 4. CONCLUSION

The grain yield of maize at both Dharwad and Belavatgi indicated that targeting 100 q $ha^{-1}$ target yield under STCR approach was found to record significantly higher yield over all other treatments. The per cent achievement of the targeted yield was within 10% variance at both locations, demonstrating the validity of the equations for prescribing integrated fertilizer doses for maize. STCR-IPNS treatments recorded relatively higher per cent achievement than other treatments. STCR equation developed at Jabalpur and STCR-NPK fertilizers alone developed at UAS Dharwad gave higher net returns followed by STCR-IPNS equation. The post-harvest soil available N, $P_2O_5$, and $K_2O$ status demonstrated soil fertility build-up and maintenance as a result of soil test-based fertilizer recommendation under IPNS. Hence, the fertilizer prescription equations developed for maize under IPNS can be recommended for *vertisols* of Northern Karnataka for achieving yield target of 100 q $ha^{-1}$ with sustained soil health, for both assured rainfall and command areas of maize cultivation belts.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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