Biological Forum – An International Journal **14(2): 1314-1322(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Growth and Yield of Maize (*Zea mays* L.) as Influenced by Nutrient Management through Soil Test Crop Response (STCR) approach at varied Soil Fertility Gradients in *Vertisols*

Roopa K. Muttappanavar[1*], C.P. Chandrashekara[2] and M.P. Potdar[3]
Department of Agronomy, UAS, Dharwad (Karnataka), India.
[1]Ph.D. Scholar, Department of Agronomy, College of Agriculture, University of Agricultural Sciences, GKVK, Bengaluru (Karnataka), India.
[2]Principal Scientist (Agronomy), AICRP on IFS-OFR, College of Sirsi, University of Agricultural Sciences, Dharwad (Karnataka), India.
[3]Professor, Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Dharwad (Karnataka), India.

*(Corresponding author: Roopa K. Muttappanavar*****)*
(Received 17 April 2022, Accepted 08 June, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Maize being a high yielding cereal crop which is responsive to chemical fertilizers. Nutrient management through Soil Test Crop Response (STCR) equations cannot be adopted without validation study because, they are very specific to a type of crop, soil, season and situation (Irrigated/ rainfed). So, the validation of the STCR fertilizer prescription equations for maize in Northern Transition Zone of Karnataka is very much essential to identify the most suitable STCR prescription model for cultivation of maize in *Vertisols* to exploit greater yield potential of a crop. A field experiment was conducted during summer and *Kharif* 2018-19. There were two phases of the field experimentation. Gradient experiment (Phase I) was conducted during summer, 2018 by growing an exhaustive crop fodder maize to create fertility gradient (FG). Phase II experiment on validation of STCR equations carried out during *Kharif*, 2018-19 in split plot design with three fertility gradients (low, medium and high) as main plots and four STCR equations developed for maize at Jabalpur, Jagtial, Rahuri and Coimbatore, RDF and control as sub plot treatments. Maize green fodder yield increased with increasing fertilizer levels (25.53, 34.63 and 40.38 t ha^{-1}, 0, 100 and 200 %, respectively) and gradients are created. Among soil fertility gradients, higher grain and stover (82.3 and 101.2 q ha^{-1}, respectively) yields were recorded with medium FG than low FG. However, high FG was on par with MFG. Nutrients applied as per Jabalpur STCR equation recorded higher grain and stover yield (101.4 and 120.9 q ha^{-1}, respectively) than other STCR equations. Significantly higher growth parameters namely plant height (50.1, 204.3 and 212.6 cm), number of green leaves plant^{-1} (6.51, 12.6 and 3.1), LA (23.7, 68.1 and 17.8 dm^2), LAI (1.97,5.67 and 1.49), LAD (153 and 143 between 40-80 DAS and 80 DAS-at harvest, respectively), SPAD values (45.0 and 54.2 at 40 DAS and 80 DAS respectively) and stem girth (5.21, 8.44 and 8.60 cm) of maize observed with Jabalpur STCR equation at all growth stages (40, 80 DAS and at harvest, respectively) than other STCR equations, RDF and control. Among interactions, nutrients applied as per Jabalpur STCR equation at MFG recorded higher grain and stover yield (105.1 and 124.1 q ha^{-1}) and all the growth parameters than other treatment combinations.

Keywords: Maize, soil fertility gradients, STCR equations validation, *Vertisols*, growth and yield.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most widely grown cereal crop which stands first with respect to production in the world. It is grown in an area of 184.3 million ha in the world with a production of 1041.7 million tons and 5,742 kg ha^{-1} productivity annually. In India currently, it is grown in an area of 9.86 million ha with a production of 31.51 million tons and productivity of 3,195 kg ha^{-1}. In Karnataka, maize is grown in an area of 1.68 million ha with a production of 5.18 million tons and productivity of 3,092 kg ha^{-1} (Anon., 2021).

In Indian Agriculture, at present, nutrient depletion is one of the threats as there is a wider gap between the removal and addition of nutrients. Agriculture is operating on a net negative balance (@ 10 million tons per annum) of plant nutrients in India (Ramakrishna *et al.,* 2012). Use of fertilizers in an imbalanced manner by the farmer is one of the reason for lower production. Application of fertilizers without knowing the fertility status of the soil and crop nutrient requirement causes negative effects on soil and plant in terms of toxicity and deficiency of nutrients (Ray *et al.,* 2000). For achieving higher yields farmers are using excess inorganic fertilizers but the fertilizer use requires knowledge of expected crop yield and response to applied nutrients. Hence, there is a scope for using different precision nutrient management techniques such as site-specific nutrient management (SSNM), nutrient expert (NE), diagnosis and recommendation integration system (DRIS), critical ratio and Soil Test Crop Response (STCR) approach *etc.*, for balanced nutrition. Among these approaches, STCR approach helps for obtaining higher grain yield by improving the nutrient use efficiency. Fertilizer recommendation is made based on the fertilizer prescription equations in STCR approach. These equations will be developed by establishing a relationship between added fertilizers and soil test values.

The fertilizer prescription based on STCR model are more precise, quantitative and meaningful because it involves both plant and soil analysis. Whereas, in conventional blanket recommendation, fertilizer prescription is made without considering nutrient contribution from the soil. For balanced fertilization, Ramamoorthy *et al.* (1967) provided the scientific basis *i.e.,* yield target model which in turn gives a real balance between available nutrients already present in the soil and applied nutrients. The specific yield target equations based on the soil health ensures sustainable crop production (Bera *et al.,* 2006) and also grab the crop growers towards economic use of costly inputs especially the chemical fertilizers depending on their economic status. Venugopalan *et al.* (2011) suggested that to mitigate the decline in soil fertility problem, nutrient management practices through STCR should be adopted instead of general recommendation for better productivity, environmental safety and sustainability.

AICRP on STCR conducted many studies on development and validation of STCR equations for maize in many states even in Karnataka at Bangalore for red soils but, not for Northern Transitional Zone of Karnataka in *Vertisols*. So, the equations developed for similar type of soils (medium to deep black) at different places (Jabalpur, Jagtial, Rahuri and Coimbatore) were taken to validate under assured rainfall conditions. The equations cannot be adopted without validation study because, the equations developed elsewhere may not holds good for all the locations due to variation in soil type and climatic conditions and situations from one zone to another zone. So, the validation of the STCR fertilizer prescription equations for maize in Northern Transitional Zone of Karnataka is very much essential to identify the most suitable STCR prescription model for cultivation of maize in *Vertisols*. Hence, the present studies were under taken with a view of creating varied gradients in soil fertility in one and the same field and validation of different STCR equations for *Kharif* maize at varied soil fertility gradients.

MATERIAL AND METHODS

A field experiment was carried out at Main Agriculture Research Station (MARS), University of Agricultural Sciences, Dharwad, during 2018, which is situated at 15^{o} 26′N latitude and 75^{o} 07′ East longitude with an altitude of 678 m MSL. The rainfall during main cropping period was 462.8 mm and mean maximum and minimum temperature were 31.6 and 18.3^{o}C, respectively. A composite soil sample was collected and analysed in order to characterize the experimental soil. The soil of the experimental site was clay (medium to deep black) in texture, neutral in pH (7.4) with medium level of organic carbon (0.54 %) and electrical conductivity of 0.32 dS m^{-1}. The initial status of soil available N, P_2O_5 and K_2O was low (257 kg ha^{-1}), medium (31 kg ha^{-1}) and high (362 kg ha^{-1}), respectively.

Treatment structure, soil and plant analysis. The study comprised of two field experiments in two phases *viz.*, fertility gradient experiment with an exhaustive crop of fodder maize var. African Tall (Phase I) to create different fertility gradients within the same field and validation of the STCR equations on varied soil fertility gradients with grain maize hybrid NK-6240 (Phase II). The details of materials used, methods followed, cultural operations cried out and STCR equations adopted in the experiment are described below. The approved treatment structure and lay out design as followed in the All India Coordinated Research Project (AICRP) for Investigations on Soil Test Crop Response (STCR) correlation based on "Inductive cum Targeted yield model" as envisaged by Ramamoorthy *et al.* (1967) was adopted in the present investigation.

Gradient experiment. In the gradient experiment, operational range of variation in soil fertility was created deliberately to generate data covering appropriate range of values for each controllable variable (fertilizer dose) at different levels of uncontrollable variable (soil fertility) which could not be expected to occur at one place normally. Hence, in order to create fertility variations in the same field, a gradient experiment was conducted prior to the validation experiment.

The entire experimental field was divided into three equal strips. The first strip received no fertilizer ($N_0P_0K_0$), the second and third strips received 100 per cent ($N_1P_1K_1$) and 200 per cent ($N_2P_2K_2$) of the recommended dose of N, P_2O_5 and K_2O kg ha^{-1}, respectively. The recommended dose of fertilizer for fodder maize was 150:100:50 kg N, P_2O_5 and K_2O ha^{-1}, respectively as per the recommendation of University of Agricultural Sciences, Dharwad. After the fertilizer application (50 % N, entire P_2O_5 and K_2O as basal dose and another 50 % N as top dress at 30 DAS), the gradient crop fodder maize (SA-Tall) was grown by using seed rate @ 60 kg ha^{-1} and the usual agronomic practices were carried out. Crop was grown to milking stage and harvested. At harvest, each fertility strip (strip I, II and III) was divided into three blocks (total nine blocks). The green biomass yield of fodder maize was taken and soil samples from each block were collected separately. Soil samples were processed and analysed for alkaline $KMnO_4$ -N, Olsen-P and NH_4OAc-K for estimation of available N, P_2O_5 and K_2O, in I, II and III strips, respectively. The particulars of gradient experiment are depicted in Table 1.

Validation study. This experiment was laid out in split plot design with three main plot and six sub plot treatments. After the establishment of fertility gradient, the variation in soil fertility at three strips (strip I, II and III) was taken as main plots (L_0, L_1 and L_2 as low, medium and high fertility gradient, respectively) and STCR equations developed for *Kharif* grain maize under rainfed situation at four different locations *viz.*, Jabalpur, Jagtial, Rahuri and Coimbatore, one RDF and one absolute control as sub plot treatments for validation of STCR equations in phase II experiment. The quantity of nutrients required to achieve target yield of 80 q ha^{-1} through STCR was calculated by using four different STCR equations and is given Table 2. The STCR equations developed at different locations used in the study were taken from compendium prepared by AICRP on STCR, Indian Institute of Soil Science, Nabibagh, Bhopal (Anon., 2015) and are as follows:

Sl. No.	Location	STCR equations	Recommended for soil type	Season
1.	Jabalpur, Madhya Pradesh (MP)	FN = 4.40 T – 0.23 SN FP_2O_5 = 2.38 T – 1.40 SP FK_2O = 2.07 T – 0.08 SK	Shallow, medium and deep black soils	*Kharif*
2.	Jagtial, Andra Pradesh (AP)	FN = 4.19 T – 0.40 SN FP_2O_5 = 1.50 T – 1.55 SP FK_2O = 1.49 T- 0.16 SK	Black soils	*Kharif*
3.	Rahuri, Maharashtra (MH)	FN = 4.517 T – 0.65 SN FP_2O_5 = 1.93 T – 1.05 SP FK_2O = 2.577 T – 0.16 SK	Inceptisol and also validated for *Vertisols*	*Kharif*
4.	Coimbatore, Tamil Nadu (TN)	FN = 4.60 T – 0.55 SN FP_2O_5 = 2.25 T – 1.80 SP FK_2O = 5.16 T – 0.49 SK	Black clay loam and mixed black soils (Perianaickenpalayam series)	*Kharif*

Where,
FN = Nitrogen supplied through fertilizer in kg ha^{-1}
FP_2O_5 = Phosphorus supplied through fertilizer in kg ha^{-1}
FK_2O = Potassium supplied through fertilizer in kg ha^{-1}
T= Target yield (q ha^{-1})
SN, SP_2O_5, SK_2O = Initial soil test value for available N, P_2O_5 and K_2O in kg ha^{-1}, respectively.

The seeds of maize (NK-6240) were hand dibbled @ 22.5 kg ha^{-1} at 20 cm apart per hill in 60 cm rows to a depth of 4 to 5 cm on 23rd June 2018 and covered with soil. The recommended dose of fertilizer (RDF) for rainfed maize is 100:50:25 kg N: P_2O_5: K_2O ha^{-1}. These fertilizers were applied in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP), respectively. FYM was applied to the soil at the rate of 7.5 t ha^{-1} 15 days prior to sowing of crop. Full dose of 'P' and 'K' and one third dose of N was applied as per the treatment and zinc sulphate at the rate of 10 kg ha^{-1} as basal dose at the time of sowing. $ZnSO_4$ and FYM was common for all the treatments except absolute control. Remaining N was top dressed twice at 25 and 45 DAS @ one third each time. Experimental plot was kept free from weeds throughout the crop growing period. Atrazine was applied as a pre-emergent herbicide at the rate of 1 kg a.i. ha^{-1} immediately after sowing. One hand weeding was carried out at 30 DAS. One inter-cultivation cum earthing up operation was carried out immediately after second top dressing of N at 45 DAS. For stem borer management, Carbofuran was applied to the soil at the time of sowing at the rate of 7.5 kg ha^{-1}. For fall armyworm management chlorpyriphos was soil drenched at seedling stage, Emamectin benzoate sprayed at 35 DAS and later poison bait was applied to whorl on 31st July 2018 at the rate of 25 kg ha^{-1}. When the crop was at 65 days old *Nomuraea rileyi* (bio-agent) was sprayed against fall armyworm. Hexaconazole fungicide was sprayed against turcicum leaf blight and other foliar diseases at 80 DAS. All the growth parameters were recorded from five randomly selected plants at different growth stages of the crop. Agronomic parameters collected are plant height, number of green leaves $plant^{-1}$, leaf area, leaf area index (LAI), leaf area duration (LAD), SPAD value and stem girth at different growth stages of the crop (40 DAS, 80 DAS and at harvest stage). SPAD chlorophyll meter readings were recorded with the help of SPAD meter at middle lamella of youngest fully opened third leaf from the top at different stages (Rostami *et al.*, 2008). Diameter of the stem was measured at last but one internode from the ground with the help of Vernier caliper and stem girth (circumference) was worked out by using the formula $2\pi r$ (r = radius of the stem in cm and π = 3.142) and expressed in centimeters. Grain and stover yield from net plot area was converted into per hectare basis. The experimental data were analysed statistically as per the procedures given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of gradient experiment on green fodder yield and soil fertility status. Green fodder yield of exhaustive crop fodder maize was found to be increased from strip I to Strip III (25.53 to 40.38 t ha^{-1}) (Table 1). The increase in yield was due to application of graded levels of fertilizers from 0 to 100 and 200 % for L_0, L_1 and L_2 strips, respectively. The amount of fertilizer nutrients applied was also increased from strip I to strip III. Higher fodder maize yield recorded with strip III (40.38 t ha^{-1}) followed by strip II (34.63 t ha^{-1}) and lower fodder yield was recorded in strip I (25.53 t ha^{-1}). Higher fodder yield was mainly due to application of higher amount of nutrients for strip III (300:200:100 kg $N:P_2O_5:K_2O$ ha^{-1}) as compared to strip II (150:100:50 kg $N:P_2O_5:K_2O$ ha^{-1}). Whereas, lower fodder yield in strip I, which did not receive any fertilizer nutrients, might be the reason for recording lesser amount of green fodder yield. Similarly, the higher soil available major nutrients were recorded in strip III (339:38:406 kg $N:P_2O_5:K_2O$ ha^{-1}) as compared to strip II (180:35:335 kg $N:P_2O_5:K_2O$ ha^{-1}). The higher available nutrients in strip III was due to application of higher amount of nutrients. Further, lower soil available nutrients (NPK) were recorded in strip I (119:26:295 kg $N:P_2O_5:K_2O$ ha^{-1}). Since, no fertilizer was applied to strip I and fodder maize being an exhaustive crop sown with thick population and high growth rate might have removed greater amount of nutrients from the soil reserve for it's growth and development and rendered the soil with lesser nutrient status. These results are in line with the findings of Basavaraja *et al.* (2017); Santhi *et al.* (2011) with fodder maize and Singh *et al.* (2021) with wheat as an exhaustive crop.

Table 1: Graded doses of fertilizers, fodder yield obtained and soil test values after harvest of fodder maize in gradient experiment.

Strip	Level of fertilizers			Input applied (kg ha^{-1})			Fodder yield (t ha^{-1})	Soil test values after harvest of fodder maize (kg ha^{-1})		
				N	P_2O_5	K_2O		N	P_2O_5	K_2O
L_0- Low	N_0	P_0	K_0	00	00	00	25.53	119	26	295
L_1- Medium	N_1^*	P_1^*	K_1^*	150	100	50	34.63	180	35	335
L_2- High	N_2	P_2	K_2	300	200	100	40.38	339	38	406

* Recommended dose of fertilizers

Table 2: Amount of nutrients calculated and applied to achieve grain maize target yield of 80 q ha^{-1} in different treatments.

Treatment No.	Treatment combinations	Fertility gradients (L)	STCR equations developed at (Eq)	N	P_2O_5	K_2O
				(kg ha^{-1})		
T_1	L_0Eq_1	Low (L_0)	Jabalpur (MP)	325	154	142
T_2	L_0Eq_2		Jagtial (AP)	288	80	72
T_3	L_0Eq_3		Rahuri (MH)	284	127	158
T_4	L_0Eq_4		Coimbatore (TN)	302	133	268
T_5	L_0Eq_5		RDF	100	50	25
T_6	L_0Eq_6		Absolute control	0.00	0.00	0.00
T_7	L_1Eq_1	Medium (L_1)	Jabalpur (MP)	311	142	139
T_8	L_1Eq_2		Jagtial (AP)	263	66	66
T_9	L_1Eq_3		Rahuri (MH)	244	118	151
T_{10}	L_1Eq_4		Coimbatore (TN)	270	118	249
T_{11}	L_1Eq_5		RDF	100	50	25
T_{12}	L_1Eq_6		Absolute control	0.00	0.00	0.00
T_{13}	L_2Eq_1	High (L_2)	Jabalpur (MP)	274	137	133
T_{14}	L_2Eq_2		Jagtial (AP)	200	61	54
T_{15}	L_2Eq_3		Rahuri (MH)	141	114	139
T_{16}	L_2Eq_4		Coimbatore (TN)	182	111	214
T_{17}	L_2Eq_5		RDF	100	50	25
T_{18}	L_2Eq_6		Absolute control	0.00	0.00	0.00

Influence of soil fertility gradients on crop growth. Among the three soil fertility gradients (FGs), medium fertility gradient (MFG) recorded significantly higher grain and stover yield (82.3 and 101.2 q ha^{-1}) than low fertility gradient (LFG). However, high fertility gradient (HFG) (81.1 and 101.1 q ha^{-1}) was on par with MFG. The increase in grain yield in medium and high FG was to the tune of 5.24 and 3.84 per cent, respectively over low FG. Fertility gradients did not show any significant difference with respect to harvest index (Table 5). Growth parameters namely plant height (43.5, 190 and 195.6 cm), leaf area (19.5, 57.1 and 14 dm^2), leaf area index (1.63, 4.76 and 1.16), leaf area duration (128 and 118 between 40 to 80 DAS and 80 DAS to at harvest), SPAD value (40.2 and 48.5 at 40 and 80 DAS) and stem girth (4.49, 7.60 and 7.72 cm) observed at all the growth stages (40, 80 DAS and at harvest, respectively) of maize were significantly higher in medium FG than low FG. High FG was on par with medium FG. But, number of green leaves $plant^{-1}$ failed to show any significant difference (Table 3 and 4). Whereas, the performance of Rahuri and Coimbatore STCR equations were not so good in high FG even though the soil available status was more.

Table 3: Growth parameters of maize as influenced by nutrient management through different STCR equations at varied soil fertility gradients at different growth stages.

Treatments		Plant height (cm)			No. of green leaves $plant^{-1}$			Leaf area (LA) (dm^2 $plant^{-1}$)			Leaf area index (LAI)		
		40 DAS	80 DAS	AH	40 DAS	80 DAS	AH	40 DAS	80 DAS	AH	40 DAS	80 DAS	AH
	Soil fertility gradient (L)												
L	L_0: 119:26:295	40.7	182.9	188.7	5.5	11.4	2.5	18.3	53.2	13.0	1.52	4.43	1.08
L	L_1: 180:35:335	43.5	190.0	195.6	5.7	11.6	2.6	19.5	57.1	14.0	1.63	4.76	1.16
L	L_2: 339:38: 406	42.1	189.5	195.3	5.6	11.4	2.5	18.4	54.6	13.2	1.54	4.55	1.10
L	S.Em. ±	0.53	1.10	1.08	0.06	0.08	0.04	0.26	0.71	0.20	0.02	0.06	0.02
L	C.D. at 5 %	2.10	4.31	4.25	NS	NS	NS	1.02	2.80	0.79	0.09	0.23	0.07
	STCR equations (Eq) developed at												
Eq	Eq_1: Jabalpur (MP)	50.1	204.3	212.6	6.5	12.6	3.1	23.7	68.1	17.8	1.97	5.67	1.49
Eq	Eq_2: Jagtial (AP)	44.3	196.7	202.9	5.7	11.6	2.6	18.7	57.8	13.7	1.56	4.81	1.14
Eq	Eq_3: Rahuri (MH)	44.5	196.9	203.1	5.7	11.7	2.6	19.6	59.1	14.3	1.63	4.93	1.20
Eq	Eq_4: Coimbatore (TN)	48.1	200.5	208.6	6.2	12.2	2.9	22.0	64.4	16.4	1.83	5.36	1.37
Eq	Eq_5: RDF	36.8	178.0	180.6	5.1	10.7	2.2	16.2	45.8	10.7	1.35	3.82	0.89
Eq	Eq_6: Absolute Control	28.8	148.3	151.4	4.4	9.9	1.7	12.4	34.7	7.3	1.04	2.89	0.61
Eq	S.Em. ±	0.59	1.26	1.35	0.07	0.08	0.05	0.30	0.92	0.27	0.03	0.08	0.02
Eq	C.D. at 5 %	1.71	3.63	3.90	0.20	0.23	0.13	0.86	2.67	0.78	0.07	0.22	0.07
	Interactions (L×Eq)												
L_0	L_0Eq_1: 325:154:142	47.5	199.0	206.4	6.0	12.3	2.9	21.6	63.7	16.0	1.80	5.30	1.34
L_0	L_0Eq_2: 288:80:72	44.4	197.0	202.7	5.7	11.6	2.5	18.6	57.5	13.5	1.55	4.79	1.13
L_0	L_0Eq_3: 284:127:158	44.5	198.6	203.5	5.9	11.9	2.7	20.1	59.6	14.8	1.68	4.97	1.23
L_0	L_0Eq_4: 302:133:268	50.6	205.8	214.9	6.7	12.7	3.2	24.7	69.7	18.6	2.06	5.81	1.55
L_0	L_0Eq_5: 100:50:25	34.1	164.5	168.3	4.9	10.3	2.0	14.9	39.8	9.0	1.24	3.32	0.75
L_0	L_0Eq_6: Absolute control	23.1	132.3	136.4	4.0	9.6	1.5	9.7	28.9	5.8	0.81	2.41	0.48
L_1	L_1Eq_1: 311:142:139	52.9	210.3	217.5	6.9	12.9	3.3	25.0	72.0	18.9	2.08	6.00	1.58
L_1	L_1Eq_2: 263:66:66	44.5	197.6	203.8	5.9	11.7	2.7	19.4	58.6	14.4	1.62	4.88	1.20
L_1	L_1Eq_3: 244:118:151	46.5	198.9	205.3	5.9	12.0	2.8	20.9	62.4	15.6	1.75	5.20	1.30
L_1	L_1Eq_4: 270:118:249	49.3	199.6	207.5	6.1	12.3	2.9	22.3	65.6	16.7	1.86	5.47	1.39
L_1	L_1Eq_5: RDF	38.0	181.3	183.6	5.1	10.9	2.1	16.2	47.4	10.8	1.35	3.95	0.90
L_1	L_1Eq_6: Absolute Control	30.1	152.0	155.9	4.4	10.0	1.7	13.3	36.4	7.5	1.11	3.04	0.62
L_2	L_2Eq_1: 274:137:133	50.0	203.6	213.8	6.6	12.7	3.1	24.4	68.6	18.5	2.04	5.72	1.54
L_2	L_2Eq_2: 200:61:54	44.0	195.5	202.1	5.5	11.5	2.5	18.0	57.2	13.1	1.50	4.76	1.09
L_2	L_2Eq_3: 141:114:139	42.7	193.2	200.5	5.4	11.3	2.4	17.7	55.3	12.7	1.47	4.61	1.06
L_2	L_2Eq_4: 182:111:214	44.6	196.1	203.4	5.7	11.6	2.6	18.9	57.8	13.9	1.57	4.82	1.16
L_2	L_2Eq_5: RDF	38.2	188.2	189.7	5.3	11.1	2.3	17.4	50.2	12.2	1.45	4.18	1.02
L_2	L_2Eq_6: Absolute Control	33.2	160.4	162.1	4.9	10.2	1.9	14.3	38.7	8.7	1.19	3.23	0.72
Between two Eq at same L	S.Em. ±	1.02	2.18	2.34	0.11	0.14	0.08	0.52	1.60	0.47	0.04	0.13	0.04
Between two Eq at same L	C.D.(p= 0.05)	2.96	6.29	6.75	0.35	0.40	0.23	1.50	4.62	1.36	0.13	0.39	0.11
B/w two L at same or diff. Eq	S.Em. ±	1.08	2.27	2.39	0.12	0.15	0.08	0.54	1.63	0.47	0.05	0.14	0.04
B/w two L at same or diff. Eq	C.D.(p= 0.05)	3.39	7.11	7.42	0.39	0.49	0.25	1.69	5.02	1.46	0.14	0.42	0.12

RDF: Recommended dose of fertilizers: 100:50:25; All the fertilizers and soil test values are in kg $N:P_2O_5:K_2O$ ha^{-1}, respectively

Table 4: LAD, SPAD value and stem girth of maize as influenced by nutrient management through different STCR equations at varied soil fertility gradients at different growth stages.

Treatments		Leaf area duration (LAD) (days)		SPAD values		Stem girth (cm)		
		40 - 80 DAS	80 DAS - AH	40 DAS	80 DAS	40 DAS	80 DAS	AH
	Soil fertility gradient (L)							
L	L_0: 119:26:295	119	110	38.9	47.3	4.23	7.29	7.39
	L_1: 180:35:335	128	118	40.2	48.5	4.49	7.60	7.72
	L_2: 339:38: 406	122	113	39.7	48.0	4.33	7.42	7.53
	S.Em. ±	1.39	1.34	0.19	0.23	0.05	0.05	0.06
	C.D. at 5 %	5.44	5.28	0.75	0.91	0.19	0.21	0.24
	STCR equations (Eq) developed at							
Eq	Eq_1: Jabalpur (MP)	153	143	45.0	54.2	5.21	8.44	8.60
	Eq_2: Jagtial (AP)	127	119	42.2	50.7	4.52	7.64	7.76
	Eq_3: Rahuri (MH)	131	122	42.6	51.1	4.55	7.64	7.77
	Eq_4: Coimbatore (TN)	144	135	44.1	53.0	4.95	8.15	8.28
	Eq_5: RDF	103	94	36.9	44.8	3.87	6.90	6.97
	Eq_6: Absolute Control	79	70	26.9	33.8	3.00	5.87	5.90
	S.Em. ±	1.60	1.69	0.25	0.26	0.07	0.07	0.07
	C.D. at 5 %	4.63	4.89	0.71	0.76	0.19	0.20	0.21
	Interactions (L×Eq)							
L_0	L_0Eq_1: 325:154:142	142	133	44.6	53.1	4.74	7.86	8.01
	L_0Eq_2: 288:80:72	127	118	42.3	50.9	4.49	7.61	7.74
	L_0Eq_3: 284:127:158	133	124	43.4	52.0	4.64	7.75	7.88
	L_0Eq_4: 302:133:268	157	147	45.2	54.7	5.34	8.67	8.83
	L_0Eq_5: 100:50:25	91	81	33.8	42.3	3.43	6.32	6.34
	L_0Eq_6: Absolute control	64	58	24.2	30.8	2.75	5.52	5.55
L_1	L_1Eq_1: 311:142:139	162	152	45.3	54.9	5.62	8.91	9.06
	L_1Eq_2: 263:66:66	130	122	42.7	51.3	4.59	7.71	7.84
	L_1Eq_3: 244:118:151	139	130	43.8	52.4	4.68	7.81	7.96
	L_1Eq_4: 270:118:249	147	137	44.8	53.3	5.01	8.13	8.26
	L_1Eq_5: RDF	106	97	37.6	45.8	4.00	7.09	7.20
	L_1Eq_6: Absolute Control	83	73	27.0	33.6	3.01	5.96	5.98
L_2	L_2Eq_1: 274:137:133	155	145	45.0	54.6	5.28	8.55	8.71
	L_2Eq_2: 200:61:54	125	117	41.5	50.1	4.46	7.58	7.71
	L_2Eq_3: 141:114:139	122	113	40.4	49.0	4.32	7.35	7.47
	L_2Eq_4: 182:111:214	128	120	42.4	51.0	4.50	7.64	7.76
	L_2Eq_5: RDF	113	104	39.2	46.4	4.18	7.27	7.38
	L_2Eq_6: Absolute Control	88	79	29.6	37.2	3.24	6.13	6.16
Between two Eq at same L	S.Em. ±	2.78	2.93	0.42	0.46	0.11	0.12	0.12
	C.D. (p= 0.05)	8.02	8.47	1.23	1.32	0.33	0.35	0.36
Between two L at same or diff. Eq	S.Em. ±	2.89	3.00	0.43	0.48	0.11	0.12	0.13
	C.D. (p= 0.05)	9.03	9.28	1.34	1.50	0.35	0.38	0.40

RDF: Recommended dose of fertilizers: 100:50:25 kg N:P_2O_5: K_2O ha^{-1}

All the fertilizers and soil test values are in kg N:P_2O_5: K_2O ha^{-1}, respectively

This was mainly due to decreased levels of applied fertilizer nitrogen with respect to Coimbatore and Rahuri equations. The lesser performance of these two equations has led to lesser mean value of main plot (HFG) over MFG. The nutrient contribution from the soil is less as compared to applied mineral fertilizers especially the nitrogen. Giri *et al.* (2015) observed lesser nutrient (N, P_2O_5 and K_2O) contribution from soil to total uptake of maize crop over applied fertilizers during development of STCR equations and similar results were also obtained by Basavaraja *et al.* (2016) in rice crop, Basavaraja *et al.* (2017) in finger millet for both the years, Praveena *et al.* (2013) in cotton and Singh *et al.* (2021) in direct seeded rice.

Performance of different STCR equations. Among different STCR equations, application of nutrients as per the STCR equation developed at Jabalpur produced higher grain and stover yield (101.4 and 120.9 q ha^{-1}) than all other equations. The increase in grain yield was to the tune of 54.1 per cent over RDF and 12.91, 10.33 and 4 per cent over Jagtial, Rahuri and Coimbatore STCR equations (Table 5). Significantly higher growth parameters namely plant height (50.1, 204.3 and 212.6 cm), number of green leaves $plant^{-1}$ (6.51, 12.6 and 3.1), leaf area (23.7, 68.1 and 17.8 dm^2), leaf area index (1.97, 5.67 and 1.49), leaf area duration (153 and 143 between 40-80 DAS and 80 DAS-at harvest, respectively), SPAD values (45.0 and 54.2 at 40 and 80 DAS respectively) and stem girth (5.21, 8.44 and 8.60 cm) observed with Jabalpur STCR equation at all growth stages (40, 80 DAS and at harvest, respectively) of maize than other equations and RDF as well as absolute control (Table 3 and 4). The higher grain and stover yield was mainly due to better translocation of photosynthates from source to sink and higher growth parameters and yield attributing characters like cob length, cob girth, grain rows per cob, grains per row, grains per cob, grain weight per cob, test weight and shelling percentage. The above results clearly indicate the importance of nutrient application precisely to achieve specific yield targets. Application of higher levels of inorganic fertilizers have increased the above ground biomass as well as grain yield of maize (Amouzou *et al.*, 2018). These results are in line with those obtained by Basavaraja *et al.* (2014); Ghodke (2013); Singh *et al.* (2015) in grain maize and Kanchana *et al.* (2020) in pearl millet.

Interaction effect of soil fertility gradients and STCR equations developed at different centres. The interaction between two STCR equations at same fertility gradient (FG), nutrients applied as per Coimbatore STCR equation recorded higher grain and stover yield (104.1 and 123 q ha^{-1}) and growth parameters in LFG. But, at medium and high FG, higher grain (105.1 and 101.4 q ha^{-1}, respectively) and stover (124.1 and 121.4 q ha^{-1} respectively) yield and all the growth parameters were recorded with STCR equation developed at Jabalpur.

Table 5: Grain and stover yield and harvest index of maize as influenced by nutrient management through different STCR equations at varied soil fertility gradients

Treatments			Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index (HI)
	Soil fertility gradient (L)				
L	L_0: 119:26:295		78.1	96.6	44.2
	L_1: 180:35:335		82.3	101.2	44.6
	L_2: 339:38: 406		81.1	101.1	44.3
	S.Em. ±		0.79	0.99	0.16
	C.D. at 5 %		3.09	3.90	NS
	STCR equations (Eq) developed at				
Eq	Eq_1: Jabalpur (MP)		101.4	120.9	45.6
	Eq_2: Jagtial (AP)		89.8	111.7	44.6
	Eq_3: Rahuri (MH)		91.9	113.4	44.8
	Eq_4: Coimbatore (TN)		97.6	117.6	45.3
	Eq_5: RDF		65.8	84.1	43.9
	Eq_6: Absolute Control		36.6	50.1	42.1
	S.Em. ±		0.90	1.12	0.23
	C.D. at 5 %		2.60	3.24	0.67
	Interaction (L×Eq)				
L_0	L_0Eq_1: 325:154:142		97.5	117.3	45.4
	L_0Eq_2: 288:80:72		90.1	111.9	44.6
	L_0Eq_3: 284:127:158		93.4	114.8	44.9
	L_0Eq_4: 302:133:268		104.1	123.0	45.8
	L_0Eq_5: 100:50:25		56.4	73.0	43.6
	L_0Eq_6: Absolute control		27.2	39.3	40.8
L_1	L_1Eq_1: 311:142:139		105.1	124.1	45.9
	L_1Eq_2: 263:66:66		91.2	113.2	44.6
	L_1Eq_3: 244:118:151		94.4	115.8	44.9
	L_1Eq_4: 270:118:249		98.4	117.7	45.5
	L_1Eq_5: RDF		68.3	87.0	43.9
	L_1Eq_6: Absolute Control		36.6	49.2	42.6
L_2	L_2Eq_1: 274:137:133		101.4	121.4	45.5
	L_2Eq_2: 200:61:54		88.3	109.9	44.5
	L_2Eq_3: 141:114:139		87.9	109.5	44.5
	L_2Eq_4: 182:111:214		90.3	112.1	44.6
	L_2Eq_5: RDF		72.6	92.2	44.1
	L_2Eq_6: Absolute Control		46.1	61.7	42.7
Between two Eq at same L		S.Em. ±	1.56	1.94	0.40
		C.D. (p= 0.05)	4.51	5.61	NS
Between two L at same or diff. Eq		S.Em. ±	1.63	2.03	0.40
		C.D. (p= 0.05)	5.10	6.37	NS

Target yield: 80 q ha^{-1} RDF: Recommended dose of fertilizers: 100:50:25 kg N:P_2O_5: K_2O ha^{-1}
NS- Non-significant All the fertilizers and soil test values are in kg N:P_2O_5: K_2O ha^{-1}, respectively

The increase in grain yield in best treatment was to the extent of 84.57, 53.87 and 39.66 per cent over RDF and 282.72, 187.15 and 119.95 per cent over absolute control in low, medium and high FG, respectively (Table 5). The interaction between fertility gradient with same or different STCR equations was also found to be significant. STCR equation developed at Jabalpur (MP) in MFG produced higher grain and stover yield (105.1 and 124.1 q ha^{-1}) than all other treatment combinations. However, the same equation in HFG (101.4 and 121.4 q ha^{-1}) and equation developed at Coimbatore in LFG (104.1 and 123 q ha^{-1}), respectively were on par with Jabalpur STCR equation in MFG. Interaction study failed to show any significant difference with respect to harvest index. The growth parameters were also higher with Jabalpur STCR equation at MFG as depicted in Table 3 and 4. This was due to higher N and P application through Jabalpur STCR equation with optimum doses of K_2O fertilizers. Further, the increased trend in all growth parameters and yield was observed with RDF and absolute control from low to high fertility gradient. It clearly indicated the variation in soil fertility gradients. When we apply same doses of fertilizer to different soil FGs, the grain yield increases with increasing soil fertility gradients. These results are in accordance with the findings of Giri *et al.* (2015); Singh *et al.* (2015); Singh *et al.* (2021).

CONCLUSION

Application of nutrients as per the STCR equation developed at Coimbatore (FN = 4.60 T – 0.55 SN, FP_2O_5 = 2.25 T – 1.80 SP and FK_2O = 5.16 T – 0.49 SK for fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively) for low fertility gradient and Jabalpur STCR equation (FN = 4.40 T – 0.23 SN, FP_2O_5 = 2.38 T – 1.40 SP and FK_2O = 2.07 T – 0.08 SK for fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively) for medium and high fertility gradients were found to be appropriate or adoptable STCR equations for maize crop for obtaining higher growth and yield as compared to other STCR equations and RDF as well as absolute control in Northern Transitional Zone of Karnataka (ACZ - 8).

Acknowledgement. The author expresses sincere gratitude to Department of Agronomy, University of Agricultural Sciences, Dharwad for extending the field and lab facilities for conducting experiment.
Conflict of Interest. None.

REFERENCES

Amouzou, K. A., Jesse, B. N., John, P. A. L. and Mathias, B. (2018). Productivity and nutrient use efficiency of maize, sorghum, and cotton in the West African Dry Savanna. *Journal of Plant Nutrition and Soil Science, 181*: 261–274.

Anonymous (2015). Compendium on four decades of soil test crop response research-crop wise recommendations. AICRP on STCR correlation, Indian Institute of Soil Science, Nabibagh, Berasia road, Bhopal.

Anonymous (2021). Agricultural statistics at a glance. Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. pp. 1-272.

Basavaraja, P. K., Kumar, N., Nethradhani raj, C. R. and Yogendra, N. D. (2014). Effect of soil test-based fertilizer application on yield and nutrient uptake by hybrid maize under dryland conditions. *The Mysore Journal of Agricultural Sciences, 48*(4): 514-521.

Basavaraja, P. K., Mohamed Saqeebulla, H. and Dey, P. (2017). Integrated fertilizer prescription equations for finger millet (*Eleusine coracana* L.) through inductive cum targeted yield model on an *Alfisols*. *International Journal of Current Microbiology and Applied Sciences, 6*(7): 2571-2580.

Basavaraja, P. K., Mohamed Saqeebulla, H., Dey, P. and Prakash, S. S. (2016). Fertilizer prescription equations for targeted yield of rice (*Oryza sativa* L.) and their validation under aerobic condition. *International Journal of Agricultural Sciences, 8*(4): 1003-1008.

Bera, R., Seal, A., Bhattacharyya, P., Dass, T. H., Sarkar, D. and Kangjoo, K. (2006). Targeted yield concept and framework of fertilizer recommendation in irrigated rice domains of subtropical India. *Journal of Zhejiang University SCIENCE B - Biomedicine & Biotechnology, 7*(12): 963-968.

Ghodke, P. D. (2013). Validation of fertilizer prescription equations of *Kharif* grain maize in different soil orders. *Ph.D. (Agri.) Thesis*, MPKV, Rahuri, Maharashtra (India).

Giri, Y. Y., Ramana Reddy, D. V. and Balaguruvaiah, D. (2015). Soil test-based fertilizer recommendations for yield targets of *Kharif* Maize under *Alfisols*. *Journal of Pharmaceutical, Chemical and Biological Sciences, 2*(4): 270-274.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for agricultural research. IRRI, Willey-Inter Science publications, New York, USA, pp.130-150.

Kanchana B., Santhi, R., Maragatham, S. and Chandrasekhar, C. N. (2020). Validation of inductive cum targeted yield model based fertiliser prescription equations for pearl millet (*var.* CO 10) on *Inceptisol. Madras Agricultural Journal, 107*(4-6): 1-6.

Praveena K. S., Santhi, R., Maragatham, S., Natesan, R., Ravikumar, V. and Dey. P. (2013). Soil test based fertilizer prescription through inductive cum targeted yield model for transgenic cotton on Inceptisols. *Journal of Agriculture and Veterinary Science, 6*(5): 36-44.

Ramakrishna P. V. R., Munawery and Atheefa (2012). Sustainable soil nutrient management. *Journal of the Indian Institute of Science, 92*: 1-8.

Ramamoorthy, B., Narasimham, R. K. and Dinesh, R. S. (1967). Fertilizer application for specific yield targets on Sonara 64 (wheat*). Indian Farming, 17*: 43-45.

Ray, P. K., Jana, A. K., Mitra, D. N., Saha, M. N., Chaudhary, J., Saha, S. and Saha, A. R. (2000). Fertilizer prescription on soil test basis for jute, rice and wheat in a Typic Ustochrept. *Journal of the Indian Society of Soil Science, 48*: 79-84.

Rostami, M., Koocheki, A. R., Mahallati, M. N. and Kafi, M. (2008). Evaluation of chlorophyll meter (SPAD) data for prediction of nitrogen status in corn (*Zea mays* L.). *American- Eurasian Journal of Agricultural and Environmental Sci*ence, *3*(1): 79-85.

Santhi, R., Bhaskaran, A. and Natesan, R. (2011). Integrated fertilizer prescriptions for beetroot through inductive cum targeted yield model on an Alfisol. *Communications in Soil Science and Plant Analysis, 42*: 1-8.

Singh, V. K., Gautam, P., Nanda, G., Dhaliwal, S. S., Pramanick, B., Meena, S. S., ... & Hossain, A. (2021). Soil test based fertilizer application improves productivity, profitability and nutrient use efficiency of rice (*Oryza sativa* L.) under direct seeded condition. *Agronomy*, *11*(9), 1756.

Singh, Y. V., Parihar, M., Singh, S. K., Sharma, P. K. and Dey, P. (2015). Soil test-based fertilizer prescription under integrated plant nutrient management system for maize in an Inceptisols of Varanasi. *Journal of the Indian Society of Soil Science, 63*(1): 83-87.

Venugopalan, M. V., Blaise, D., Yadav, M. S. and Deshmukh, R. (2011). Fertilizer response and nutrient management strategies for cotton. *Indian Journal of Fertilisers, 7*(4): 82-94.

How to cite this article: Roopa K. Muttappanavar, C.P. Chandrashekara and M.P. Potdar (2022). Growth and Yield of Maize (*Zea mays* L.) as Influenced by Nutrient Management through Soil Test Crop Response (STCR) Approach at varied Soil Fertility Gradients in *Vertisols*. *Biological Forum – An International Journal, 14*(2): 1314-1322.