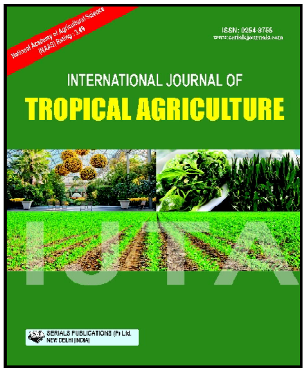

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Soil test based fertilizer prescription equation for targeted yield of dry chilli under Alfisols of eastern dry zone of Karnataka

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Abstract: Soil test crop response (STCR) study was conducted during *kharif* 2015-2016 in red soils of Zonal Agricultural Research Station, GKVK, Bengaluru, Karnataka to develop targeted yield equation for dry chilli (v. Arka Lohith) under dry land condition. The basic data required for making the fertilizer prescriptions *viz.,* nutrient requirement (NR), contribution of nutrients from soil (CS), fertilizer (CF) and organic manure (C-OM) were computed for N, P and K using the main field experimental data. Making use of these basic parameters, the fertilizer prescription equations were developed for the desired yield targets of dry chilli for a range of soil test values. As compared to inorganics alone the magnitude of response was higher under IPNS approach. With increasing soil fertility levels with reference to NPK, the per cent reduction in NPK fertilizers also increased. In comparison to STL method, STCR approach was found superior for efficient use of fertilizer nutrients without any wastage.

Key words: Dry chilli, STCR, STL, Targeted yield equation

INTRODUCTION

Fertilizers play a key role in increasing agricultural production as the crop yields may be increased considerably by appropriate doses of fertilizers. Soil test based fertilizer recommendations results in efficient fertilizer use and maintenance of soil fertility. Among the various methods of fertilizer recommendations, the one based on yield target (Ramamoorthy *et al*., 1967) [1] is unique as this not only indicates soil test based fertilizer dose but also the level of yield that can be obtained if appropriate practices are followed in raising the crop. Targeted yield approach also provides scientific basis for balanced fertilization not only between the nutrients from the external sources but also with soil available nutrients.

Chilli (*Capsicum annuum* L.) popularly known as "King of spices" is one of the important commercial crops of India. It originated in Latin American regions of the New Mexico and Guatemala as a wild crop around 7500BC. Chilli occupies an important place in Indian diet, which is an indispensable item in the kitchen as it is consumed daily as a condiment in one form or the other. Among the spices consumed per head, dried chilli fruits constitute a major share. India is the world's largest producer, consumer and exporter of chillies in the world. Indian share in global production is 50 to 60 per cent. It contributes one fourth of world's production of chilli and is mainly grown in Andhra Pradesh, Karnataka, Tamil Nadu and Orissa. Karnataka has 20 per cent of the total area under chillies in India but, its output is only 9 per cent of total production of the country. Reports shows that current productivity levels of chilli are far below the satisfactory level to meet domestic demands. Optimum and balanced fertilization is the key for sustainable higher production. Fertilizer doses affect the yield and quality of chillies. This necessitates the remodeling of our approach to the problem of economic and judicious use of fertilizers based on soil test and plant uptake values. Hence, a present study has been taken on Alfisols of Southern Karnataka for dry chilli crop under dryland condition to develop a STCR targeted yield equation with a farmers friendly ready reckoner.

MATERIAL AND METHODS

A field experiment with dry chilli (v. Arka Lohith) was conducted during *kharif* 2015-16 under Alfisols (*Kandic paleustalfs*) of Zonal Agricultural Research Station (ZARS), GKVK, Bangalore to develop a targeted yield equation. The soil of the experimental site was sandy loam in texture with pH 6.13, electrical conductivity was 0.23 dSm^{-1}. The Initial soil organic carbon was 0.51 per cent, available alkaline potassium permanganate ($KMnO_4$-N) nitrogen, available Bray's phosphorus (P_2O_5) and ammonium acetate extractable potassium (K_2O) were 181.38 (low), 90.85 (high) and 187.20 (medium) kg ha^{-1} respectively.

Three strips of fertility gradients, *viz*., low, medium and high (with respect to available nitrogen, phosphorus and potassium) were developed by taking fodder maize as the exhaustive crop. The fertility variation was deliberately created by dividing the field into three equal strips (L_1, L_2 and L_3) which were applied with ½ dose (50, 25 and 25 kg NPK ha^{-1}), standard dose (100, 50 and 50 kg NPK ha^{-1}) and 1½ dose (150, 75 and 75 kg NPK ha^{-1}) in L_1, L_2 and L_3 strip respectively. The fodder maize was harvested at 60 DAS. During harvest of maize, fodder yield was recorded and soil samples were collected for analysing major nutrients to check the development of fertility gradient in the same field. In this fertility gradient developed plot, the main experiment was conducted with chilli crop by dividing each fertility strip into three blocks of FYM taking seven different NPK combinations + 1 absolute control in each FYM block. So, a total of 21 treatments of NPK combinations and 3 controls were imposed in each strip, making a total of 72 plots from three strips. From all these plots, initial soil samples were collected (0-20 cm) for NPK analysis.

Chilli crop was taken as test crop with four levels of N (0, 50, 100 and 150 kg ha^{-1}), P_2O_5 (0, 25, 50 and 75 kg ha^{-1}) and K_2O (0, 25, 50 and 75 kg ha^{-1}) and three levels of FYM (0, 25 and 50 t ha^{-1}). Half dose of N fertilizer along with full dose of P and K were applied to chilli crop at the time of transplanting and remaining half dose of N was applied at 30 DAT as per package of practice (POP).The crop was raised as per the standard POP. Ripened chilli fruits and biomass yield were recorded from all the plots, and expressed in kg ha^{-1}. Representative plant and fruit samples were collected from all the plots and were dried at 60^0 C to attain a constant weight, ground and analysed for nitrogen, phosphorus and potassium contents by following standard procedures outlined by Jackson (1973) [2] and total nutrient uptake was computed. Initial soil data, dry chilli yield, plant biomass yield and nutrient uptake by chilli crop were used for calculating the four important basic parameters *viz.,* nutrient required to produce a quintal of dry chilli yield (NR), per cent contribution of nutrients from soil (% CS), per cent contribution of nutrients from fertilizers (% CF) and per cent contribution of nutrients from organic matter (C-OM) using following formulae (Ramamoorthy *et al.,* 1967) [1].

$$NR\,(kg\,q^{-1}) = \frac{Nutrient\ uptake\,(NPK)\,(kg\,ha^{-1})\ by\ fruit + stalk}{Fruit\ yield\ or\ any\ economic\ produce\,(q\,ha^{-1})}$$

$$\%CS = \frac{Nutrient\ uptake\,(NPK)\,(kg\,ha^{-1})\ by\ fruit + stalk\ in\ control\ plot}{Soil\ test\ values\,(Av.NPK)\ in\ control\ plot\,(kg\,ha^{-1})} \times 100$$

$$\%CF = \frac{\{Nutrient\ uptake\ by\ fruit + stalk\ in\ treated\ plot\} - \left\{\frac{[Soil\ test\ values\ in\ treated\ plot] \times [\%Contribution\,(NPK)\ from\ soil]}{100}\right.}{Nutrient\ doses\ applied\ in\ treated\ plot\,(kg\,ha^{-1})} \times 100$$

$$\%C-OM = \frac{\{Total\ uptake\ of\ NPK\ in\ organic\ plot\,(kg\,ha^{-1})\} - \left\{\frac{[Soil\ test\ values\ in\ organic\ plot] \times [\%Contribution\,(NPK)\ from\ soil)]}{100}\right.}{Amount\ of\ organic\ manure\ added\ in\ organic\ plots\,(kg\,ha^{-1})} \times 100$$

These basic parameters were transformed into simple, workable fertilizer adjustment equations for calculating specific yield target based on soil test values by following the procedure of Ramamoorthy *et al.* (1967) [1].

RESULTS AND DISCUSSION

The data on initial nutrient status is presented in Table 1. Mean values of Alkaline $KMnO_4$-N, Bray's-P and NH_4OAc-K was 193.56, 201.06, 205.84 kg ha^{-1} for N; 100.55, 110.64 and 145.55 kg ha^{-1} for P_2O_5 and 55.83, 93.02, 99.78 kg ha for K_2O in strip I, II and III respectively. The soil available NPK values increased with increase in fertilizer doses in gradient study which indicated that the establishment of marked fertility gradient by application of graded doses of fertilizers and FYM. Such extent of gradient build up has also been reported by Rawat *et al.* (2015) [3] with a preliminary oats crop in Mollisols and Durga *et al.* (2017) [4] with marigold in an Inceptisols.

Range and mean values of dry chilli yield and NPK uptake by chilli crop (Table 1) revealed that the highest output and nutrient uptake were obtained from strip III followed by strip II and lowest in strip I. Mean dry chilli yield from over all plots were in the ascending order of 680, 750 and 1260 kg ha^{-1} in strip I, II and III respectively. The N uptake in strip I, II and III ranged respectively from 3.86 to 41.07, 8.64 to 39.81 and 15.58 to 60.56 with the mean values of 19.42, 20.17 and 24.01 kg ha^{-1}. The P uptake ranged from 1.73 to 20.40 kg ha^{-1}with a mean of 9.70 kg ha^{-1} in strip I, from 3.96 to 21.82 kg ha^{-1} with a mean of 11.70 kg ha^{-1} in strip II and from 10.53 to 34.97 kg ha^{-1} with a mean of 13.03 kg ha^{-1} in strip III. The K uptake ranged from 3.54 to 44.82, 9.51 to 53.37 and 23.80 to 87.16 kg ha^{-1} with mean values of 18.88, 21.72 and 30.33 kg ha^{-1} respectively in strip I, II and III. The above results showed that a wide variability existed in the soil test values, grain yield and nutrient uptake among the strips and treatments which is a pre-requisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertilizer doses for specific yield targets.

Optimization of nutrients is highly essential to explore the genetic potential of the crop which is based on the contribution of applied nutrients and indigenous soil supplying capacity (Durga *et al.* 2017 [4]; Katharine *et al.* 2013 [5]). Nutrient requirement to produce one quintal of dry chilli was computed as 0.848 kg of N, 0.274 kg of P_2O_5 and 0.399 kg of K_2O (Table 2). From this study it was observed that chilli requires 68 times more of nitrogen and 31 times more of potassium in comparison with phosphorous. Durga *et al.* (2017) [4] reported that marigold requires 7 times more of potassium and 6.57 times more of nitrogen in comparison with phosphorous. These results were also in conformity with findings of Mahajan *et al.* (2014) [6]. Contribution of nutrients estimated from fertilizer was computed as 5.466, 4.259 and 5.475 per cent of N, P_2O_5 and K_2O respectively towards the total uptake by dry chilli. Order of percentage contribution of fertilizer nutrient to total nutrient uptake was observed as K>N>P which is in close conformity with Jadhav *et al*. (2013) [7] with garlic in an Inceptisols. Contribution of soil nutrients towards uptake was 0.945, 2.197 and 0.846 percent of N, P_2O_5 and K_2O respectively. These results indicate that nutrient contribution from fertilizer sources was greater than the soil source. Meena *et al.* (2001) [8] indicated that nutrient contributions from the fertilizer sources were greater than those from the soil source and fertilizer doses required for attaining a specific yield target of onion decreased with increasing soil test values. Present findings also closely accorded with those reported by Ray *et al.* (2000) [9]. Higher contribution of N from organic matter (3.408 %) might be due to enough carbon from FYM for buildup of bacterial population to enhance N availability and these findings are in conformity with Ahmed *et al.* (2015) [10] and Vijayalakshmi (2008) [11]. Sizable contribution of NPK requirement through FYM was noticed towards the crop requirement which helps in saving of nutrients to be applied through costly fertilizers.

Fertilizer prescription equations for dry chilli crop under dryland condition

By relating the basic parameters obtained from the main experiment, soil test based fertilizer prescription equations were formulated as below to obtain desired yield target of dry chilli crop.

NPK alone – Inorganic equation

F.N = 15.50608 T – 0.17297 STV ($KMnO_4$-N)

F.P_2O_5 = 6.43276 T – 0.51573 STV (Bray's P_2O_5)

F.K_2O = 7.29618 T – 0.15454 STV (Am. Ac.K_2O)

NPK with organic matter – IPNS equation

F.N = 15.50608 T – 0.17297 STV ($KMnO_4$-N) – 0.62342OM

F.P_2O_5 = 6.43276 T – 0.51573 STV (Bray's P_2O_5) – 0.30331OM

F.K_2O = 7.29618 T – 0.15454 STV (Am. Ac.K_2O) – 0.265326OM

Where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg ha^{-1} respectively; T is the yield target in q ha^{-1}; SN, SP and SK are alkaline $KMnO_4$-N, Bray's-P_2O_5 and NH_4OAc-K in kg ha^{-1} respectively and OM is organic matter in kg ha^{-1}. Using the above equations, a farmer-friendly ready reckoner was formulated for a range of soil test values and desired yield targets of dry chilli with chemical fertilizers alone as well as in combination with FYM (Table 3).

For achieving a yield target of 10 q $ha^{-1}$of dry chilli with soil test values of 280: 23: 130 kg ha^{-1} of $KMnO_4$- N, Bray's-P and NH_4OAc-K, the fertilizer N, P_2O_5 and K_2O doses required are 106.63, 52.47 and 52.87 kg ha^{-1} respectively when no FYM was applied. However, for the same soil test values and the same yield target, 91.04, 44.88 and 46.24 kg ha^{-1}

of fertilizer N, P_2O_5 and K_2O, respectively were required with 25 tones FYM ha^{-1} (Table 3). Similarly, when the soil test values are 560.00, 52.00 and 300.00 kg ha^{-1} of N, P_2O_5 and K_2O respectively, the fertilizer NPK nutrients required for the same target yield (10 q ha^{-1}) are 42.61, 29.93 and 19.97 kg ha^{-1} respectively with 25 t ha^{-1} of FYM. Therefore, targeted yield equations generated from STCR-IPNS technology ensures not only sustainable crop production but also economic use of costly fertilizer inputs. Under IPNS approach the required dose of fertilizer nutrient is low due to nutrient availability increased by FYM through mineralization. Santhi *et al*. (2011) [12] reported that under integrated plant nutrient system, required dose of fertilizer to achieve desired yield target are reduced. Similar results were also reported by Ahmed *et al.* (2015) [10] and Durga *et al.* (2017) [4]. These results clearly showed that the fertilizer requirements varied with the soil test values for the same level of crop production. Hence, balanced fertilization through soil testing becomes essential for increasing crop production. The variation in nutrients application to be made are 15.50 kg N ha^{-1}, 6.43 kg P_2O_5 ha^{-1} and 7.29 kg K_2O ha^{-1} to increase or decrease one quintal (10 ± 1 q ha^{-1}) of dry chilli yield from values of fertilizer nutrients required to produce specific yield target. Similar variations in nutrient doses were recorded by Basavaraja *et al.* (2017) [13] for dryland finger millet with targeted yield of 35 q ha^{-1}.

Table 1
Initial soil available NPK, dry chilli yield and NPK uptake by chilli crop under dry land condition in various strips (kg ha^{-1})

Strip		*Initial soil test values (kg ha^{-1})*			*Yield (kg ha^{-1})*		*Uptake (kg ha^{-1})*		
		$KMnO_4$ - N	*Bray's P_2O_5*	*NH_4OAc - K_2O*	*Dry chilli yield*	*Stalk yield*	*N*	*P*	*K*
I	**Min**	134.77	39.43	43.20	150	24.86	3.86	1.73	3.54
	Max	212.07	187.39	108.00	1530	465.30	41.07	20.40	44.82
	Mean	**193.56**	**100.55**	**55.83**	**680**	**208.02**	**19.42**	**9.70**	**18.88**
II	**Min**	175.37	39.43	58.80	700	77.81	8.64	3.96	9.51
	Max	217.96	249.33	186.00	1450	498.85	39.81	21.82	53.37
	Mean	**201.06**	**110.64**	**93.02**	**750**	**273.38**	**20.17**	**11.70**	**21.72**
III	**Min**	192.85	63.60	43.20	650	137.38	15.58	10.53	23.80
	Max	217.96	268.41	225.60	2400	671.15	60.56	34.97	87.16
	Mean	**205.84**	**145.55**	**99.78**	**1260**	**443.35**	**24.01**	**13.03**	**30.33**

Table 2
Nutrient requirement and per cent contribution of nutrients from soil, fertilizers and organic matter for dry chilli

Parameters	*Basic data*		
	N	*P_2O_5*	*K_2O*
Nutrient requirement (NR) (kg q^{-1})	0.848	0.274	0.399
Contribution from soil (CS) (%)	0.945	2.197	0.846
Contribution from fertilizers (CF) (%)	5.466	4.259	5.475
Contribution from organic matter (C-OM) (%)	3.408	1.292	1.452

Table 3

Ready reckoner of soil test based fertilizer recommendations of N, P and K for 10 q ha^{-1} of dry chilli yield with and without farmyard manure @ 25 tones ha^{-1}

STV $KMnO_4$-N	*Only Inorganics F. N. Req.*	*With 25 tha^{-1} FYM F. N. Req.*	*STV P_2O_5*	*Only inorganics F. P_2O_5. Req.*	*With 25 t ha^{-1} FYM F. P_2O_5. Req.*	*STV K_2O*	*Only inorganics F. K_2O. Req.*	*With 25 t ha^{-1} FYM F. K_2O. Req.*
250.00	111.82	96.23	**15.00**	56.59	49.01	**110.00**	55.96	49.33
260.00	110.09	94.50	**17.00**	55.56	47.98	**120.00**	54.42	47.79
280.00	106.63	91.04	**19.00**	54.53	46.95	**125.00**	53.64	47.01
290.00	104.90	89.31	**21.00**	53.50	45.91	**130.00**	52.87	46.24
300.00	103.17	87.59	**23.00**	52.47	44.88	**140.00**	51.33	44.69
320.00	99.71	84.13	**25.00**	51.43	43.85	**150.00**	49.78	43.15
340.00	96.25	80.67	**30.00**	48.86	41.27	**160.00**	48.24	41.60
400.00	85.87	70.29	**32.00**	47.82	40.24	**170.00**	46.69	40.06
440.00	78.96	63.37	**35.00**	46.28	38.69	**180.00**	45.14	38.51
480.00	72.04	56.45	**38.00**	44.73	37.15	**200.00**	42.05	35.42
520.00	65.12	49.53	**41.00**	43.18	35.60	**220.00**	38.96	32.33
560.00	58.20	42.61	**44.00**	41.64	34.05	**240.00**	35.87	29.24
600.00	51.28	35.69	**46.00**	40.60	33.02	**260.00**	32.78	26.15
			47.00	40.09	32.51	**280.00**	29.69	23.06
			50.00	38.54	30.96	**300.00**	26.60	19.97
			52.00	37.51	29.93	**320.00**	23.51	16.88
			54.00	36.48	28.90	**340.00**	20.42	13.79
			58.00	34.42	26.83	**440.00**	4.96	-1.67
			62.00	32.35	24.77		0.00	

To increase or decrease the yield target by one q ha-1, the variations to be made in the fertilizer recommendations are as follows

N = ± 15.50 kg ha^{-1} P_2O_5 = ± 6.43 kg ha^{-1} K_2O = ± 7.29 kg ha^{-1}

The amount of fertilizer nitrogen, phosphorus and potassium required for a fixed yield target of 10 q ha^{-1} with 25 tons FYM ha^{-1} based on STCR and STL (Soil test laboratory) method of fertilizer prescription is presented in Table 4. As per STL recommendation fertilizer nitrogen required to obtain the yield target of 10 q ha^{-1} dry chilli is 100.00 kg ha^{-1} if the soil test value is in medium range (280.00 and 560.00 kg N ha^{-1}), whereas in STCR approach, at lower soil nitrogen level (280.00 kg N ha^{-1}), fertilizer N required for the same yield target (10 q ha^{-1}) is 91.04 kg ha^{-1}. At higher soil test value of 560.00 kg soil nitrogen, just 42.61 kg of fertilizer nitrogen is needed to achieve the same yield target. Similarly, for soil test values of medium range (23.00 to 52.00 kg P_2O_5 ha^{-1}), amount of fertilizer phosphorus recommended as per STL is 50.00 kg ha^{-1}; But, in the STCR approach, 44.88 kg of fertilizer phosphorus is recommended (Table 4) when soil test value is 23.00 kg P_2O_5 ha^{-1}, whereas at 52.00 kg ha^{-1}

Table 4
Comparison of STCR and STL approach of fertilizer application for dry chilli yield target of 10 q ha^{-1} under dry land condition

STV $KMnO_4$-N	*STCR F. N. Req.*	*STL F. N. Req.*	*STV P_2O_5*	*STCR F. P_2O_5 Req.*	*STL F. P_2O_5 Req.*	*STV K_2O*	*STCR F. K_2O. Req.*	*STL F. K_2O. Req.*
	With FYM (25 t ha^{-1})			*With FYM (25 t ha^{-1})*			*With FYM (25 t ha^{-1})*	
250.00	96.23	125.00	**15.00**	49.01	62.50	**110.00**	49.33	62.50
260.00	94.50	125.00	**17.00**	47.98	62.50	**120.00**	47.79	62.50
280.00	**91.04**	**100.00**	**19.00**	46.95	62.50	**125.00**	47.01	62.50
290.00	89.31	100.00	**21.00**	45.91	62.50	**130.00**	**46.24**	**50.00**
300.00	87.59	100.00	**23.00**	**44.88**	**50.00**	**140.00**	44.69	50.00
320.00	84.13	100.00	**25.00**	43.85	50.00	**150.00**	43.15	50.00
340.00	80.67	100.00	**30.00**	41.27	50.00	**160.00**	41.60	50.00
400.00	70.29	100.00	**32.00**	40.24	50.00	**170.00**	40.06	50.00
440.00	63.37	100.00	**35.00**	38.69	50.00	**180.00**	38.51	50.00
480.00	56.45	100.00	**38.00**	37.15	50.00	**200.00**	35.42	50.00
520.00	49.53	100.00	**41.00**	35.60	50.00	**220.00**	32.33	50.00
560.00	**42.61**	**100.00**	**44.00**	34.05	50.00	**240.00**	29.24	50.00
600.00	35.69	75.00	**46.00**	33.02	50.00	**260.00**	26.15	50.00
			47.00	32.51	50.00	**280.00**	23.06	50.00
			50.00	30.96	50.00	**300.00**	**19.97**	**50.00**
			52.00	**29.93**	**50.00**	**320.00**	16.88	37.50
			54.00	28.90	37.50	**340.00**		37.50
			58.00	26.83	37.50	**440.00**		37.50
			62.00	24.77	37.50			37.50

of available phosphorus, only 29.93 kg of fertilizer phosphorus is required to get a yield target of 10 q ha^{-1} dry chilli. Similarly, 50.00 kg ha^{-1} potassium fertilizer is required to produce 10 q $ha^{-1}$of dry chilli, when the soil test values are in medium range (130.00 to 300.00 kg K_2O ha^{-1}) as per STL recommendations. However, if one follows the STCR approach of fertilizer application, 46.24 kg ha^{-1} of potassic fertilizer needs to be added when the soil test value is 130.00 kg K_2O ha^{-1}. But, when the soil test value is 300.00 kg K_2O ha^{-1}, only 19.97 kg ha^{-1} potassic fertilizer is required to achieve the yield target of 10 q ha^{-1}. Fertilizer use by following these equations is more economical and environment friendly and helps in judicious use of nutrients in STCR approach without accruing any wastage as compared to STL method of fertilizer prescription. These results are in conformity with the findings of Basavaraja *et al.* (2011) [14] for carrot root with targeted yield of 20 t ha^{-1}.

The findings of the present study clearly revealed that fertilizer prescription equations developed through inorganics or under IPNS could be effectively used in Alfisols of Karnataka for achieving the specific targeted yield of dry chilli. Inclusion of IPNS component like farmyard manure in the present investigation resulted in reduction in fertilizer nutrient requirement for desired yield targets. STCR approach of fertilizer application is found to be superior over STL approach in efficient use of costly fertilizers in a balanced way without any wastage or under usage of any nutrients to achieve the specific yield target. Thus, STCR practice of fertilizing the crops on yield targets appears precise, meaningful and economically feasible and needs to be popularized among chilli growers to attain sustainable yield.

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