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Soil test based targeted yield equations for Ratoon sugarcane in alluvial soils

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Abstract
A field experiment was conducted during 2014-15 for developing STCR based targeted yield equation for ratoon sugarcane at SRS, Vuyyur, Krishna district, Andhra Pradesh. The results indicate that per cent contribution of nutrients from soil (C_s) was 106.70 per cent of available N, 79.2 per cent of available P and 52.48 percent of available K towards the total N, P and K uptake by sugarcane. The nutrient contribution of the soil to sugarcane was relatively higher for N as compared to that by P_2O_5 and K_2O. The per cent contribution from fertilizer nutrients (C_f) towards the total uptake by sugarcane was 22.88, 66.51 and 112.20 per cent, respectively for N, P_2O_5 and K_2O and followed the order of $K_2O > P_2O_5 >$ N. The per cent contribution of N, P_2O_5 and K_2O from FYM was 75.76, 20.79 and 49.97 respectively for sugarcane which indicated that relatively higher contribution was recorded for N followed by K_2O and P_2O_5 and the response yardstick recorded was 5.31 kg kg^{-1}.Soil Test based targeted yield equations were developed. These fertilizer prescription equations are transformed into ready reckoner for knowing the fertilizer requirements of N, P, K for different yield targets of Sugarcane (Ratoon) of soils with varying soil test values.

Keywords: Ratoon sugarcane, target yield, STCR, soil test values

Introduction
Sugarcane is an important commercial cash crop and plays vital role in Indian agriculture. It ranks second after Brazil both in area and production among sugar producing countries. It is grown in 4.5 per cent of the total cropped area of the country. Ratoon is unique phenomenon in the sense that a number of succeeding sugarcane crops will be raised from a single planting which is an integral component of sugarcane production system. In India more than 50 to 55 per cent of sugarcane acreage is occupied by ratoons, which are often poor yielders than the plant cane due to non adoption of improved agricultural technologies. However, its contribution to the total cane production is about 30 per cent. Ratooning in sugarcane is economical for the farming community as the production cost is lowered by 25 - 35 per cent over plant crop in addition to saving on cost of seed material. But the productivity is 10 to 30 per cent less than the plant crop of sugarcane. A ratoon crop matures prior to plant crop ensuring early supply of cane to mills. Under similar conditions sugarcane ratoon have a supplementary advantage of better juice quality and sugar recovery more than plant crop of same variety (Yang and Chen, 1991) [17].
Fertilizer is one of the most important agricultural inputs for increasing the crop production. Soil testing is now accepted as a procedure for the recommendation of fertilizer doses for various crops in India. But soil testing would become a useful tool only when it is based on intimate knowledge of soil-crop-variety-fertilizer-climate management interaction for a given situation (Kanwar, 1971) [3]. In this regard targeted yield approach has been found to be beneficial which recommends balanced fertilization considering available nutrient status in the soil and the crop needs. Targeted yield approach was first developed by Truog (1960) [15] and Ramamoorthy *et al.* (1967) [10] established theoretical basis and experimental technique suit to Indian conditions. Excessive and indiscriminate use of inorganic fertilizers creates imbalance of nutrition causing decline in productivity and simultaneously increase the cost of production per ton of cane. Application of adequate inorganic fertilizers supplemented with organic manures and biofertilizers on soil test basis will certainly be helpful for increasing productivity

of sugarcane with better soil health (Sakarvadia *et al.* 2012) [11]. Milap Chand *et al.* (2006) [6] and Khosa *et al.* (2012) [5] reported the superiority of the target yield concept over other practices for different crops as it gave higher yields, net benefit and optimal economic returns. The present investigation was undertaken to assess the feasibility of fertilizer prescription equations of target yield approach in ratoon sugarcane. The specific target yield equation based on soil fertility besides ensuring sustainable crop production also steers the farmers towards economic use of costly fertilizer inputs depending on their financial status and market price of the crop under consideration (Bera *et al.* 2006) [1].

Materials and Methods

A field experiment was conducted in clay loam soils of Sugarcane Research Station, Vuyyuru (A.P), India to develop Targeted yield equation for ratoon sugarcane. This study comprised of two field experiments in two phases *viz.*, fertility gradient experiment with maize (Phase I) and test crop experiment with pre seasonal sugarcane ratoon cv. 2003V 46 (Phase II).The methodology adopted in this study was as outlined by Truog (1960) [15] and modified by Ramamoorthy *et al.* (1967) [10]. The gradient crop experiment was conducted during *kharif* 2013 followed by plant crop during *rabi* 2013 and ratoon crop of the test crop trial during March 2014 to February 2015. The soil of the experimental site was neutral (pH 7.05) in reaction, non saline (EC 0.35 d Sm^{-1}) in nature and medium in organic carbon (0.62%). It was low in available nitrogen (240 kg ha^{-1}), high in available phosphorus (39.5 kg ha^{-1}) and high in available potassium (600 kg ha^{-1}). The treatment structure adopted in the present investigation was based on "Targeted yield model" (Ramamoorthy *et al.*, 1967) [10].

Gradient experiment

In the gradient experiment, the experimental field was divided into three equal strips, the first strip received no fertilizer ($N_0P_0K_0$), the second and third strips received one ($N_1P_1K_1$) and two ($N_2P_2K_2$) times the standard dose of N, P_2O_5 and K_2O respectively. Maize was grown as gradient crop. Pre-sowing and post-harvest soil samples were collected from each fertility strip and analysed for available N (Subbiah and Asija, 1956) [14], available P (Olsen *et al.*, 1954) [8] and available K (Muhr *et al.*, 1965) [7].

Test crop experiment

After establishment of fertility gradients, each strip was divided into 21 plots and initial soil samples were collected from each plot and analyzed for available nitrogen, phosphorus and potassium. The experiment was laid out in a mixed factorial RBD design comprising twenty one treatments. The test crop/ main experiment was conducted with four levels each of nitrogen (0,140, 280 and 420 kg ha^{-1}), phosphorus (0, 50, 100 and 150 kg ha^{-1}) and potassium (0, 84, 168 and 252 kg ha^{-1}) and three levels of FYM (0, 5 and 10 t ha^{-1}) were superimposed across the strips. There were 18 fertilizer treatments along with three controls. The treatment structure is given in Fig.1. Sugarcane was grown to maturity, harvested and plot wise cane yields were recorded. The plant and post-harvest soil samples were collected from each plot. The soil and plant samples were processed and analyzed. Making use of data on the cane yield of ratoon sugarcane, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P_2O_5 and K_2O applied, the basic parameters *viz.*, nutrient requirement (NR), contribution of nutrients from soil (C_s), fertilizer (C_f) and farmyard manure (C_{fym}) were calculated as outlined by Ramamoorthy *et al.* (1967)[10]. Making use of these parameters, the fertilizer prescription equations (FPEs) were developed for ratoon sugarcane.

1) $N_1 P_1 K_1$	8) $N_2 P_2 K_2$	15) $N_3 P_2 K_3$
2) $N_1 P_1 K_2$	9) $N_2 P_2 K_3$	16) $N_3 P_3 K_1$
3) $N_1 P_2 K_1$	10) $N_2 P_3 K_2$	17) $N_3 P_3 K_2$
4) $N_1 P_2 K_2$	11) $N_2 P_3 K_3$	18) $N_3 P_3 K_3$
5) $N_2 P_1 K_1$	12) $N_3 P_1 K_1$	19) $N_0 P_0 K_0$
6) $N_2 P_1 K_2$	13) $N_3 P_2 K_1$	20) $N_0 P_0 K_0$
7) $N_2 P_2 K_1$	14) $N_3 P_2 K_2$	21) $N_0 P_0 K_0$

Fig 1: Treatment structure

Results and Discussion

Cane yield, Uptake and Initial available NPK status

The range and mean values (Table 1) indicate that the cane yield ranged from 38 t ha^{-1} in absolute control to 100 t ha^{-1} in N_{420} P_{150} K_{252} + FYM @ 10 t ha^{-1} of strip III with mean values of 52, 68 and 76 t ha^{-1}, respectively in strips I, II and III. The total N uptake by sugarcane varied from 108 to 315 kg ha^{-1}; total P uptake from 33 to 223 kg ha^{-1} and total K uptake from 138 to 614 kg ha^{-1} across the three strips. Soil test data revealed that, the mean available nitrogen was 155, 128 and 152 kg ha^{-1}, respectively in strips I, II and III. In strips I to III mean available phosphorus was 73, 74 and 82 kg ha^{-1}. Mean available potassium values were 420, 394 and 493 kg ha^{-1} in three strips (Table 1).

Table 1: Soil available NPK, cane yield nd NPK uptake by sugarcane

Parameters	Strip I		Strip II		Strip III	
	Range	Mean	Range	Mean	Range	Mean
$KMnO_4$–N (kg ha^{-1})	100-226	155	113-163	128	88-226	152
Olsen–P (kg ha^{-1})	50-92	73	52-99	74	58-120	82
NH_4OAc-K (kg ha^{-1})	312-517	420	343-449	394	374-647	493
Cane yield (t ha^{-1})	38-65	52	42-88	68	53-100	76
N uptake (kg ha^{-1})	108-207	159	113-297	192	126-315	207
P uptake (kg ha^{-1})	33 - 87	59	35-137	78	41-223	108
K uptake (kg ha^{-1})	138-410	265	161-483	370	188-614	363

The basic parameters required for the development of target yield equation for ratoon sugarcane are (i) nutrient requirement (NR) in kg per ton of cane yield, per cent contribution of available NPK from soil (C_S), fertilizers (C_F) and farmyard manure (C_{FYM}). Making use of data on the ratoon cane yield of sugarcane, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P_2O_5 and K_2O applied, the basic parameters were computed. The basic data for fertilizer requirement for targeted yield of sugarcane ratoon is furnished in Table 2. The different formulae required for the calculation of basic parameters are given below.

$$\text{Nutrient requirement (NR) For one quintal cane yield} = \frac{\text{Total uptake of nutrient (kg ha}^{-1}\text{)}}{\text{cane yield (q ha}^{-1}\text{)}}$$

%Contribution from soil (C_S) = [(Total uptake of N or P_2O_5 or K_2O in control plot (kgha^{-1})/ (Soil test value for available N or P_2O_5 or K_2O in control plot (kg ha^{-1})] X 100

% Contribution from fertilizer (C_F) ={[(Total uptake of N or P_2O_5 or K_2O in treated plot (kg ha^{-1})) - (Soil test value for available N or P_2O_5 or K_2O in control plot (kg ha^{-1}) X (Average Cs)] / Fertilizer N or P_2O_5 or K_2O applied (kg ha^{-1})} X 100

% Contribution from FYM (C_{FYM}) = {[(Total uptake of N or P or K in FYM treated plot (kg ha^{-1})) – (Soil test value for available N or P or K in FYM treated plot (kg ha^{-1}) X (Average Cs)] / Nutrient N/P/K added through FYM (kg ha^{-1})} X 100

Nutrient requirement of sugarcane (Ratoon)

In the present investigation, the results reveals that nutrient requirement to produce one ton of sugarcane was 2.87 kg of N, 1.21 kg of P_2O_5 and 5.03 kg of K_2O (Table 2) indicating that the requirement of K_2O was higher which is followed by N and P_2O_5. It is calculated by the formula given above. Similarly Ghube *et al*., (2017) [2] also reported the more nutrient requirement of K_2O (1.64 kg) followed by N (1.56 kg) and phosphorous (0.58 kg) to produce one ton of ratoon sugarcane. Katharine *et al*., (2013) [4] also reported that the nutrient requirement to produce one quintal of seed cotton was 4.43 kg of N, 2.20 kg of P_2O_5 and 4.83 kg of K_2O.

Per cent contribution of nutrients from soil (C_s), fertilizers (C_F) to total uptake of sugarcane and FYM (C_{FYM})

The per cent contribution of nutrients from soil (C_s) was 106.70 per cent of available N, 79.2 per cent of available P and 52.48 per cent of available K towards the total N, P and K uptake by ratoon sugarcane. The nutrient contribution of the soil to ratoon sugarcane was relatively higher for N as compared to that by P_2O_5 and K_2O. The per cent contribution from fertilizer nutrients (C_f) towards the total uptake by sugarcane was 22.88, 66.51 and 112.20 per cent, respectively for N, P_2O_5 and K_2O and followed the order of $K_2O > P_2O_5 >$ N (Table 2).

The per cent contribution of N, P_2O_5 and K_2O from FYM was 75.76, 20.79 and 49.97, respectively for sugarcane which indicated that relatively higher contribution was recorded for N followed by K_2O and P_2O_5. The present findings are in conformity with the findings of Santhi *et al*. (2002) [12] and Saranya *et al*. (2012) [13] and the response yardstick recorded was 5.31 kg kg^{-1}

Table 2: Nutrient requirement, contribution of nutrients from soil, fertilizer and FYM (%) for ratoon sugarcane

Parameters	Basic data			Response yard stick (kg kg^{-1})
	N	P	K	
Nutrient requirement (kg ton^{-1})	2.87	1.21	5.03	5.31
Per cent contribution from soil (C_s)	106.70	79.20	52.48	
Per cent contribution from fertilizers (C_F)	22.88	66.51	112.20	
Per cent contribution from FYM (C_{FYM})	75.76	20.79	49.97	

Fertilizer prescription equations for ratoon sugarcane

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

NPK + FYM

FN = 12.53 T – 4.66 SN – 3.31 FYMN

FP_2O_5 = 1.82 T – 1.19 SP – 0.31 FYMP

FK_2O = 4.48 T – 0.47 SK – 0.45 FYMK where,

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 t ha^{-1}

SN, SP and SK are soil available N, P and K in kg ha^{-1}, respectively.

FYM N, FYM P and FYM K are nutrient content of N, P and K in FYM, respectively.

Fertilizer prescription equations were transformed into ready reckoners for requirement of fertilizer NPK for different yield targets of sugarcane (ratoon) on soils with varying soil test values. In the present investigation, there was a marked response to the application of NPK fertilizers; the magnitude of response was higher under NPK with FYM as compared to NPK without FYM. The per cent reduction in NPK fertilizers under NPK with FYM also increased with increasing soil fertility levels with reference to NPK and decreased with increase in yield targets. These could be achieved by integrated use of FYM with NPK fertilizers. Similar trend of results were reported by potdar *et al.* (2014) [9] in sugarcane. Vajantha *et al.*, (2014) [16] reported that the application of fertilizers based on STCR equation for target yield of 120 t ha^{-1} recorded highest cane yield (121.5, 117.8, 114.2 t ha^{-1} in plant crop I, plant crop II, ratoon, respectively). However, the STCR equation for targeted yield of 100 t ha^{-1} in sugarcane could be achieved without any negative deviation in Chittoor district soils. The yield targets were achieved within reasonable limits when the fertilizer was applied on soil test basis in majority of the crops thus establishing the utility of the prescription equations for recommending soil test based fertilizer application to the farmers. The data clearly revealed the fact that the fertilizer N, P_2O_5 and K_2O requirements decreased with increase in soil test values and increased with increase in yield targets. Similar finding also reported in cotton by Katharine *et al.* (2013) [4].

Fertilizer prescription equations were transformed into ready reckoners for requirement of fertilizer NPK for different yield targets of sugarcane (ratoon) on soils with varying soil test values (Table 3). Fertilizer rates increased with increasing yield targets of sugarcane (ratoon) and fertilizer rates decreased with increasing the soil test values. Thus in the targeted yield concept yield potential and soil test values were taken into account while making fertilizer recommendations.

Table 3: Fertilizer requirements of ratoon sugarcane based on different soil test values for the targeted yields.

Available nutrients (kg ha^{-1})	Fertilizer-N (kg ha^{-1})			
	70 t ha^{-1}		80 t ha^{-1}	
$KMnO_4$-N	Only chemical fertilizers	Chemical fertilizers +FYM	Only chemical fertilizers	Chemical fertilizers +FYM
100	411	278	536	404
125	294	162	419	287
150	178	45	303	170
175	61	0	186	54
200	0		70	0
Phosphorus	**Fertilizer P_2O_5 (kg ha^{-1})**			
20	104	99	122	117
30	92	87	110	105
40	80	75	98	93
50	68	63	86	81
60	56	51	74	69
70	44	39	62	57
80	32	27	50	46
90	20	15	38	34
100	8	4	26	22
Potassium	**Fertilizer K_2O (kg ha^{-1})**			
150	244	230	288	275
200	220	207	265	252
250	197	183	242	228
300	173	160	218	205
350	150	137	195	181
400	127	113	171	158
450	103	90	148	135
500	80	66	125	111
550	56	43	101	88

V. Conclusion

To conclude, soil test based IPNS for desired yield targets of Sugarcane (ratoon) was developed. This envisages a balanced nutrient supply to ratoon sugarcane which is site specific and can play a major component of precision agriculture. The specific yield equation based on soil health will not only ensure sustainable crop production but will also steer the farmers towards economic use of costly fertilizer inputs. The fertilizer prescription equations developed using this model can be applied to Vertisols by substituting the soil nutrient status of the particular field. Moreover, the methodology adopted in the present investigation viz., the prescription procedure outlined by Truog (1960) [15] and modified by Ramamoorthy *et al.* (1967) [10] as "Inductive cum Targeted yield model" can very well be used to derive fertilizer prescription equations for any field or horticultural crop (except perennial crops) on any soil series.

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