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RESEARCHARTICLE

SOIL TEST BASED TARGETED YIELD EQUATIONS AND ITS VALIDATION FOR PRESEASONAL SUGARCANE ON INCEPTISOL

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ABSTRACT

Three field experiments viz. fertility gradient experiment with fodder maize, test crop experiment with preseasonal sugarcane and test verification trial with preseasonal sugarcane cv. were conducted at at Central Sugarcane Research Station, Padegaon (M.S.), India during 2007 to 2011 to develop the Soil Test based yield target equations for newly released variety CoM 0265 and to test the validity of these equations on Inceptisols. The basic data of nutrient requirement, contribution of nutrients from soil, fertilizer and farmyard manure were calculated and the equations were developed. The per tonne of requirement of nitrogen, phosphorus and potassium was 1.38 kg, 0.44 kg and 1.64 kg, respectively. The yield targets of 175 t ha-1 and 200 t ha-1 were achieved with a variation of 4.7 and 5.2 % without FYM and 1.7 and 0.6 % with FYM indicating the validity of the equations. Application of fertilizers based on STCRC target 200 t ha-1 with FYM recorded significantly higher cane yield (201.21 tha-1).The same treatment application of fertilizers based on STCRC target 200 t ha-1 with FYM is found beneficial for highest net return return (Rs. 234337ha^{-1}) and better B:C ratio (3.01).

INTRODUCTION

Sugarcane is an important commercial crop and plays vital role in Indian agriculture. India ranks 2nd after Brazil among sugar producing countries of the world and contributes 25 % and 22 % in area and production of world, respectively (Anonymous, 2011). The Sugarcane productivity in Maharashtra is continuously decreasing from last decade (90 t/ha in 1999-2000 to 81.8 t/ha in 2010-11). The major factors responsible for declining of Sugarcane productivity in Maharashtra are imbalance use of fertilizers and poor irrigation management. Thus, scientific control in the application of fertilizers certainly needed to improve sugarcane yield. Fertilizer application based on targeted yield approach was found beneficial in increasing yield (Rama Moorthy *et al*., 1967; Bhandari *et al*., 2002; Ladha *et al*., 2003; Manna *et al*., 2005). Excessive and indiscriminate use of inorganic fertilizers creates imbalance of nutrition causing decline in productivity and simultaneously increased cost of production per tonne 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. (Patil *et al*., 1994 and Jadhav *et al*., 2002) Sakarvadia *et al*. (2012). Milap Chand *et al*. (2006) and Khosa *et al*. (2012) 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 research workers are more or less successful in achieving the targeted yield of sugarcane. (Sonar *et al*.,2002). The present investigation was under taken to assess the feasibility of fertilizer prescription equations of yield target approach in sugarcane. The specific yield equation based on soil health besides ensuring sustainable crop production also steers the farmers towards economic use of costly fertilizer inputs depending on their financial status and prevailing market price of the crop under consideration (Bera *et al*., 2006).

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MATERIALS AND METHODS

Studies on Soil Test Crop Response were conducted on Inceptisol at Central Sugarcane Research Station, Padegaon (M.S.), India. This study comprised of three field experiments in three phases *viz.,* fertility gradient experiment with fodder maize (Phase I), test crop experiment with preseasonal sugarcane cv. CoM 0265 (Phase II) and test verification trial with preseasonal sugarcane cv. CoM 0265 (Phase III). The methodology adopted in this study is the prescription procedure outlined by Truog (1960) and modified by Ramamoorthy *et al.* (1967). In order to create fertility variations, a gradient experiment was conducted. The gradient and test crop experiments were conducted during June2007 to February 2009 and the test verification trial during October 2009 to March 2011. The soil of the experimental field belongs to clay loam texture, moderately alkaline reaction (pH 7.9) and non – saline conditions (EC 0.31 dS m^{-1}). The initial soil fertility status showed low organic carbon (0.52 %), low available N (198 kg ha^{-1}), medium available P (16.3 kg ha^{-1}), high available K (321 kg ha^{-1}). The details of crops and important cultural operations carried out in the experiments are furnished in Table 1. The treatment structure based on "Targeted yield model" (Ramamoorthy *et al*., 1967) was adopted in the present investigation.

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 and a gradient crop of fodder maize was grown. Pre-sowing and post-harvest soil samples were collected from each fertility strip and analysed for available N (Subbiah and Asija, 1956), available P (Olsen *et al*., 1954) and available K (Stanford and English, 1949).

Test crop experiment

After establishment of fertility gradients, each strip was divided into 24 plots, and initial soil samples were collected from each plot and analyzed for available N, available P and available K. The experiment was laid out in a fractional factorial design comprising twenty four treatments. The test crop/ main experiment was conducted with four levels each of N (0, 240, 340 and 440 kg ha^{-1}), P_2O_5 (0, 120, 170 and 220 kg ha^{-1}) and K_2O (0, 120, 170 and 220 kg ha-1) and three levels of FYM (0, 15 and 30 t ha^{-1}). The treatments *viz*., NPK alone, NPK+ FYM @ 15 t ha^{-1} and NPK+FYM @ 30 t ha^{-1} were superimposed across the strips. There were 21 fertilizer treatments along with three controls. The treatment structure is given in Fig.1. The sugarcane was planted with a row spacing of 120 cm. The crop was grown to maturity, harvested and plot wise cane yield was recorded. The plant and post-harvest soil samples were collected from each plot. The soil and plant samples were processed and analyzed and NPK uptake by sugarcane was computed. Making use of data on the 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 *viz*., nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and farmyard manure (Cfym) were calculated as outlined by Ramamoorthy *et al*. (1967). Making use of these parameters, the fertilizer prescription equations (FPEs) were developed for sugarcane.

RESULTS AND DISCUSSION

Cane yield, Uptake and Initial available NPK status

The range and mean values (Table 2) indicated that the cane yield ranged from 103 t ha-1 in absolute control to 182.13 t ha-1 in $N_{440}P_{220}K_{170}$ + FYM @ 15 t ha^{-1} of strip II with mean values of 139.1, 143.1 and 147.8 t ha^{-1}, respectively in strips I, II and III. The N uptake by sugarcane varied from 102.32 to 241.48 kg ha^{-1}; P uptake from 17.22 to 98.39 kg ha^{-1} and K uptake from 152.07 to 286.13 kg ha^{-1} in strips I, II and III.The data on initial soil test values of sugarcane revealed that, the mean available N was 209, 215.5 and 207.5 kg ha^{-1}, respectively in strips I, II and III. The mean available P values were 15.6, 15.45 and 14.55 , kg ha^{-1} respectively in strips I to III and the mean available K values were 351.1, 355.5 and 358 kg ha^{-1} in strips I, II and III, respectively (Table 2).

Nutrient requirement of preseasonl sugarcane

The data on basic parameter for fertilizer prescription equation was presented in table 4. Nutrient requirement to produce one tonne (1000 kg) sugarcane was 1.38 kg of N, 0.44 kg of P_2O_5 and 1.64 kg of K_2O. In the present investigation, the requirement of K_2O was higher which is followed by N and P_2O_5.

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

The per cent contribution of nutrients from soil (Cs) was 48.89 per cent of available N, 86.98 per cent of available P and 40.46 percent of available K respectively towards the total N, P and K uptake by sugarcane. The nutrient contribution of the soil to sugarcane was relatively higher for P_2O_5 as compared to that by N and K_2O. The per cent contribution from fertilizer nutrients (Cf) towards the total uptake by sugarcane was 34.22, 35.66 and 72.55 per cent, respectively for N, P_2O_5 and K_2O and followed the order of $K_2O > P_2O_5 > N$.

Contribution of nutrients from FYM

The per cent contribution of N, P_2O_5 and K_2O from FYM was 17.66, 13.36 and 15.05 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) and Saranya *et al*. (2012).

Fertilizer prescription equations for presesonal sugarcane

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

NPK alone (Without FYM)

$FN = 4.21\ T - 1.49\ SN$
$FP_2O_5 = 1.39\ T - 2.75\ SP$
$FK_2O = 2.36\ T - 0.58\ SK$

NPK + FYM

$FN = 4.03\ T - 1.43\ SN - 3.81\ FYM$
$FP_2O_5 = 1.23\ T - 2.44\ SP - 1.83\ FYM$
$FK_2O = 2.26\ T - 0.55\ SK - 1.40\ FYM$

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

Fertilizer prescription for desired yield target of preseasonal sugarcane

A ready reckoner table was prepared using these equations for a range of soil test values and for a yield target of 160 t ha^{-1} to 200 t ha^{-1} for sugarcane (Table 5). For achieving an yield target of 200 t ha^{-1} of sugarcane a soil test value of 320, 20 and 400 kg ha^{-1} of available N, available P and available K, the

Fig. 1. Treatment structure

1)	$N_1 P_1 K_1$	2)	$N_1 P_1 K_2$	3)	$N_1 P_2 K_1$	4)	$N_1 P_2 K_2$
5)	$N_2 P_1 K_1$	6)	$N_2 P_1 K_2$	7)	$N_2 P_2 K_1$	8)	$N_2 P_2 K_2$
9)	$N_2 P_2 K_3$	10)	$N_2 P_3 K_2$	11)	$N_2 P_3 K_3$	12)	$N_2 P_2 K_0$
13)	$N_2 P_0 K_2$	14)	$N_0 P_2 K_2$	15)	$N_3 P_1 K_1$	16)	$N_3 P_2 K_1$
17)	$N_3 P_2 K_2$	18)	$N_3 P_2 K_3$	19)	$N_3 P_3 K_1$	20)	$N_3 P_3 K_2$
21)	$N_3 P_3 K_3$	22)	$N_0 P_0 K_0$	23)	$N_0 P_0 K_0$	24)	$N_0 P_0 K_0$

Table 1. Details of crops and important cultural operations

Sr. No.	Details of cultural operations	Gradient experiment fodder maize	Test crop experiment Sugarcane CoM 0265	Test verification trial Sugarcane CoM 0265
1	Season	*Kharif*	Preseason	Preseason
2	Plot size	10.0 mX 6.0 m	10.0 mX 6.0 m	9.5 m x 7.2 m
3	Date of sowing/ planting	24.06.2007	18.11.2007	6.11.2009
4	Row Spacing		1.20 m	1.20 m
5	Date of harvest	21.09.2007	18.02.2009	10.1.2011

Table 2. Pre-sowing soil available NPK, cane yield and NPK uptake by sugarcane (kg ha-1)

Parmeters (kg ha-1)	Strip I		Strip II		Strip III	
	Range	Mean	Range	Mean	Range	Mean
Available N (Kg ha^{-1})	198-220	209	192-239	215.5	189-226	207.5
Available P (Kg ha^{-1})	10.80-20.40	15.6	10.7-20.21	15.45	11.1-18.0	14.55
Available K (Kg ha^{-1})	312-319	351.1	315-396	355.5	318-398	358.0
Cane yield (t ha-1)	103-175.2	139.10	104.08-182.13	143.10	107.3-88.3	147.80
N uptake (Kg ha^{-1})	102.32-231.05	166.68	118.25-236.08	177.16	122.28-241.48	181.88
P uptake (Kg ha^{-1})	17.22-82.19	49.70	25.25-85.38	55.31	32.12-98.39	65.25
K uptake (Kg ha^{-1})	152.07-283.25	217.66	159.88-285.5	222.69	171.25-286.13	228.69

Table 3. Nutrient requirement, contribution of nutrients from soil, fertilizer and FYM (%)for sugarcane

Parameters	Basic data		
	N	P_2O_5	K_20
Nutrient requirement (kg t-1)	1.38	0.44	1.64
Per cent contribution from soil (Cs)	48.89	86.98	40.46
Per cent contribution from fertilizers (Cf)	34.22	35.66	72.55
Per cent contribution from FYM (Cfym)	17.66	13.36	15.05

Table 4. Soil test based fertilizer prescription for yield target of 160, 180 and 200 t ha^{-1} of sugarcane (kg ha^{-1})

Soil Test Values (kg ha-1)	Fertilizer-N (kg ha-1)		Per cent reduction over NPK	Fertilizer-P (kg ha-1)		Per cent reduction over NPK	Fertilizer-K (kg ha-1)		Per cent reduction over NPK
	NPK alone	NPK+ FYM		NPK alone	NPK+ FYM		NPK alone	NPK+ FYM	
Ava. N		160 t/ha			180 t/ha			200 t/ha	
160	435	340	21.84	519	420	19.08	604	501	17.05
200	376	283	24.73	460	363	21.09	544	444	18.38
240	316	225	28.80	400	306	23.50	484	387	20.04
280	256	168	34.38	341	249	26.98	425	329	22.59
320	197	111	43.65	281	192	31.67	365	272	25.48
Ava. P									
10	194.9	135.8	30.32	222.7	160.4	27.97	250.5	185	26.15
15	181.2	123.6	31.79	209.0	148.2	29.09	236.8	172.8	27.03
20	167.4	111.4	33.45	195.2	136	30.33	223.0	160.6	27.98
25	153.7	99.2	35.46	181.5	123.8	31.79	209.3	148.4	29.10
Ava. K									
250	233	196.1	15.84	280	241.3	13.82	327	286.5	12.39
300	204	168.6	17.35	251	213.8	14.82	298	259	13.09
350	175	141.1	19.37	222	186.3	16.08	269	231.5	13.94
400	146	113.6	22.19	193	158.8	17.72	240	204	15.00
450	117	86.1	26.41	164	131.3	19.94	211	176.5	16.35

fertilizer N, P_2O_5 and K_2O doses required were 281, 195 and 193 kg ha^{-1}, respectively NPK alone and 192, 136 and 159 kg ha^{-1} under NPK + FYM @ 20 t ha^{-1}. 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 Anon (2012) in cotton.

Table 5. Results of the test verification trial on sugarcane

Sr. No.	Treatments	Fertilizer doses(kg ha-1)			Yield (t ha-1)	Achievement (%)	Net returns (Rs. ha^{-1})	B : C Ratio
		N	P2O5	K2O				
1	Control	--	--	--	109.29	--	--	--
2	GRD	340	170	170	143.21	--	147957	2.35
3	As per soil test	340	170	170	146.44	--	153771	2.40
4	STCRC Yield target 175 t ha^{-1} without FYM	260	170	293	166.70	95.3	188347	2.71
5	STCRC Yield target 200 tha^{-1} without FYM	365	204	352	189.65	94.8	228780	3.03
6	STCRC Yield target 175 tha^{-1} with 10 t FYM ha^{-1}	210	132	268	177.94	101.7	202338	2.72
7	STCRC Yield target 200 tha^{-1} with 10 t FYM ha^{-1}	311	162	324	201.21	100.6	241743	3.01
8	Only 20 t ha^{-1} FYM	--	--	--	115.76		88999	1.75
	SE ±				1.61		2897	
	CD at 5 %				4.88		8787	

Test verification trial

In order to validate the fertilizer prescription equations developed for sugarcane on Inceptisol, test verification trial was conducted at Central Sugarcane Research Station, Padegaon (M.S.), India. There were eight treatments *viz*., absolute control, recommended dose, as per soil test, STCRC yield targets of 175 t ha^{-1} and 200 t ha^{-1} with and without FYM and only FYM 20 t ha^{-1}. The treatment details and results are furnished in Table 6.

Cane yield and achievement

The results of the test verification trial revealed that the cane yield ranged from 109.29 t ha^{-1} in control to 201.21 t ha^{-1} in STCRC yield targets of 200 t ha^{-1} with FYM. Irrespective of the yield targets, the yield recorded in the NPK with FYM treatments were higher when compared to their corresponding NPK alone treatments. The results of the test verification trial on sugarcane clearly indicated that the per cent achievement was within ± 10 per cent variation (90 to 110 %) at all yield target levels proving the validity of the fertilizer prescription equations. According to Velayutham *et al.* (1984), if the targeted yield was achieved within ± 10 per cent variation, then the equations are found to be valid. The highest achievement of the yield target was recorded with STCRC yield targets of 175 t ha^{-1} with FYM (101.7 %) followed by STCRC yield targets of 200 t ha^{-1} with FYM treatments (100.6 %). It is evident from the data that lower yield targets were better achieved than the higher one. This might be due to the better use efficiency of applied NPK fertilizers at low yield target levels (Santhi *et al*., 2002 and Bera *et al*., 2006) (Table 6).

Conclusion

The soil test based fertilizer equations developed for prseasonal sugarcane are as follows.

Only NPK (Without FYM)

FN = 4.21 T – 1.49 SN
FP_2O_5 = 1.39 T – 2.75 SP
FK_2O = 2.36 T – 0.58 SK

NPK + FYM

FN = 4.03 T – 1.43 SN – 3.81 FYM
FP_2O_5 = 1.23 T – 2.44 SP – 1.83 FYM
FK_2O = 2.26 T – 0.55 SK – 1.40 FYM

These equations were verified on Inceptisol and the yields were achieved are within a range of variation of ± 10 per cent variation. Hence, the equations are valid for preseasonal sugarcane on Inceptisols. Moreover the response of fertilizers is more when chemical fertilizers used with FYM, resulting in saving in chemical fertilizers. The ecomomics of the verification trial shows that the STCRS targeted application of fertilizers found beneficial for net return and B:C ratio. This envisages a balanced nutrient supply to sugarcane 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.

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