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

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DOI: https://doi.org/10.22271/chemi.2020.v8.i5ai.10704

Abstract
A field experiment was conducted during 2014-15 for developing STCR based targeted yield equation for ratoon sugarcane at SRS, Vuyyuru, Krishna district, Andhra Pradesh. The results indicate that per cent contribution of nutrients from soil (CSo) 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 uptake by sugarcane. The nutrient contribution of the soil to sugarcane was relatively higher for N as compared to that by P2O5 and K2O. The per cent contribution from fertilizer nutrients (Cf) towards the total uptake by sugarcane was 22.88, 66.51 and 112.20 per cent, respectively for N, P2O5 and K2O and followed the order of K2O > P2O5 > N. The per cent contribution of N, P2O5 and K2O 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 K2O and P2O5 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 Truong (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, Vyyuru (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 khariif 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 (N0P0K0), the second and third strips received one (N1P1K1) and two (N2P2K2) times the standard dose of N, P2O5 and K2O 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, P2O5 and K2O applied, the basic parameters viz., nutrient requirement (NR), contribution of nutrients from soil (Cso), fertilizer (Ci) and farmyard manure (Cfym) 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.

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 N420 P150 K252 + 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).

| Parameters                  | Strip I | Strip II | Strip III |
|-----------------------------|---------|----------|-----------|
| KMnO4-N (kg ha⁻¹)           | 100-226 | 113-163  | 113-163   |
| Olsen-P (kg ha⁻¹)           | 50-92   | 52-99    | 52-99     |
| NH₄OAc-K (kg ha⁻¹)          | 312-517 | 343-449  | 343-449   |
| Cane yield (t ha⁻¹)         | 38-65   | 42-88    | 42-88     |
| N uptake (kg ha⁻¹)          | 108-207 | 113-297  | 113-297   |
| P uptake (kg ha⁻¹)          | 33-87   | 35-137   | 35-137    |
| K uptake (kg ha⁻¹)          | 138-410 | 161-483  | 161-483   |

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 (Cso), fertilizers (Ci) and farmyard manure (Cfym). 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, P2O5 and K2O applied, the basic parameters were computed. The basic data for fertilizer requirement for targeted yield of sugarcane ratoon is furnished in Table 2. The

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

different formulae required for the calculation of basic parameters are given below.

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

% Contribution from soil (C_s) = \[ \left( \frac{\left( \text{Total uptake of N or P or K}_2\text{O in control plot (kg ha}^{-1}) \right) \text{Soil test value for available N or P or K}_2\text{O in control plot (kg ha}^{-1}) \times 100}{\text{Average Cs}} \right) \]

% Contribution from fertilizer (C_f) = \[ \left( \frac{\left( \text{Total uptake of N or P or K}_2\text{O in treated plot (kg ha}^{-1}) \right) \left( \text{Soil test value for available N or P or K}_2\text{O in treated plot (kg ha}^{-1}) \right) \times 100}{\text{Average Cs}} \right) \]

Nutrient requirement of sugarcane (Ratoon)
In the present investigation, the results reveal that nutrient requirement to produce one ton of sugarcane was 2.87 kg of N, 1.21 kg of P2O5 and 5.03 kg of K2O (Table 2) indicating that the requirement of K2O was higher which is followed by N and P2O5. It is calculated by the formula given above. Similarly Ghube et al., (2017) \[ ^{[3]} \] also reported the more nutrient requirement of K2O (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 P2O5 and 4.83 kg of K2O.

Per cent contribution of nutrients from soil (C_s) 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 uptake by ratoon sugarcane. The nutrient contribution of the soil to ratoon sugarcane was relatively higher for N as compared to that by P2O5 and K2O. 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, P2O5 and K2O and followed the order of K2O > P2O5 > N (Table 2). The per cent contribution of N, P2O5 and K2O 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 K2O and P2O5. 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 ha\(^{-1}\)) |
|--------------------------------------|------------|--------------------------------------|
|                                      | N          | P          | K          | 5.31       |
| Nutrient requirement (kg ton\(^{-1}\)) | 2.87       | 1.21       | 5.03       |            |
| 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
FP2O5 = 1.82 T – 1.19 SP – 0.31 FYMP
FK2O = 4.48 T – 0.47 SK – 0.45 FYMK where,

Where FN, FP2O5 and FK2O are fertilizer N, P2O5 and K2O 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) \[ ^{[10]} \] reported that the application of fertilizers based on STCRK 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, P2O5 and K2O requirements decreased with increase in soil test values and increased with increase in yield targets. Similar finding also reported in cotton by Katharne et al. (2013) \[ ^{[8]} \].

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.
Vertisols by substituting the soil nutrient, fertilizer gets of Allium cepa L. var. aggregatum in Inceptisol of Tamil Nadu. Journal of Indian Society of Soil Science. 2002;50:489-492.

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 | Chemical fertilizers + FYM | Only chemical fertilizers | Chemical fertilizers + FYM |
|-----------------------------|------------------------|------------|---------------------------|--------------------------|---------------------------|
| KMnO₄-N                    | Only chemical fertilizers | 411        | 278                       | 536                      | 404                       |
| 100                         | 294                    | 162        | 419                       | 287                      |
| 125                         | 178                    | 45         | 303                       | 170                      |
| 150                         | 61                     | 0          | 186                       | 54                       |
| 175                         | 0                      | 70         | 0                         |
| Phosphorus                 | Fertilizer P₂O₅ (kg ha⁻¹) | 104        | 99                        | 122                      | 117                       |
| 20                          | 92                     | 87         | 110                       | 105                      |
| 30                          | 80                     | 75         | 98                        | 93                       |
| 40                          | 68                     | 63         | 86                        | 81                       |
| 50                          | 56                     | 51         | 74                        | 69                       |
| 60                          | 44                     | 39         | 62                        | 57                       |
| 70                          | 32                     | 27         | 50                        | 46                       |
| 80                          | 20                     | 15         | 38                        | 34                       |
| 90                          | 8                      | 4          | 26                        | 22                       |
| Potassium                  | Fertilizer K₂O (kg ha⁻¹) | 244        | 230                       | 288                      | 275                       |
| 150                         | 220                    | 207        | 265                       | 252                      |
| 200                         | 197                    | 183        | 242                       | 228                      |
| 250                         | 173                    | 160        | 218                       | 205                      |
| 300                         | 150                    | 137        | 195                       | 181                      |
| 350                         | 127                    | 113        | 171                       | 158                      |
| 400                         | 103                    | 90         | 148                       | 135                      |
| 450                         | 80                     | 66         | 125                       | 111                      |
| 500                         | 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 Truong (1960) and modified by Ramamoorthy et al. (1967) 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.

VI. References
1. Bera R, Seal A, Bhattacharyya P, Das TH, Sarkar D, Kangoo K. Targeted yield concept and a framework of fertilizer recommendation in irrigated rice domains of subtropical India. Journal of Zhejiang University Science. 2006;7(12):963-968.
2. Ghube NB, Kadlag AD, Kamble BM. Soil test crop response based integrated plant nutrition system for desired yield target of pre seasonal sugarcane ratoon on Inceptisol. Journal of Applied and Natural Science. 2017;9(2):799-804
3. Kanwar JS. Soil testing service in India-retrospect and prospect. Proceedings of International Symposium on Soil Fertility Evaluation held at New Delhi in 1971;1:1103-1113.
4. Katharine SP, Santhi R, Maragatham S, Natesan R, Ravikumar V, Pradip Dey. Soil test based fertilizer prescriptions through inductive cum targeted yield model for transgenic Cotton on Inceptisol. IOSR Journal of Agriculture and Veterinary Science. 2013;6(5):36-44.
5. Khosa MK, Sekhon BS, Ravi MS, Benipal DS, Benbi DK. Performance of target yield based fertilizer prescription equations in rice-wheat cropping system in Punjab. Indian Journal of Fertilizers. 2012;8(2):14-18
6. Milap Chand, Benbi DK, Benpal DS. Fertilizer recommendations based on soil tests for yield targets of mustard and rapeseed and their validations under farmer’s field conditions in Punjab. Journal of Indian Society of science. 2006;54(3):316-321.
7. Muhr R, Gilbert, Dutta NPB, Sankara Subramoney H, Dever RF, Laley VK et al. Soil testing in India (United States Agency for International Development Mission to India, New Delhi), 1965.
8. Olsen SR, Cole CW, Watanabe FS, Dean LA. Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. United States Department Agricultural Circular 1954,639.
9. Potdar DS, Deshmukh SU, Rathod BG, Pawar SM. Soil test based targeted yield equations and its validity for preseasonal sugarcane on Inceptisol. International Journal of Current Research. 2014;9(06):8273-8277.
10. Ramamoorthy B, Narsimhan RL, Dinesh RS. Fertilizer application for specific yield targets of Sonora-64(wheat). Indian Farming. 1967,25(5):43-45.
11. Sakarvadia HL, Polara KB, Davaria RL, Parmar KB, Babariya NB. Soil test based fertilizer recommendation for targeted yields of garlic crop. An Asian Journal of Soil Science. 2012;7(2):378-382.
12. Santhi R, Natesan R, Selvakumari G. Soil Test Crop Response Correlation Studies under integrated plant nutrition system for onion (Allium cepa L. var. aggregatum) in Inceptisol of Tamil Nadu. Journal of Indian Society of Soil Science. 2002;50:489-492.
13. Saranya S, Santhi R, Appavu K, Rajamani K. Soil Test based integrated plant nutrition system for ashwagandha on *Inceptisols*. Indian Journal of Agriculture Research. 2012;46:88-90.

14. Subbaiah BV, Asija GL. A Rapid Procedure for the Determination of Available Nitrogen in Soil. Current Science. 1956;25:226-230.

15. Truog E. Fifty years of Soil Testing. Transactions of 7th International Congress of Soil Science, Madison, Wisconsin, USA. 1960;(III, IV):36-45.

16. Vajantha B, Subbarao M, Nagamadhuri KV, Hemanth Kumar M, Sarala NV. STCR approach for optimizing yield, quality and economics in Sugar cane. Current Biotica, 2014;8(3):309-312.

17. Yang SJ, Chen JM. A review of fertilizer trials carried out by the Fiji Sugar Corporation between 1977 and 1987. Taiwan Sugar. 1991;38:19-24.