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# Enhancement of sugarcane productivity through balanced fertilization

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**Abstract**
A field experiment was conducted during March 2012 to validate the balanced fertilization package to attain a factory average sugarcane yield of 150 t $ha^{-1}$ from the present average of 95 t $ha^{-1}$ at M/S. Rajshree Sugars and Chemicals Ltd. (RSCL) farm. The properties of experimental soil were neutral in pH, non-saline, low in organic carbon and available nitrogen, while high in available phosphorus and potassium status. The DTPA extractable Fe, Mn and Cu were sufficient while Zn was deficient. The effect of balanced fertilization on yield attributes and cane yields were significant. Among the treatments, STCR based fertilizer application ($T_6$) recorded more number of millable cane and it was on par with $T_9$ (RSCL package). The STCR based fertilizer application also recorded highest cane yield and sugar yield of 122.9 and15.91 t $ha^{-1}$, respectively. The leaf nitrogen, phosphorus, potassium and sulphur nutrients content at different growth stages *viz.*, 90<sup>th</sup>, 150<sup>th</sup>, 210<sup>th</sup> and 270<sup>th</sup> days after planting and at harvest indicated that the nutrients content were declined with advancement of growth stages. Considering B:C ratio, among the treatments $T_9$ and $T_{10}$ (TNAU package) which was on par with increase the yield from 102 t $ha^{-1}$ to 128 t $ha^{-1}$ could be recommended. But a revised balanced fertilization package with N at 275 to 300 kg, 112.5 kg $P_2O_5$ and 150 kg $K_2O$ along with 50 kg $FeSO_4$ $ha^{-1}$ and 5 t $ha^{-1}$ bio-compost or any other organic manure with recommended bio-fertilizers such as phosphate solubilizing bacteria and arbuscular mycorrhizae has to be test verified to maximize sugarcane productivity.

**Keywords:** Sugarcane, Bio-fertilizers, yield attributes, cane yield, STCR, fertility, ustropept

## Introduction
Sugarcane (*Saccharum officinarum* L.) is a crop that acts as a natural renewable agricultural resource and provides sugar, bio-fuel, fiber and manure besides many by products. The crop is grown mainly for sugar production and for making gur and khandasari. It is one of the important commercial sugar crops in the world (Anon., 2005) [4]. In India, sugarcane is grown under diverse agro-climatic conditions covering an area of 5.1 million ha with an annual production of 357.7 million tonnes and an average productivity of 70 tonnes $ha^{-1}$ (Economic Survey, 2013) [13]. In Tamil Nadu, sugarcane is cultivated to the extent of 0.31 million hectare (mha) with the production of 32.5 million tonnes of cane and an average productivity of 104 tonnes $ha^{-1}$ (Season and Crop Report 2015) [32]. Among the cane growing states, Tamil Nadu stands third in area and production, and first in productivity, which is about 35% higher than national productivity.

Fertilizers plays a vital role in production and productivity of sugarcane but continuous and indiscriminate use of N fertilizer and inadequate application of P, K, S and micronutrients results in imbalance in the supply of plant nutrients to sugarcane. Subsequently, most of the productive soils become unproductive (Srivastava *et al.*, 2013) [37]. Use of chemical fertilizers in combination with organic manure is essentially required to improve the soil health. The fertilizers need to be applied according to soil and crop characteristics so that nutrient use efficiency and the crop yield levels will be increased (Tiwari, 2002) [40]. The quantities of fertilizer for sugarcane varied in different regions depending upon the soil type, organic matter (OM), and nutrient content of the soil (Plucknett *et al.*, 1970) [27]. Most of soils in the country are low in OM, generally containing less than 1.5% while 2.5 to 3.0% OM are necessary for sustainable crop production (Bhander, 1998) [28]. Sugarcane is an exhaustive crop and depletes soil nutrient heavily. A sugarcane crop giving cane yield of 100 t $ha^{-1}$ may removes about 130 kg of N, 2 kg of P, 146 kg of K, and 30 kg of S per hectare from soil besides other micronutrients and losses of nutrients from soil (Sammuels, 1965) [30]. Application of fertilizers is one of the ways to minimize the yield gap of plant.

In more recent times, considerable gap between the potential and actual cane yields has been realized in different parts of Tamil Nadu and specifically in Theni district where the average yield is 88 t $ha^{-1}$, which is lower than many other parts of Tamil Nadu (Balaji *et al*., 2006) [7]. In experimental field and best maintained farmers field, average yield of sugarcane recorded to the tune of 250 t $ha^{-1}$. But, the district average yield of sugarcane only 88 t $ha^{-1}$ with a sugarcane area of 7,510 ha. Hence, this study was conducted to develop a balanced fertilization package for maximizing sugarcane productivity to 200 t $ha^{-1}$ through soil nutrient database based balanced fertilization. In this study, the effect of balanced fertilization package on plant growth characteristics, nutrient contents, yield and yield attributes and quality parameters of sugarcane were assessed.

## 2. Materials & Methods

### 2.1 Location

The Theni district is located in the foot of Western Ghats between 9º30' and 10º12' North latitude and 77º10' and 77º42' East longitude and 200-400 m above mean sea level in the plains. It is bounded by Dindigul district in the north, Madurai in the east, Virudunagar district in the south and Kerala state in the west. The district has a total geographical area of 2,89,000 ha has a bimodal rainfall pattern and the mean annual rainfall was 765 mm. The rainy season covers June to December and maximum rainfall (50%) is received during North East monsoon from October to December followed by South West monsoon from June to September which contributes 25% of the annual rainfall. The mean maximum, minimum and average air temperatures are 33.3, 23.5 and 28.5$^0$C respectively.

### 2.2 Experimental site and soil characteristics

A field experiment was conducted during 2012-2013 with sugarcane (var. Co 86032) as test crop to validate the balanced fertilization package for maximizing sugarcane productivity at RSCL farm in Theni district of Tamil Nadu. Initial soil samples (0-15 cm) were collected from experimental plots, samples were air dried and ground to pass through a 2 mm sieve. The soil was a calcareous sandyloam (Thulukkanur soil series Typic Ustropept) containing sand, silt and clay at the rate of 70.7, 12.4, and 16.8 %, respectively with pH 7.55 and EC 1.15 dS $m^{-1}$. The soil had 7.4 g $kg^{-1}$ organic carbon, 226 kg $ha^{-1}$ of available N, 43 kg $ha^{-1}$ of available P, of 705 kg $ha^{-1}$ available K, 4.6 $\mu g\ g^{-1}$ of available S, and 0.9 $\mu g\ g^{-1}$ of Zn contents. Also, cation exchange capacity (CEC) of the soil was 15.0 cmol (p+) $kg^{-1}$.

### 2.3Treatment details and fertilizer application

In the RSCL farm experimental site, sugarcane (Var. Co 86032) was grown with following the treatments were imposed.

- $T_1$ - Recommended dose of fertilizers N, $P_2O_5$, $K_2O$ @ 275:150:150 kg $ha^{-1}$
- $T_2$ - 125% N+100% $P_2O_5$+ 100% $K_2O$
- $T_3$ - 100% N+75% $P_2O_5$+ 75% $K_2O$
- $T_4$ - 100%N+50% $P_2O_5$+ 50% $K_2O$
- $T_5$ - 125%N+75% $P_2O_5$+100% $K_2O$
- $T_6$ - STCR based fertilizer prescription for an yield target of 200 t $ha^{-1}$*****
  **(**N: $P_2O_5$: $K_2O$ @ 555:145:115 kg $ha^{-1}$)
- $T_7$ - $T_1$ + Zn (as $ZnSO_4$) @ 25 kg $ha^{-1}$
- $T_8$ - $T_7$ + elemental S (as Gromor) @ 25 kg $ha^{-1}$
- $T_9$ - RSCL package T1+ elemental S (as Gromor) and $ZnSO_4$ each @ 25 kg $ha^{-1}$, $FeSO_4$ @ 50 kg $ha^{-1}$ and Bio-A (*Azospirillum*), P (*Bacillus subtilis* ) and K (*Frateuria*) each @ 2.5 L $ha^{-1}$
- $T_{10}$ - TNAU package (300:100:200:100:37.5 for N, $P_2O_5$, $K_2O$, $FeSO_4$, $ZnSO_4$ kg $ha^{-1}$ and *Azospirillum* and phosphate solubilizing bacteria each @ 2 kg $ha^{-1}$)

*****STCR based fertilizer prescription was computed based on the following equation is given below.

FN = 3.42 T– 0.56 SN – 0.93 ON
F $P_2O_5$ = 1.15 T– 1.94 SP – 0.98OP
F $K_2O$ = 3.16 T– 0.73 SK – 0.99 OK

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 respectively are alkaline $KMnO_4$-N, Olsen-P and $NH_4OAc$-K in kg $ha^{-1}$; ON, OP and OK are the quantities of N, P and K supplied through FYM kg $ha^{-1}$.In all the treatments, 10 % recommended N and 50 % P were applied basally remaining 90 % N was applied in three equal splits @ 30 % with K @ 20, 40 and 40 % at 30$^{th}$, 60$^{th}$ and 90$^{th}$ days after planting. The remaining 50 % of P was applied in 2 equal splits at 60$^{th}$ and 90$^{th}$ days after planting. The crop was harvested at maturity stage and yield attributes were recorded.

### 2.4. Plant sampling and chemical analyses

The effect of balanced fertilization package on growth characteristics number of tillers (120 DAP) and that of millable cane stalks, yield and yield attributes and quality character of sugarcane at harvest were studied. The index leaf samples (3$^{rd}$ - 4$^{th}$) from top of plant cane stalks were collected from the sampled cane at 90$^{th}$, 150$^{th}$, 210$^{th}$, 270$^{th}$ DAP and at harvest and separated into leaf blade and leaf sheath. Midribs were excluded from leaf blade and samples were dried at 70 ºC and milled for nutrient analysis and analyzed for total N, P, K, S, as per the crop logging procedure described by Lakmikantham *et al.* (1970). Soil textural class was determined by hydrometer method and the pH and EC was measured with glass electrode in a 1:2.5 soil/water suspension (Jackson, 1973) [15], Organic Carbon estimation by Walkley and Black (1934), available Nitrogen by Subbaiah and Asija (1956) [38], available soil Phosphorus by Olsen's extractants of 0.5M $NaHCO_3$ as described by Olsen *et al.* (1954) [26] and estimated by Murthy and Riley method using ascorbic acid as reducing agent and as described by Watanabe and Olsen (1965) using spectrometer with red filter at 660 nm wave length. Available potassium was extracted with neutral 1N $NH_4OAc$ and then determined by flame photometer (Jackson, 1973) [15] and available S by turbidimetric method of Williams and Steinbergs (1959) [43] for soil and plant leaf. Micronutrients, were analyzed using atomic absorption spectrometry (Perkin-Elmer 3111) following Petersen (2000). Data were statistically analyzed by using analysis of variance (ANOVA) and the treatment differences were adjudged by Agres test.

### 2.5 Assessment of juice quality criteria

The bio-chemical parameters viz., brix %, pol %, purity % and CCS % were estimated in the laboratory as per the procedure outlined by Meade and Chen (1977) [23]. The analysis was performed on five stalk samples which were collected at the age of 12 months. The stalks were shredded using a cutter grinder. The shredded material was then mixed thoroughly and juice was extracted. The juice was clarified using lead acetate, filtered and polarization reading was taken using Polatronic Universal and the juice was analyzed for quality parameters by using Standard Methods.

## 3. Results and Discussion

### 3.1 Effect of balanced fertilization on yield attributes of sugarcane

#### 3.1.1 Number of tillers

Tillering is an important physiological activity in sugarcane crop. The tiller production and their survival reflect on the total number of millable canes at harvest which ultimately reflects on cane yield. The effect of balanced fertilization on number of tillers of sugarcane at 120$^{th}$ days after planting (DAP) was significant is given in Table 1. The number of tillers of sugarcane varied between 158.3 ('000 ha$^{-1}$) and 184.7('000 ha$^{-1}$) in the RSCL farm. The STCR based fertilizer application ($T_6$) recorded the highest number of tillers 184.7 ('000 ha$^{-1}$), which was on par with $T_9$ (RSCL package), $T_2$ (125% N + 100%P&K) and $T_{10}$ (TNAU package). The results revealed that higher dose of fertilizer application and balanced fertilization package recorded the highest number of tillers due to lower rate of mortality and optimum nutrition. The early application of N in three splits on 30$^{th}$, 60$^{th}$ and 90$^{th}$ DAP induced more vegetative growth and more production of number of tillering (Srinivas *et al.,* 2003) [36]. The balanced fertilizer application along with organic and bio-fertilizers, increase the rate of biosynthesis of various plant metabolites and physiological process in the plant system leading to increased rate of tiller formation (Navnit Kumar, 2012) [25]. The lowest number of tillers of 158.3 ('000 ha$^{-1}$) was recorded in $T_4$ (100% N + 50% P&K).

**Table 1:** Effect of balanced fertilization on yield attributes, juice quality and B:C ratio of sugarcane at RSCL farm

| Treatment No. | No. of tillers (× 10$^3$ ha$^{-1}$) | Number of millable cane (× 10$^3$ ha$^{-1}$) | Brix (%) | Pol (%) | Purity (%) | CCS (%) | B:C ratio |
|---|---|---|---|---|---|---|---|
| $T_1$ | 166.2 | 104.6 | 20.93 | 18.44 | 88.19 | 12.74 | 2.39 |
| $T_2$ | 181.9 | 119.4 | 21.05 | 18.66 | 88.65 | 12.92 | 2.43 |
| $T_3$ | 162.0 | 102.8 | 20.34 | 17.97 | 88.47 | 12.43 | 2.40 |
| $T_4$ | 158.3 | 99.1 | 19.93 | 17.73 | 88.96 | 12.30 | 2.38 |
| $T_5$ | 175.9 | 112.0 | 20.90 | 18.50 | 88.50 | 12.80 | 2.40 |
| $T_6$ | 184.7 | 122.7 | 21.15 | 19.06 | 90.14 | 13.31 | 2.37 |
| $T_7$ | 171.8 | 108.3 | 20.69 | 18.55 | 89.70 | 12.92 | 2.40 |
| $T_8$ | 175.0 | 110.6 | 20.85 | 18.56 | 89.09 | 12.88 | 2.39 |
| $T_9$ | 183.3 | 120.4 | 21.52 | 19.47 | 90.78 | 13.62 | 2.45 |
| $T_{10}$ | 179.6 | 115.7 | 21.09 | 18.83 | 89.31 | 13.09 | 2.43 |
| SEd | 3.36 | 3.05 | 0.551 | 0.447 | 1.05 | 0.450 | |
| CD (P=0.05) | 7.05 | 6.40 | 1.158 | 0.938 | NS | 0.946 | |

### 3.2 Number of millable cane

The number of millable cane is an important yield attribute in determining the ultimate cane yield in sugarcane. Attempt to increase the number of millable cane (NMC) through enhanced tillering are of paramount importance in yield maximization of sugarcane mentioned in table 1. The effect of balanced fertilization on number of millable cane (NMC) was found to be significant and it's varied between 99.1 ('000 ha$^{-1}$) and 122.7 ('000 ha$^{-1}$). The STCR based fertilizer application ($T_6$) recorded the maximum NMC of 122.7 ('000 ha$^{-1}$) which was on par with $T_9$ (RSCL package) and $T_2$ (125% N+100% P&K). The results revealed that balanced use of inorganic fertilizers (major-micronutrients), bio-compost and bio-fertilizers resulted is an increase in number of millable cane. The higher dose of nitrogenous fertilizers recorded higher number of millable cane at harvest due to higher tiller production. Higher NMC was attributed to high tiller production, higher uptake and utilization of plant nutrients (Natarajan, 1998) [24]. The sulphur mediated nitrogen metabolism might have increased the nitrate reductase and sulphate reductase activities, thereby improving chlorophyll formation, which contributed greatly to increased number of millable canes and greater cane diameter (Jamal *et al*., 2003). Also $T_3$ (100%N+75% P&K) and $T_4$ (100% N+50% P&K) were on par with each other and recorded the minimum NMC at the experimental sites.

### 3.3 Effect of balanced fertilization on nutrient content of sugarcane

The effect of balanced fertilization on nutrient content of sugarcane was studied by analyzing the index leaf (3-4$^{th}$ leaf) for leaf N, P, K &S content at different growth stages *viz.,*90$^{th}$, 150$^{th}$, 210$^{th}$, and 270$^{th}$ DAP and at harvest in the RSCL farm site indicated that declined with advancement of growth stages (Figure 1-4). With regards to nutrient content except on 90$^{th}$ DAP in all other stages, the STCR based fertilizer application ($T_6$) on par with $T_5$ (125% N +75 % P + 100 % K), $T_2$ (125 % N + 100 % P&K), $T_{10}$ (TNAU package) or $T_9$ (RSCL package) recorded the highest leaf N content of 2.40, 2.36, 2.34, 1.93 and 1.48 % during 90$^{th}$, 150$^{th}$, 210$^{th}$, 270$^{th}$ DAP and at harvest respectively.

In general a gradual and steady decline in leaf N concentrations was recorded with advancement of growth stages. This might be due to dilution effect of N with growth period. Higher leaf N due to application of higher dose of nitrogen to sugarcane was also reported by Ibrahim (1979) [14]. The leaf N contents in all the treatments were within the sufficiency level upto 270$^{th}$ DAP as reported by Andersen and Bowen (1990) [2] who reported that a critical value for N as 1.8 % for sugarcane. Irrespective of the growth stages of sugarcane the lowest leaf N concentration of 2.10, 2.09, 2.07, 1.68 and 1.20 % were recorded in $T_4$ (100% N+50% P&K) which was on par with $T_1$ (RDF) and $T_3$ (100% N+75 % P&K). In the site all the five stages, the RSCL package ($T_9$) on par with $T_6$ (STCR based fertilizer application), $T_8$ ($T_7$ + S) and $T_7$ ($T_1$+Zn) recorded the highest leaf P content of 0.331, 0.322, 0.305, 0.283 and 0.264 % during 90$^{th}$, 150$^{th}$, 210$^{th}$, 270$^{th}$ DAP and at harvest respectively. In general a gradual and steady decline in P content of the leaves was recorded with advancement of growth stages. The high P content in the plant tissues due to P nutrition enabled the plant to maintain high rate of metabolic and physiological activities, increase the sink size and utilize the photosynthate at a faster rate, which laid down the foundation of higher yield. This corroborates with the findings of Bokhtiar *et al*. (2002) [10] and Kumar *et al.* (2004). The $T_4$ (100% N+50% P&K) recorded the minimum leaf P content of 0.212, 0.204, 0.185, 0.166 and 0.147 % at different growth stages of sugarcane.

In the RSCL farm the TNAU package ($T_{10}$) recorded the highest leaf K content of 2.64, 2.56, 2.27, 1.92 and 1.53 % during 90th, 150th, 210th, 270th DAP and at harvest respectively. The results showed that the higher level of K application @ 200 kg $K_2O$ $ha^{-1}$ increased the K concentration in index leaf which enhanced the activities of leaf carbonic anhydrase (CA) and nitrate reductase (NR) thereby inducing efficient photosynthesis and the formation of primary organic N-containing molecules necessary for amino acids required for protein synthesis. The increasing level of K increased the activities of photosynthesis, protein synthesis and regulation of stomatal movement (Marschner, 1995) [22]. In general, $T_4$ (100% N+50% P&K) recorded the lowest K content while $T_{10}$ (TNAU package) recorded the highest K content. In general a gradual and steady decline in K concentrations of the leaves was noted with advancing crop growth stages. Sangwan *et al.* (2010) [31] also reported that the application of K fertilizers upto 125 kg $K_2O$ $ha^{-1}$ increased the K concentration in index leaf of sugarcane. Irrespective of the growth stages of sugarcane the lowest leaf K content of 1.81, 1.83, 1.62, 1.30 and 1.17 % was recorded in $T_4$ (100% N+50% P&K).

Sulphur is a key component of balanced nutrient application for yields and superior quality of the produce. In the site except 90th and 150th DAP in remaining growth stages, the RSCL package ($T_9$) on par with $T_8$ ($T_7$ +S) recorded the highest leaf S content of 0.280, 0.251, 0.226, 0.185 and 0.148 % during 90th, 150th, 210th, 270th DAP and at harvest respectively. In general, a gradual and steady decline in S concentrations of the leaves was noted with progressing crop growth stages. Bokhtiar and Sakurai (2004) [9] also observed that the S content was higher at tillering stage than grand growth stage and further decreased with advancement of crop growth. Joshi and Amodkar (2000) [17] also reported that application of 60 kg S $ha^{-1}$ increased the S content in leaves from 0.188 to 0.238 %.Irrespective of the growth stages of sugarcane the lowest leaf S content of 0.138, 0.123, 0.114, 0.103 and 0.092 % was recorded in $T_4$ (100% N+50% P&K).

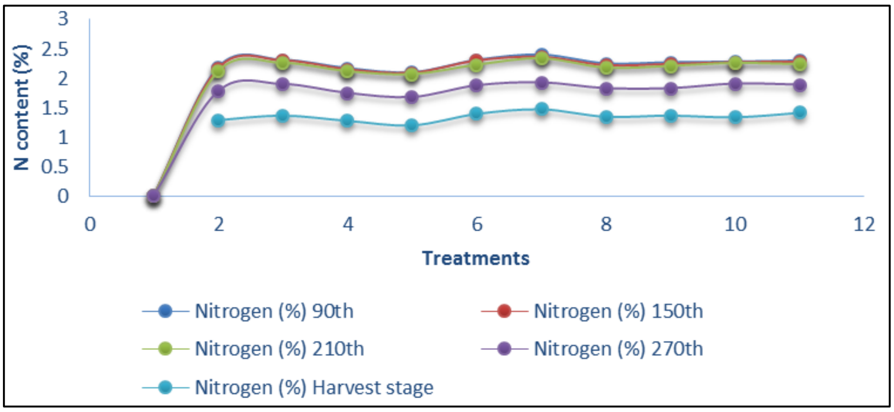


**Fig 1:** Nitrogen content (%) in leaf tissues of sugarcane in different growth stages

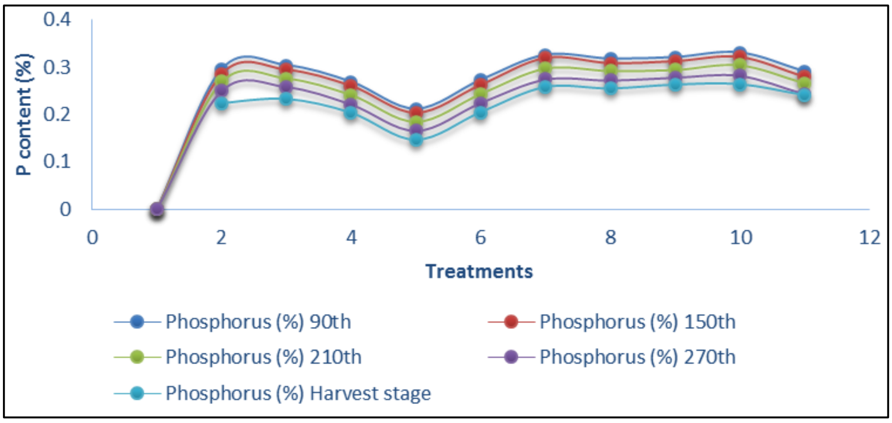


**Fig 2:** Phosphorus content (%) in leaf tissues of sugarcane in different growth stages

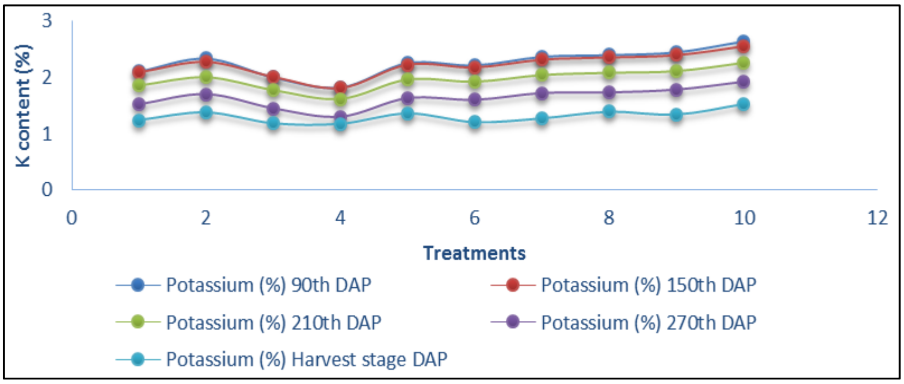


**Fig 3:** Potassium content (%) in leaf tissues of sugarcane in different growth stages

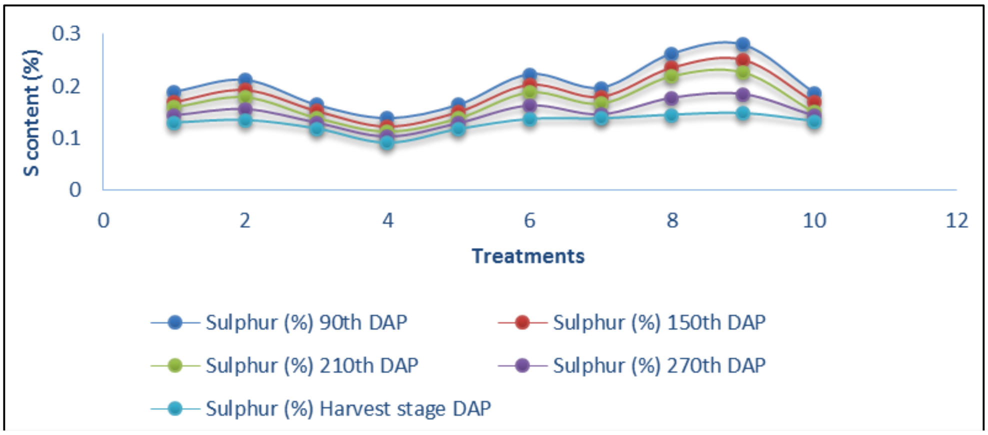


**Fig 4:** Sulphur content (%) in leaf tissues of sugarcane in different growth stages

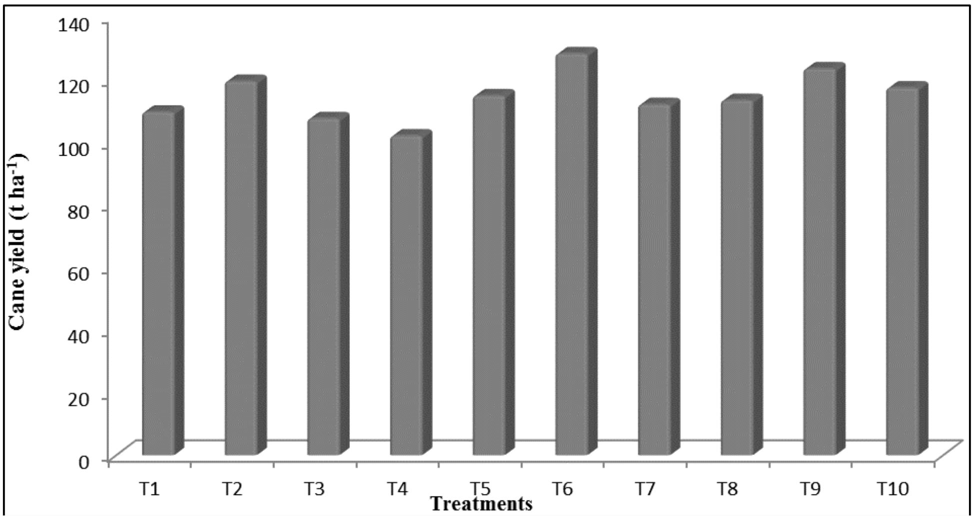


**Fig 5**: Effect of balanced fertilization on cane yield (t $ha^{-1}$) at RSCL farm

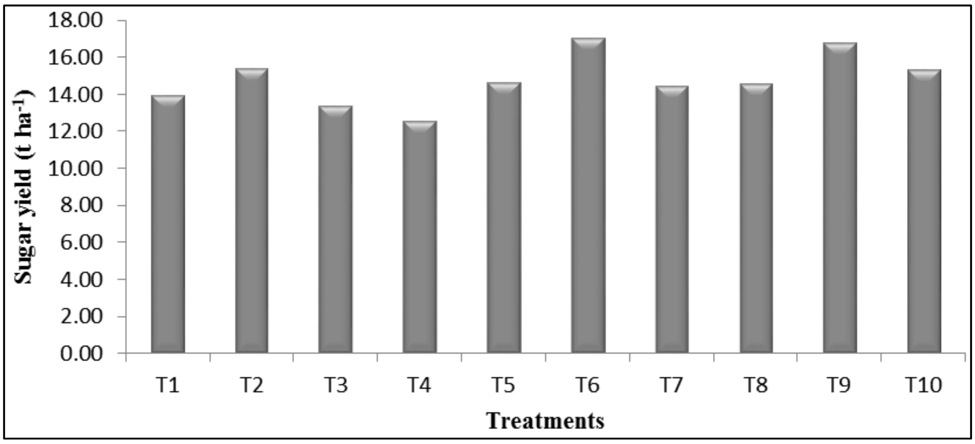


**Fig 6:** Effect of balanced fertilization on sugar yield (t $ha^{-1}$) at RSCL farm

### 3.4. Effect of balanced fertilization on quality parameters of sugarcane

Quality of the crops is very important in deciding the economic value of the produce. In sugarcane, brix %, sucrose % and CCS % are the deciding factors for quality assessment (Table 1). Hence, it is essential to study the effect of balanced fertilization on the quality of the produce for deciding the value of the produce. The effect of balanced fertilization on brix, pol and CCS % of sugarcane juice varied from 19.93 to 21.52, 17.73 to 19.47 and 12.30 to 13.62 % respectively. Among the treatments, the RSCL package ($T_9$) recorded the highest brix, pol and CCS % of 21.52, 19.47 and 13.62, respectively. The increase in quality attributes in the form of brix, pol and CCS % might be due to the balanced supply of nutrients through inorganic fertilizers along with bio-compost and bio-fertilizers, enhanced plants physiological activities which had improved the juice quality of cane. Thangavelu (2007) [39] recorded significantly higher brix and pol % juice of cane grown with Zn fertilization in addition to NPK as compared to those without fertilizers or supplied only with NPK. Singh *et al.* (1997) [29] also observed a significant increase in brix % in sugarcane due to application of Zn. Compared to RSCL package the STCR based fertilizer application recorded lower quality parameters which might be due to higher dose of N addition resulting in vigorous crop growth leading to increased diversion of photosynthate and minerals to meet the requirements for vegetative growth. Also, utilization of photosynthate for sucrose accumulation might have been reduced, resulting in lower brix reported by Rakkiyappan (1987) [28]. As in the case of sucrose %, the CCS % was also affected by the increased doses of applied N and the reduction in CCS % was probably due to the reduced sucrose percentage.

### 3.5. Effect of balanced fertilization of sugarcane yield and economics at RSCL farm

### 3.5.1 Cane yield

The effect of balanced fertilization on sugarcane yield was found to be significant is given in Fig. 5. The mean value of sugarcane yield varied from 101.9 to 128.1 t $ha^{-1}$. Among the treatment practiced, the STCR based fertilizers application ($T_6$) recorded the highest cane yield of 128.1 which was on par with $T_9$ (RSCL package). Increase in cane yield with phosphorus supply might be attributed to increase in number of millable canes at harvest. As soil pH, P and Mn concentrations were important factors in predicting sugarcane yield (Kaler *et al*., 2017) [18]. It was confirmed that a significant positive correlation was observed between number of millable cane and cane yield (r=0.798**) at harvest stage (Arjun *et al*., 2008) [5]. Compared to the existing RDF ($T_1$), $T_6$ and $T_9$ recorded 16.9 and 12.6 % increase in sugarcane yield indicated that the balanced use of inorganic fertilizers, bio-compost and bio-fertilizers resulted in higher productivity. This balanced fertilization mainly attributed to the increase of metabolic process resulting in buildup of dry matter in sugarcane, improvement in soil fertility and increase in total yield due to steady nutrient supply (Bakiyathu Saliha, 2009) [6]. Choudhary and Sinha (2001) [12] also reported that positive improvement in all the growth and yield attributes by balanced dose of fertilization that led to accelerated carbohydrates production and utilization which ultimately resulted in higher yield.

Also $T_2$ (125%N+100%P&K) on par with $T_9$ and $T_{10}$ (TNAU package) established the non-necessity for excess N application above the 100% recommended dose of fertilizers. The results proved the advantages of balanced fertilization on cane yield, it implies that there are no deficiencies, no excess, no antagonisms effect and no negative interactions. The $T_8$ ($T_7$+S) and $T_7$ ($T_1$+Zn) on par with $T_1$ (RDF) recorded 3.0 and 2.19 % increase in sugarcane yield. Compared to the existing RDF ($T_1$), $T_5$ (125% N+75% P+100% K) recorded 4.7 % increase in sugarcane yield, while $T_3$ (100% N+75% P&K) recorded low sugarcane yield of 1.91 % at the site. However, $T_3$ and $T_5$ on par with $T_1$, hence the P can be reduced to the level of 25%. The $T_4$ (100% N+50% P&K) was significantly differed from existing RDF ($T_1$) and there is a reduction in P&K @ 50 %, which recorded lowest sugarcane yield of 6.8 %. Targeted yield concept strikes a balance between 'fertilizing the crop' and 'fertilizing the soil'. Achuthan *et al*. (1989) [1] observed that increased N application upto 450 kg $ha^{-1}$ increased the cane yield. The cane yield in $T_9$ (RSCL package) was significantly increased due to the application of $ZnSO_4$ (25 kg $ha^{-1}$), $FeSO_4$ (50 kg $ha^{-1}$) and elemental S (25 kg $ha^{-1}$). Organic resources are not only sources of major nutrients, but also provide several micronutrients and plant growth promoting hormones, which get together leading to better crop yields (Tyagi *et al*., 2011) [41]. Aneg Singh *et al*.(2003) [29] reported that the increase in cane yield with sulphur application. The higher cane yield with Zn application @ 25 kg $ZnSO_4$ $ha^{-1}$ might be due to the favourable effects of Zn on the biosynthesis of plant hormone, Indole Acetic Acid, which in turn increased the plant height, number of internodes and millable canes (Rohtash Kumar and Singh, 1997) [29]. As $T_6$ and $T_9$ are on par with each other compare to better B:C ratio, the RSCL package ($T_9$) is recommended for obtaining the yield level of 123 t $ha^{-1}$. As $T_9$ is on par with $T_2$ (125% N+100% P&K) and $T_{10}$ (TNAU package), it is concluded that there is no need to apply 25 % extra N or its sufficient to apply $FeSO_4$@ 50 kg $ha^{-1}$. When major NPK alone are applied there is a response for application of 125 % N to the tune of 8.5 % yield. As $T_8$ ($T_7$+S) and $T_7$ ($T_1$+Zn) on par with RDF ($T_1$) there is no response to separate application of either $ZnSO_4$ @ 25 kg $ha^{-1}$ or sulphur @ 25 kg $ha^{-1}$ alone or in combination was not established. As $T_3$ (100% N+75% P&K) and $T_5$ (125% N+75% P+100% K) on par with $T_1$ (RDF) about 25 % P can be reduced. As soil contain high in native P and K, the use of P and K solubilizing bacteria is efficient to utilize fixed nutrients. On the other hand reducing P and K to the tune of 50 % in $T_4$ resulted significantly lower cane yield, hence P and K doses cannot be reduced to beyond 25 %. This might be due to imbalanced application of fertilizers results in poor yields, deterioration of soil fertility and emergence of multiple nutrient deficiencies (Tyagi *et al*., 2011) [41].

### 3.5.1 Sugar Yield

The effect of balanced fertilization on sugar yield was found to be significant is given in Fig. 6. The mean sugar yield varied between 12.54 and 17.04 t $ha^{-1}$. The STCR based fertilizers application ($T_6$) recorded the highest sugar yield of 17.04 t $ha^{-1}$. An, application of 100% N and 50% P and K of RDF ($T_4$) recorded the lowest sugar yield of 12.54 t $ha^{-1}$. The STCR based fertilizer application ($T_6$) recorded the highest sugar yield of 17.04 t $ha^{-1}$ which was on par with the RSCL package ($T_9$) at RSCL farm (16.78 t $ha^{-1}$). Sugar yield had similar trend as that of the cane yield indicating that the juice quality did not influence the sugar yield significantly. The results are in agreement with the earlier findings of Shukla and Lal (2007) [33] followed by Sreelatha *et al*. (2010) [35] who reported that though juice quality is more in organic manure treatments and sugar yield is significantly less due to less cane yields. Kumar *et al*. (2003) [16] reported that application of potassium @ 125 kg $ha^{-1}$ recorded the highest sugar yield (16.9 t $ha^{-1}$) compared to other treatments.

### 3.6 Benefit: Cost ratio

The details of cost of cultivation, gross income, net income and Benefit: Cost ratios of sugarcane in the experimental site given in Table 1. The total cost of cultivation of sugarcane varied from Rs. 100,312 to 126,314 $ha^{-1}$ among the different treatments. The net income, among the treatment varied from Rs. 138,134 to 173,440 $ha^{-1}$ at the sites. The overall, RSCL package ($T_9$) and TNAU package ($T_{10}$) recorded the highest B: C ratio of 2.45 and 2.43 respectively at RSCL farm. The higher cost of cultivation and gross and net return was noticed with STCR based fertilizer application ($T_6$), which might be due to application of higher dose of nitrogenous fertilizers based on targeted yield approach.

## 4. Conclusion

Based upon the experimental results, a treatment combination of 275 to 300 kg N, 112.5 kg $P_2O_5$, 150 kg $K_2O$ and 50 kg $FeSO_4$ per ha along with input like bio-compost and bio-fertilizers can be validated through a farm trials in farmers' fields to increase the sugarcane yield beyond 128 t $ha^{-1}$.

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