Research Article

Impact of Integrated Nutrient Management on Soil Fertility and Nutrient Uptake of Ratoon Sugarcane

S. Udayakumar*[1], K. Baskar[1], B.Bhakiyathu Saliha[2], and C. Jemila[1]

[1]Department of Soils Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore-641003, Tami Nadu, India
[2]Agricultural Research Station, Aruppukottai-626 107, Virudhunagar District, Tamil Nadu, India

Abstract

A field experiment was conducted in Palani Chettipatti (P.C.Patti) village of Theni district, Tamil Nadu with test crop of Sugarcane (*var*. CO 86032) during 2013-2014 to study the impact of integrated nutrient management on soil fertility and nutrient uptake of ratoon sugarcane. The soil test based fertiliser application recorded the highest soil available N (298 kg ha^{-1} and 250 kg ha^{-1}), P (58.6 ha^{-1} and 49 kg ha^{-1}) and K (250 kg ha^{-1} and 213 kg ha^{-1}) at grand growth stage and post-harvest stage of ratoon sugarcane and also recorded the highest nitrogen (487 kg ha^{-1}) and potassium (357 kg ha^{-1}) uptake at harvest stage. The rajshree sugars and chemicals Ltd. package and soil test based fertiliser application recorded the maximum total P uptake of 114.7 and 111.5 kg ha^{-1}, respectively. Combination of fertilisers along with other input like bio-compost and bio-fertilisers for ratoon sugarcane is suggested to improve both soil fertility and nutrient uptake.

Keywords: Ratoon sugarcane, Soil fertility, Nutrient uptake, Integrated nutrient management

***Correspondence**
Author: S. Udayakumar
Email: udhayagri307@gmail.com

Introduction

Importance of fertiliser use to enhance food production is well recognized from quite a few decades, though intensity of fertiliser use increased with wide regional variations in use and consumption. Application of higher doses of fertilisers by the farmers in the field without information on soil fertility status and nutrient requirement by the crop, causes adverse effect on soil and crop regarding both nutrient toxicity and deficiency either by over use or inadequate use [1].

Soil test based application of plant nutrients helps to realize higher response ratio as the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and the correction of the nutrient imbalance in soil helps to harness the synergistic effects of balanced fertilization [2]., it is necessary to have information on the optimum doses of fertilisers and organic manures based on soil testing, nutrient uptake and efficiency of added nutrients by the crop to develop a guideline for judicious application of fertiliser under integrated nutrient management system.

Sugarcane is an important agricultural commercial cash crop, is grown on 4.5 per cent of the total cropped area of the country. Ratoon is unique in the sense that a number of succeeding sugarcane crops is raised from a single planting which is an integral component of sugarcane production system. In India the sugarcane is cultivated on an area of 50.9 lakh hectares with cane production of 3576.7 lakh tonnes and sugar production of 263.42 lakh tonnes [3]. The average cane yield in the country is low when compared to yield level of other countries under similar conditions [4]. 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. The productivity of ratoon crop is 10 to 30 per cent less than the plant crop of sugarcane. Thus, even a small improvement in ratoon crop would add considerably to overall sugarcane production and ratoon crop often gives better yield, quality and sugar recovery than plant cane [5].

In this context, the present investigation on impact of integrated nutrient management on soil fertility and nutrient uptake of ratoon sugarcane was taken up.

Experimental

A field experiment was conducted in Palani Chettipatti (P.C.Patti) village of Theni district with test crop of Sugarcane (*var.* CO 86032) during 2013-2014 to study the impact of integrated nutrient management (INM) on soil fertility and nutrient uptake of ratoon sugarcane. The study site situated in Theni district at 9^o28' and 10^o12' N and 77^o9' and 77^o38' E and 200-400 m. 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 28.5^0C respectively. The soil of the experimental site belonged to Somayanur series and according to USDA soil taxonomy is could be classified as sandy clay loam containing sand, silt and clay at the rate of 63.6, 12.8 and 23.6 per cent clay respectively with pH of 7.70 and moderately fine non arid kaolinitic isomegathermic family of *Typic Haplustalf*. With regard to the fertility status of the soil it was low in available N, high in available P and K (**Table 1**).

Table 1 Initial soil characteristics of experimental field

Soil Characteristics	Value
Soil reaction (pH)	7.70
Electrical conductivity (dS m^{-1})	1.28
Organic carbon (g/kg)	6.8
Total N (%)	0.059
Total P (%)	0.066
Total K (%)	0.275
C/N ratio	13.90
CEC (cmol (p+) kg^{-1})	24.8
Available N (kg ha^{-1})	229
Available P (kg ha^{-1})	38.8
Available K (kg ha^{-1})	295
Available S (mg kg^{-1})	12.0
Available Fe (mg kg^{-1})	3.21
Available Mn (mg kg^{-1})	7.34
Available Zn (mg kg^{-1})	1.25
Available Cu (mg kg^{-1})	1.50

The field experiment was laid out in a randomised block design (RBD) with replicated thrice with the following treatments- T_1-Recommended dose of fertilisers N, P_2O_5, K_2O @ 350:150:150 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 (Soil Test Crop Response) based fertiliser prescription for an yield target of 200 t 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 T_1+ 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 Lha-1, T10-TNAU package (375:100:200:100:37.5 for N, P_2O_5, K_2O, $FeSO_4$, $ZnSO_4$ kg ha^{-1} and *Azospirillum* and phosphate solubilising bacteria each @ 2 kg ha^{-1}).

The soil samples collected from the experimental field were processed and analyzed for experimental studies. The samples were air dried, powdered and sieved through 2.0 mm sieve for the analysis of basic parameters like pH, electrical conductivity and available nitrogen was analyzed by alkaline permanganate method [6], available phosphorus by [7] and available potassium by ammonium acetate method [8].

Plant samples were collected at harvest stage. All the samples were air dried and then oven dried at 60-70 degree celcius for 12 hours. The dried samples were ground and preserved for assessing the nutrient contents and uptake of nutrients. The data were analyzed by ANOVA using AGRES software.

The nutrient uptake of above ground parts of sugarcane was calculated using the following formula.

$$\text{Nutrient uptake} = \frac{\text{Nutrient content (\%) x total dry matter yield (kg ha}^{-1})}{100}$$

Results and Discussion

Effect of INM on available nutrients status of soils of ratoon sugarcane

Soil samples were analysed for major nutrients (NPK) at grand growth stage (GGS) and post-harvest stage (PHS) in ratoon sugarcane field.

Available Nitrogen

Nitrogen is the primary nutrient influencing the yield and quality of cane. Response to applied nitrogen is universal. Nitrogen is generally the determining factor for sugarcane stalk yield and sugar content [9].

The effect of fertilisation on soil available nitrogen status of ratoon sugarcane at grand growth stage (GGS) varied from 268 to 298 kg ha^{-1}. Similarly, in post-harvest stage (PHS) the available N status varied from 224 to 250 kg ha^{-1}. The STCR based fertiliser application (T_6) recorded the highest soil available N status of 298 kg ha^{-1} at GGS and 250 kg ha^{-1} at PHS. This was followed by the treatment T_{10} and T_9 recorded higher available N status, whereas the T_4 (100% N + 50% P_2O_5 and K_2O) recorded the lowest soil available N content (268 kg ha^{-1} and 224 kg ha^{-1}) at GGS and PHS respectively (**Table 2**).

Table 2 Effect of integrated nutrient management on soil svailable N, P and K status of soil

Treatment	Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	GGS	GGS	GGS	PHS	PHS	PHS
T_1	270	44.0	188	144	38.0	228
T_2	290	43.3	201	171	37.6	242
T_3	281	38.6	170	137	32.3	232
T_4	268	31.6	141	118	27.3	224
T_5	290	40.0	210	162	33.0	241
T_6	298	58.6	250	213	49.0	250
T_7	287	51.0	191	151	45.0	239
T_8	290	49.6	199	164	43.3	241
T_9	293	56.0	229	196	47.3	244
T_{10}	294	46.0	218	174	39.6	245
Mean	**286**	**45.9**	**200**	**163**	**39.2**	**239**
SEd	**8.6**	**1.7**	**14.7**	**17.8**	**1.3**	**6.0**
CD (P=0.05)	**18.2**	**3.6**	**31.0**	**37.5**	**2.8**	**12.7**

This indicates that irrespective of the treatment, the soil available N status decreased with advancement of crop growth and it is in the low or marginally medium in available N status. The declining trend in the available N status of the soil could be attributed to the removal of nitrogen for the growth and development of ratoon sugarcane. Crop removal, volatilization and leaching losses reduced the available N status in soil [10]. Leaching and gaseous losses were reported to be major nitrogen loss pathways in ratoon crops [11].

Among the treatments, the STCR based fertilisers application recorded the highest available N status at grand growth stage as well as post-harvest stage, which might be due to the application of higher dose of N (553 kg ha^{-1}), which was followed by RSCL package (T_9) that recorded higher soil available N due to application fertilizer along with bio-compost. These results are in accordance with the findings of [12] who has reported that the application of N @ 387.5 kg ha^{-1} recorded higher level of available N content in soil. [13] reported that application of N @ 210 kg ha^{-1} improve the available N status of soil of 212 kg kg ha^{-1}, due to residual effect. The integrated application of FYM, seasoned pressmud and fertilisers had marked influence on the available N in the soil as reported by [14]. Irrespective of sources, the effect of organic manures in conjoint with inorganic fertilisers was superior over the inorganic treatment alone [15].

Available phosphorus

Phosphorus is essential to fasten the formation of shoots, roots and to increase tillering but its availability depends on the fixation of native and applied P. [16]. (Elamin *et al.*, 2007).

The effect of fertilisation on soil available phosphorus status of ratoon sugarcane at grand growth stage (GGS) varied from 31.6 to 58.6 kg ha^{-1}. Similarly, in post-harvest stage (PHS) the available P status varied from 27.3 to 49 kg ha^{-1}. The STCR based fertiliser application (T_6) recorded the highest available P status of 58.6 ha^{-1} at GGS and 49 kg ha^{-1} at PHS. On the other hand, the T_4 (100 % N + 50 % P_2O_5 and K_2O) recorded the lowest available P status of 31.6 kg ha^{-1} at GGS and 27.3 kg ha^{-1} at PHS (Table 2). The T_6 was on par with T_9 at grand growth stage and post-harvest stages. The available P status was medium to high, which may be due to the continuous application of phosphatic fertilisers both as basally and top dressing and also higher available status of study area.

The STCR based fertiliser application (T_6) significantly recorded the highest available P status which was on par with T_9 (RSCL package) and statistically significant with other treatments. The increased availability of P with inorganic fertilisers along with organics could be ascribed to their solubilizing effect on native soil P and its contribution to labile pool. The potential effect of manure/seasoned pressmud in combination with inorganic fertilisers in enhancing soil available P was in conformity with the results of [17]. Organic anions formed during the decomposition of organic inputs can compete with P for the same sorption sites and thereby increase P availability in soil [18]. Also, presence of higher amounts of sulphur in the soil solution was reported to release higher phosphates in the labile pool due to adsorption of sulphate on the colloidal complexes [19]. The application of N at 150 kg ha^{-1} was significantly increased the maximum available P status of (30.9 kg ha^{-1}) reported by [20]. Umesh *et al.* (2013).

Available potassium

Among the major nutrients, potassium is the key element which maintains cellular organization, stabilizes various enzymatic activities and increases formation and translocation of starch, while its deficiency induces water imbalance in the plant due to the lack of stomatal regulation [21].

The effect of fertilisation on soil available potassium status of ratoon sugarcane at grand growth stage (GGS) varied from 141 to 250 kg ha^{-1}. Similarly, in post-harvest stage (PHS) the available K status varied from 118 to 213 kg ha^{-1}. The STCR based fertiliser application (T_6) recorded the highest available K status of 250 kg ha^{-1} at GGS and 213 kg ha^{-1} at PHS, while the lowest status of soil available K 141 kg ha^{-1} at grand growth stage and 118 kg ha^{-1} at post-harvest stage was observed in T_4 (100 % N+50 % P_2O_5 and K_2O). However, the T_6 was on par with T_9 (RSCL package) and T_{10} (TNAU package) at grand growth stage and on par with T_9 (RSCL package) at post-harvest stage (Table 2).

The ammonium ions generated during mineralisation of N from manures could have caused displacement of K^+ ions from the lattice positions on clay surfaces by ion exchange and resulted in high available potassium [14]. The decline in the available K content from grand growth stage to post-harvest stage of soil could be the result of crop removal. [22] reported that the available K content exhibited a slight reduction between grand growth and internode elongation stage in the plant crop and upto harvest in the ratoon crop. [23] reported that application of farm yard manure along with inorganics in ratoon crop will improve the higher availability of K. [24] reported that the available K content of soil declined from tillering to post harvest stage of sugarcane crop due to crop uptake. This is also in agreement with the findings of [25, 26].

Effect of fertilisation on nutrients uptake of ratoon sugarcane

Total uptake of nitrogen

Nitrogen uptake by ratoon sugarcane is the key factor influencing ratoon sugarcane yield and quality. N is required for vegetative growth *i.e*., tillering, foliage formation, stalk formation, stalk growth (inter node formation, inter node elongation, increase in stalk girth and weight) and root growth.

The effect of fertilisation on total uptake of nitrogen of ratoon sugarcane at harvest varied between 207 to 487 kg ha^{-1}. Among the treatments, STCR based fertilisers application (T_6) significantly recorded the maximum N uptake of 487 kg ha^{-1}. This was followed by the RSCL package (T_9) which was on par with T_2 (125% N and 100% P_2O_5 and K_2O) and T_5 (125% N+ 75% P_2O_5 +100% K_2O). The T_4 (100% N+50% P_2O_5 and K_2O) recorded the lowest total N uptake of 207 kg ha^{-1} (**Table 3** and **Figure 1**). Nitrogen uptake by ratoon sugarcane increased with increasing dose of fertilisers could be attributed to an initial increasing of vegetative growth. [23] revealed that application of full dose of recommended nitrogen (300 kg ha^{-1}) along with biofertiliser recorded higher N uptake up to 282 kg ha^{-1}. [10] also reported that N uptake increased progressively up to 400 kg ha^{-1} in CO 86032 and the increased N uptake with differing N applications was attributed to increased tissue N content and to a lesser extent from increased dry matter production. The higher N uptake due to improved physical condition of soils and better N availability was reported by [27]. [28] reported that sugarcane is highly nutrient exhaustive crop as evident from nutrient removal as the plant crop at the recommended level of added NPK removed 777.1, 119, 651.6 kg ha^{-1} N, P_2O_5 & K_2O respectively.

Table 3 Effect of integrated nutrient management on primary nutrients uptake (kg ha^{-1}) by ratoon sugarcane

Treatment	Total N	Total P	Total K
T_1	241	70.7	250
T_2	426	82.2	329
T_3	246	52.6	217
T_4	207	41.0	183
T_5	422	74.3	294
T_6	487	111.5	357
T_7	285	76.2	289
T_8	317	95.1	303
T_9	428	114.6	354
T_{10}	406	87.4	333
Mean	**346**	**80.5**	**291**
SEd	**9.1**	**5.38**	**7.50**
CD (P=0.05)	**19.3**	**11.3**	**15.7**

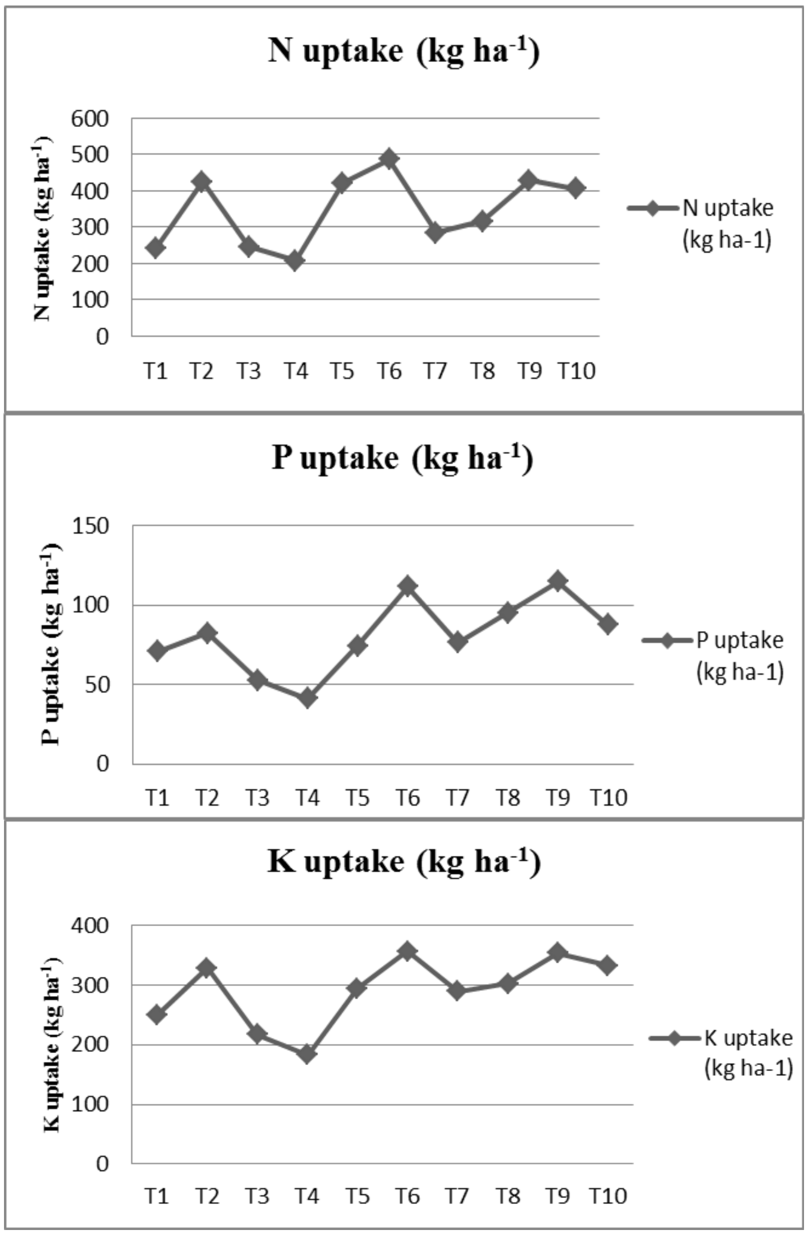

Figure 1 Impact of INM on total NPK uptake of ratoon sugarcane

The RSCL package (T_9) recorded the next highest total N uptake of 428 kg ha^{-1}, which may be attributed to the balanced application of inorganic fertilisers, bio-fertilisers and bio-compost might have improved the physical and chemical properties of the soil facilitating the growth of microorganisms and the transformation and availability of nutrients there by resulting in the better uptake of nitrogen in ratoon sugarcane crop. The integrated use of organics, inorganics and bio-fertilisers exhibited better response in N uptake over inorganic fertilizer alone due to steady supply of nutrients throughout the growing period of crops as reported by [29]. [30] reported that application of 100 per cent recommended NPK (150:60:40 kg ha^{-1}) along with trash and biofertiliser for ratoon crop significantly recorded the highest N uptake of 511.3 kg ha^{-1}.

Total uptake of phosphorus

The effect of balanced fertilization of sugarcane on total phosphorus uptake at harvest varied between 41 to 114.7 kg ha^{-1}. The RSCL package (T_9) and STCR based fertiliser application (T_6) significantly recorded the maximum total P uptake of 114.6 and 111.5 kg ha^{-1} respectively. The T_4 (100% N+50 % P_2O_5 and K_2O) recorded the lowest total P uptake of 41 kg ha^{-1} (Table 3, Figure 1). This was due to increase in drymatter accumulation with simultaneous increase in P concentration which helped in enhancing P uptake. Thus, it produced more dry matter and energy for increased nutrient uptake with longer and thicker canes. Several workers [17, 31, 32] have reported similar results. [33] reported that application of 125 per cent of recommended fertilizer dose of NPK each @ 475, 91.3 and 176.3 kg ha^{-1} recorded highest total P uptake of sugarcane (128.35 kg ha^{-1}) as compared to other treatments in fine clay texture soils at Rahuri. [30] revealed that application of 60 kg P ha^{-1} recorded highest P uptake of 63.7 kg ha^{-1} in ratoon crop of sugarcane.

Total uptake of potassium

The effect of fertilisation on total K uptake of ratoon sugarcane at harvest varied between 183 to 357 kg ha^{-1}. The STCR based fertiliser application (T_6) recorded the maximum total K uptake of 357 kg ha^{-1}, which on par with the RSCL package (T_9) recorded the maximum total K uptake of 354 kg ha^{-1}. The lowest total K uptake of 183 kg ha^{-1} was recorded by T_4 (100% N+50% P_2O_5 and K_2O), (Table 3, Figure 1).

The amount of K removed by plants depends on the production level, soil type, and the retention or removal of plant residues [34]. The lowest total K uptake was observed in T_4 (100% N + 50% P&K) which might be due to 50 per cent reduction of K dose. [28] reported that application of K along with vermicompost and *Gluonacetobactor diazotrophics* significantly recorded the highest K uptake of 651.6 kg ha^{-1} in ratoon crop of sugarcane. [35] reported that application of 66 kg K_2O ha^{-1} improved the K uptake in ratoon crop in subtropical India. This was in accordance with findings of [36] who reported that even if the soil is rich in K, it becomes K deficient under conditions where no K is supplied, because of the continuous K removal during uptake by crops. [37] More *et al*. (2009) reported that the recommended dose of NPK (400:170:170 kg ha^{-1}) along with green manure recorded statistically higher K uptake (351 kg ha^{-1}).

Conclusion

Based upon the experimental results it can be concluded that combination of 350 to 375 kg N, 100 to 150 kg P_2O_5, 150 kg K_2O and 50 kg $FeSO_4$ per ha along with other input like bio-compost and bio-fertilisers for ratoon sugarcane is suggested to improve the soil fertility status and enhance the uptake of nutrients.

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