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Assessment of Optimum Dose and Source of Sulphur for Getting Improved Yield, Quality and Nutrient Uptake in Sugarcane

B. Asha Jyothi[1*], T. Sujatha[2] and K. Subhash Chandra Bose[3]
[1]Senior Scientist (Soil Science), Krishi Vigyan Kendra, Ghantasala, Krishna (Dt.), Acharya N.G. Ranga Agricultural University, (Andhra Pradesh), India.
[2]Principal Scientist (Crop Physiology), RRU, RARS, Lam, Acharya N.G. Ranga Agricultural University, (Andhra Pradesh), India.
[3]Principal Scientist (Crop Physiology)-Retired, Sugarcane Research Station, Vuyyuru, Acharya N.G. Ranga Agricultural University, (Andhra Pradesh), India.

(Corresponding author: B. Asha Jyothi)*
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ABSTRACT: Sulphur plays an important role in the plant's metabolism, and required for amino acids, proteins and photosynthesis. The intensification of agriculture with high yielding crop varieties and multiple cropping coupled with the use of high analysis sulphur free fertilisers along with restricted use of organic manures have accrued in depletion of the soil sulphur reserve. The crops which produce higher biomass and the quality such as sugarcane removes higher amount of sulphur from soil which necessitates the replenishment. Therefore, A field experiment was conducted at sugarcane Research Station, Vuyyuru to know the optimum dose and proper source of sulphur for sugarcane plant crop. Three levels of sulphur *viz;* 30, 60 and 90 kg/ha along with recommended doses of nitrogen, phosphorus and potassium were applied through two sources such as gypsum and elemental sulphur. These were tested against no sulphur treatment. Thus seven treatments were replicated thrice in RBD design with the sugarcane variety 99 V 30. The treatments include T_1: Recommended doses of NPK only (RDF), T_2: RDF + 30 kg of 'S' per ha. through elemental Sulphur, T_3: RDF + 60 kg of 'S' per ha. through elemental Sulphur, T_4: RDF + 90 kg of 'S' per ha. through elemental Sulphur, T_5: RDF + 30 kg of 'S' per ha. through Gypsum, T_6: RDF + 60 kg of 'S' per ha. through Gypsum and T_7: RDF + 90 kg of 'S' per ha. through Gypsum. Shoot population at different stages of crop growth, cane yield, commercial cane sugar yield and nutrient uptake of nitrogen, phosphorus and potassium by sugarcane plant crop were increased with increase in the level of sulphur application and were more at 90 kg sulphur per hectare. Application of sulphur @ 90 kg/ha in the form of gypsum recorded highest cane yield (95.05 t/ha) and CCS yield (11.96 t/ha), 10.31 % increase in juice sucrose and 12.42 % increase in CCS percentage compared to no sulphur application. Whole nutrient uptake of nitrogen (424.84 kg/ha), phosphorus (90.30 kg/ha) and potassium and nutrient availability in the post harvest soils was also increased with the application of sulphur and were more at 90 kg/ha in the form of gypsum. Among the sources tried, gypsum recorded highest cane and CCS yields and nutrient uptake and elemental sulphur was significantly on par with gypsum. As the gypsum is economical in use than elemental sulphur, proper source is gypsum and optimum dose of sulphur for sugarcane plant crop is 90 kg/ha along with the recommended doses of nitrogen, phosphorus and potassium for getting highest cane, CCS yields and nutrients uptake.

Keywords : Sulphur, gypsum, elemental sulphur, sugarcane, cane yield, CCS yield, juice sucrose, nutrient uptake.

INTRODUCTION

Sulphur is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium (Tandon and Messick 2002). Sulphur plays a predominant role in improving the yield and quality of crops and also the use efficiency of nitrogen and phosphorus. Sulphur helps in the synthesis of cystein, methionine, chlorophyll, vitamins (B, biotin and thiamine), metabolism of carbohydrates, oil content, protein content and also associated with growth and metabolism, especially by its effect on the protolytic enzymes (Najar *et al*., 2011). Sulphur is required for synthesis of chlorophyll and is constituent of chlorophyll. Now a days deficiency of sulphur is being observed due to use of straight fertilizers, intensive cropping pattern, minimal use of organic manures in intensive cropping system, increase in use of high yielding varieties of cash crops, increase in cultivable area under irrigation, decreasing fertilizer use efficiency, deteriorating soil health, imbalanced use of fertilisers etc. The tillering and growth of cane is adversely affected in sulphur deficient soil despite application of NPK fertilizers.

Sugarcane is one of the preferred cash crops because of its certain inherent features viz., capacity to cope up with the adverse weather, good survival under poor management, higher photosynthetic efficiency and huge biomass accumulation. Adoption of balanced and judicious use of all needed nutrients can help improve cane productivity and enhance sugar recovery by rendering resistance against biotic and abiotic stresses, and better synthesis and storage of sugar (Yadav, 1993). Imbalance in the use of fertilizer nutrients and depletion in the organic matter status of soils aggravated the problem of sulphur deficiency is soils and crops and became a serious constraint in the use efficiency of other nutrients. This condition implies to Krishna district soils where the sulphur deficiencies were noticed, finally leading to reduction in yield and quality of crops. The crops which produce higher biomass such as sugarcane removes higher amount of sulphur from soil which necessitates the replenishment. Hence the present study is proposed to assess the best source and correct level or dose of sulphur for improving yield and quality of sugarcane crop.

MATERIALS AND METHODS

A field experiment was conducted in sugarcane plant crop using the variety 99 V 30 at Sugarcane Research Station, Vuyyuru, Krishna district of Andhra Pradesh. The experiment was conducted in soil having pH value 7.63 and EC 0.42 d Sm^{-1} (Table 1). Soil is low in organic carbon (0.46 %), medium in available nitrogen (376 kg/ha) high in phosphorus (36 kg/ha) potassium (452 kg/ha) and low in available sulphur (8 ppm). Recommended dose of nitrogen, phosphorus and potassium were applied @ 168, 75 and 100 kg/ha, respectively. Entire dose of phosphorus and potassium were applied as basal at the time of planting and nitrogen was applied in two equal splits at 45 and 90 days after planting. Sulphur was applied in three different levels (30, 60 and 90 kg/ha) through two sources of sulphur (Elemental sulphur and gypsum). These sulphur applied treatments were tested against the control where recommended dose of N, P and K only applied without sulphur. Thus seven treatments were replicated thrice in R.B.D design.

Table 1: Initial soil analysis results in which experiment was conducted.

Sr. No.	Parameter	Value
1.	pH	7.63
2.	E.C.	0.42 dSm^{-1}
3.	Available nitrogen	376 $kgha^{-1}$
4.	Available phosphorus	36 $kgha^{-1}$
5.	Available potassium	452 $kgha^{-1}$
6.	Organic carbon	0.46 %
7.	Available sulphur	8 ppm

Treatments include:

T_1: Recommended doses of NPK only (RDF)

T_2: RDF + 30 kg of 'S' per ha. through elemental Sulphur.

T_3: RDF + 60 kg of 'S' per ha. through elemental Sulphur.

T_4: RDF + 90 kg of 'S' per ha. through elemental Sulphur.

T_5: RDF + 30 kg of 'S' per ha. through Gypsum.

T_6: RDF + 60 kg of 'S' per ha. through Gypsum.

T_7: RDF + 90 kg of 'S' per ha. through Gypsum

Data was collected on shoot population at different stages of crop growth, cane yield and juice quality. Whole cane plant samples were collected at grand growth period, cut into pieces, oven dried, powdered and analysed for nutrient contents of N, P & K using standard methods (Bremner and Mulvaney (1982); Jackson, (1973); Muhr *et al.*, (1963), respectively. Uptake of nutrients was calculated using the following formula

$$\text{Uptake of nutrient (kg/ha)} = \frac{\text{\% Conc. of nutrient} \times \text{Cane yield (t/ha)} \times 1000}{100}$$

RESULTS AND DISCUSSION

Yield and quality: Application of sulphur recorded increased shoot population at different stages of crop growth *i.e* at 90, 160 180 and 240 days after planting compared to control and was more at 90 kg sulphur per ha in the form of gypsum followed by elemental sulphur. Application of sulphur @ 90 kg/ha in the form of gypsum recorded highest cane yield (95.05 t/ha) and CCS yield (11.96 t/ha) and were on par with T_4 (Application of sulphur @ 90 kg/ha in the form of elemental sulphur. Increase in yield attributes such as number of millable canes, cane weight, cane girth and plant height with the application of sulphur along with recommended doses of nitrogen, phosphorus and potassium might have resulted in improved yield and quality. Similar findings were also reported by Satisha *et al.*, (1996), Ghosh *et al.*, (1990); Singh *et al.*, (2007); Shukla and Lal (2007); Hamid *et al.*, (2014) in sugarcane. The results are in cognizance with the findings of Reddy *et al.*, (2021) in pearlmillet, Dileep *et al.*, (2021) in groundnut who reported improved grain and stover yield in pearlmillet, seed yield and oil content in groundnut.

Application of sulphur also increased the quality of sugarcane such as juice sucrose % and CCS % but the increase was not significant (Table 2). Application of sulphur at 90 kg/ha in the form of gypsum resulted with 10.31 % increase in juice sucrose and 12.42 % increase in CCS percentage compared to no sulphur application. These results are in confirmation with Singh *et al.*, (2008); Satisha *et al.*, (1996) and Naga Madhuri *et al.*, (2011).

Table 2: Effect of different sources and levels of sulphur on yield and quality of sugarcane.

Treatments	Shoot population ('000 /ha)					Cane Yield (t/ha)	Juice sucrose (%)	CCS %	CCS Yield (t/ha)
	90 DAP	120DAP	160DAP	180DAP	240DAP				
T_1	56.34	67.88	73.87	63.89	60.50	67.53	15.91	11.19	7.54
T_2	58.24	71.27	78.300	68.57	61.98	80.21	16.35	11.52	9.23
T_3	62.76	72.30	81.77	69.36	65.02	80.21	16.50	11.63	9.29
T_4	63.72	74.39	83.94	70.31	68.14	88.06	17.15	12.66	11.16
T_5	59.03	71.70	81.07	64.67	62.93	80.90	16.62	11.72	9.48
T_6	62.67	73.18	82.38	69.79	66.49	85.55	17.40	12.53	10.71
T_7	64.06	79.25	84.46	73.00	69.01	95.05	17.55	12.58	11.96
C.D@5%	3.60	NS	5.65	5.01	6.30	5.39	NS	NS	1.56
C.V (%)	3.30	8.60	4.00	4.20	5.50	3.70	6.90	8.6	8.9

Nutrient uptake by whole cane plant: Whole plant nutrient uptake of nitrogen, phosphorus and potassium by sugarcane plant crop was increased with the application of sulphur and was more at 90 kg S/ha in the form of gypsum (Table 3) and T_4 where 90 kg sulphur per hectare was applied in the form of elemental sulphur was on par with the gypsum. Nitrogen uptake (424.84 kg/ha) was high with the application of sulphur at 90 kg/ha through gypsum. Das and Das (1994) were reported the increase in nitrogen uptake due to a profuse vegetative growth and higher yield due to sulphur application. The cumulative effect of higher yield along with higher content might have found profound influence on the significant increase of nitrogen uptake with sulphur application. Increased uptake over control indicates the synergism between sulphur and nitrogen in nutrition thus indicating the maintenance of ionic balance in the plant system for favourable increase in yield (Aulakh *et al.,* 1977).

From the Table 3, it can be clear that phosphorus uptake by sugarcane was increased with the increase in dose of application of sulphur and was more at 90 kg/ha in the form of gypsum (80.85 kg/ha). This might be due to increased phosphorus absorption in the presence of sulphur which has the ability to mobilise phosphorus in to available form. Raikhy *et al.,* (1985) and Tiwari *et al.,* (1984) reported that more uptake of phosphorus resulted from enhanced mobilisation of soil phosphorus thereby enhanced efficiency of native and applied phosphorus due to decrease in pH and its utilisation by crops.

Application of sulphur also recorded increased uptake of potassium by sugarcane crop (Table 3). This might be mainly due to the favourable effect of sulphur in increasing the potassium concentration and cane yield indicating the synergistic effect of sulphur and potassium on cane yield and CCS yield. Similarly, increase in uptake of nitrogen, phosphorus and potassium with sulphur application were also reported by Sreemannarayana *et al.,* (1998); Sagare *et al.,* (1990) in sunflower, Singh *et al.,* (1986) in mustard, Das and Das, (1994) in rapeseed and Raikhy *et al.,* (1985) in cowpea.

Gypsum recorded highest nutrient uptake of N, P and K at 90 kg S/ha among the sources tried and elemental sulphur was on par with it. Higher response of gypsum over elemental sulphur was might be due to the fact that gypsum releases available sulphur faster than the elemental sulphur and also supplies calcium which helped in increasing nutrient uptake and yield attributes and thereby resulting in increase in cane yield and CCS yield finally.

Nutrient availability in post harvest soils: pH in the soils after harvest of sugarcane plant crop was more in T_1 where no sulphur was applied along with recommended doses of N, P and K. Reduction in pH was noticed with increasing the levels of sulphur and was less in T_7 where 90 kg sulphur per hectare was applied through gypsum (Table 4). E.C and available nitrogen in the post harvest soils has not shown significant effect with sulphur application. Available phosphorus and potassium in post harvest soils were increased with the sulphur application and were more with 90 kg/ha sulphur application in the form of gypsum. Favourable effects of sulphur application on soil available may be attributed to solubilisation of calcium bound phosphorus due to decreased pH (Table 4) because of oxidation of sulphur inturn making it more available to the plant use (Lal *et al*., 1997).

Table 3: Effect of different sources and levels of sulphur on nutrient uptake by sugarcane.

Treatments	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
T_1	206.81	50.76	317.63
T_2	288.68	68.03	422.76
T_3	285.83	66.56	364.69
T_4	409.31	90.30	464.39
T_5	252.57	62.64	397.82
T_6	334.36	76.55	515.73
T_7	424.84	80.85	466.04
C.D @ 5%	126.97	21.70	NS
C.V (%)	22.7	17.2	22.9

Table 4: Effect of different sources and levels of sulphur on nutrient availability of soil after harvest of sugarcane crop.

Treatments	pH	E.C (dS/m)	Available nitrogen(kg/ha)	Available phosphorus kg/ha)	Available potassium (kg/ha)
T_1	7.87	0.45	234.33	41.06	251.83
T_2	7.77	0.41	246.00	51.18	355.84
T_3	7.71	0.44	242.00	57.14	354.73
T_4	7.55	0.44	248.00	69.82	418.56
T_5	7.69	0.49	243.00	48.22	375.83
T_6	7.70	0.47	249.00	61.44	401.51
T_7	7.65	0.45	238.67	73.68	404.78
C.D 5%	0.125	NS	NS	5.29	46.72
C.V (%)	0.9	11.2	4.5	6.80	7.2

CONCLUSION

Finally to summarise, the shoot population at different stages of crop growth, cane yield, CCS yield, quality, nutrient uptake and nutrient availability in post harvest soils were increased with increase in the dose of sulphur application from no sulphur to 90 kg/ha. Among the sources, gypsum recorded highest yields, quality and nutrient uptake and elemental sulphur was on par with it. However, gypsum is economical in use than elemental sulphur. Hence, it can be concluded that 90 kg sulphur per hectare is the optimum dose and gypsum is the better source for sugarcane plant crop for getting the improved cane, CCS yields, quality, nutrient uptake and nutrient availability of nitrogen, phosphorus and potassium in post harvest soils.

FUTURE SCOPE

For the past two decades, significant progress has been achieved in sulphur research aimed at explaining the role of sulphur in increasing yields and improving the nutritional quality of crops, nutrient uptake and metabolism, identifying the role of sulphur in abiotic and biotic stress responses, and formulating recommended sulphur application rates for different crop species. Further, investigations on the interactions between sulphur and other plant nutrients need to be advanced to establish the exact sulphur contributions (synergistic or antagonistic) to other nutrients uptake and metabolism by plants. This is so relevant considering that sulphur deficiency or over supply may result in toxicity or fixation of other essential nutrients. The other one is the interactions between the plants and rhizospherical microbes, particularly rhizobia and arbuscular mycorrhizal fungi, should be investigated in order to establish the symbiotic relationships between plants and these microbes, with regards to sulphur mineralization and nitrogen fixation. The role of sulphur metabolites in aiding mutualistic interactions between plants and rhizospherical microbes still needs to be explored.

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Conflict of Interest. Nil.

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