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Influence of Sulphur Fertilization on Yield, Nutrient Content and Uptake by Sugarcane in Sulphur Deficient soil of Thiruppuvanam Block of Sivagangai District

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Effect of various levels of sulphur (50,100 and 150 kg ha^{-1}) with three sources of sulphur fertilizers was studied on sugarcane crop in a field experiment conducted in *Typic ustropept* at Thiruppuvanam block of Sivagangai district during 2018-2019. The results revealed that the application of sulphur @ 100 kg ha^{-1} as $FeSO_4$ as soil application along with application of N, P_2O_5 and K_2O on Soil Test Crop Response (STCR) basis registered the maximum nutrient content of N, P, K & S in cane, leaf and total nutrient uptake. The cane yield (162 t ha^{-1}) was maximum at the application of sulphur @ 100 kg ha^{-1} as $FeSO_4$ followed by the treatment receiving 150 kg ha^{-1} of sulphur as $FeSO_4$ inconjoint with N, P_2O_5 and K_2O on STCR basis (157.00 t ha^{-1}).

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1. INTRODUCTION

In India, sugarcane is the most important commercial crop. Sugarcane is used to make commercial sugar (*Saccharum sp*.). In India, around 35.5 crore tonnes of sugarcane and 3 crore tonnes of sugar are produced each year. India is in second place behind Brazil and Cuba in terms of sugar production and consumption. According to the estimation of current financial year, around 2.6 crore tons of sugar is used for domestic purpose. In India, around 35 per cent of sugar is used in household and consumed as food. In the manufacture of beverages and food products, more than 65 per cent of sugar is used as industrial raw material and main ingredient [1]. During 2019-2020, the total area under sugarcane cultivation in India was 4867 (000' ha), with production of 376.905 million tonnes and productivity of 77.6 t ha^{-1}. In Tamil Nadu the total cultivated area was 206 (000' ha) with production of 20600 ('000 tonnes) and productivity of 100 tonnes ha^{-1} [2,3].

Sulphur is one of the essential nutrient elements in crop production, and play an important role improving the yield and quality of crops often ranked next to nitrogen, phosphorus and potassium [4]. Sulphur is placed in the 4^{th} position next to N, P, K [5]. Sulphur is essential for plant photosynthesis and protein metabolism. Sugarcane has a greater sulphur need, and it has been discovered that applying sulphur boosts sugarcane productivity and quality [6]. Sulphur is essential for all living things because it aids in the creation of methionine and cysteine. The amino acid cysteine which forms protein thiamine, biotine and hormones for which sulphur nutrition in needed [7]. Among the various diffidence of sugarcane production the sulphur deficiency plays an important role [8]. Sulphur deficiency in soil is on the rise, due to agricultural practices involving non application of sulphur based fertilizers (or) organic manures. To avoid production losses, S must be supplemented because it is required for sugarcane development and nutritional quality. The purpose of this study was to see how different supplies and quantities of sulphur affected cane yield, yield characteristics, content, and nutrient uptake in Typic Ustropept soils that were sulphur deficient.

2. MATERIALS AND METHODS

A field experiment was carried out to study the response of sulphur on growth and yield of sugarcane in a farmer's field at Sottathatti village of Thiruppuvanam block in Sivagangai district, Tamil Nadu during the year 2018 - 19. The experimental soil classified under Typic *Ustropept*. It was neutral in soil reaction (pH 7.78), low in available N (179 kg ha^{-1}), medium in available P (20 kg ha^{-1}) and K (325 kg ha^{-1}), respectively. The soil was deficient in available sulphur (9 mg kg^{-1}).

There were 12 treatments and replicated thrice with the test crop of Sugarcane (var.CO 86032). The treatment details are follows T_1 - Control, T_2 - Recommended dose of fertilizer (275:62.5:112.5 kg N, P_2O_5 and K_2O ha^{-1}), T_3 - N, P_2O_5 , K_2O on STCR basis, T_4 -T_3 + Sulphur @ 50 kg ha^{-1} as Gypsum, T_5 - T_3 + Sulphur @ 100 kg ha^{-1} as Gypsum, T_6 - T_3 + Sulphur @ 150 kg ha^{-1} as Gypsum, T_7 -T_3 + Sulphur @ 50 kg ha^{-1} as Elemental S, T_8- T_3+ Sulphur @ 100 kg ha^{-1} as Elemental S, T_9 -T_3+ Sulphur @ 150 kg ha^{-1} as Elemental S, T_{10} - T_3 + Sulphur @ 50 kg ha^{-1} as $FeSO_4$, T_{11}-T_3+ Sulphur @ 100 kg ha^{-1} as $FeSO_4$ and T_{12} - T_3 + Sulphur @ 150 kg ha^{-1} as $FeSO_4$.

From each treatment five plants were randomly selected and tagged for observing the yield parameters number of millable canes, cane length, cane girth and cane yield were recorded. The plant samples were collected at critical growth stages *viz.,* Tillering (90DAP), Grand growth stage (150DAP) and Internodes elongation stage (210DAP). The processed plant sample is analyzed to N, P, K and S contents at critical growth stages and uptake was computed at harvest stage.

The crop was kept free of weeds by manual hoeing and hand weeding to avoid possible competition between weed-crop. All other cultural practices were kept normal and identical for all treatments. Observations on desired parameters were recorded using standard procedures. The data collected were subjected to statistically analyzed using "Analysis of variance test". The critical difference at 5% level of significance was calculated to find out the significance of different treatments over each other [9].

3. RESULTS AND DISCUSSION

3.1 Yield Parameters

3.1.1 Number of millable canes (Table 1)

The effect of sulphur fertilization on number of millable cane (NMC) was found to be significant. It ranged from 104.52 (‘000 ha^{-1}) to 52.63 (‘000 ha^{-1}). Among the various sources of sulphur, application of sulphur as $FeSO_4$ performed better as compared to gypsum and elemental sulphur in registering the number of millable canes. The highest number of number millable canes were observed while applying 100 kg sulphur as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O (T_{11}) (104.52(000 ha^{-1}). Application of N, P_2O_5, K_2O on STCR basis recorded the millable canes of 88.44(000) ha^{-1}. The absolute control recorded of the lowest value 52.63 (000 ha^{-1}) (Table 1). Number of millable cane is an important yield attributing factor that decides the cane yield. The increase in number of millable cane due to sulphur application increases the nitrate reductase activity, vegetative growth of the plants. Aneg singh et al*.* [10] reported that application of sulphur @ 80 kg ha^{-1} registered highest number of millable cane.

3.1.2 Single cane weight (Table 1)

Application of sulphur had a positive influence on cane weight of sugarcane. The maximum cane weight of 1.55 kg was recorded in the treatment which has received STCR based N, P_2O_5 and K_2O along with sulphur @ 100 kg ha^{-1} as $FeSO_4$ (T_{11}) and it is statistically onpar with T_{12} (1.54 kg $cane^{-1}$). Using the various sources of sulphur application of elemental sulphur showed the lowest impact on cane weight because of its slow oxidation rate [11]. The lowest cane weight (0.95 kg $cane^{-1}$) was observed in T_1. The treatments T_5 and T_9 were onpar with each other (1.41 and 1.40 kg $cane^{-1}$). Similar observation was already made by, Vijay kumar et al. [12]; Baluram et al. [13] found that application of sulphur increased the test weight of rice crop as sulphur application increases the energy transformation and translocation from source to sink.

3.1.3 Length and girth of millable cane

The effect of sulphur fertilization on the length of millable cane clearly indicated that a positive response was observed irrespective of source and levels of sulphur. It ranged from 248.70 to 182.40 cm. The highest cane length was observed in the T_{11} treatment (248.70) (Table 1). Similar to the cane length the effect of sulphur fertilization on girth of millable cane was also found to be significant. The mean value varied between 10.90 and 6.50 cm (Table 2). The treatments T_5 (9.50 cm) and T_9 (9.40cm) were onpar with each other and recorded lower girth as compared to T_{11} (10.90) while comparing with $FeSO_4$ lower response was observed in gypsum. The reason attributed could be due to poor solubility of gypsum (Ksp = 2.4 x 10^{-5}). Similarly, due to poor oxidation of elemental sulphur, the sulphate availability in the labile pool could have been by reduced. These findings are incorroboration with earlier report of Shukla and Menhilal [14].

3.1.4Number and length of internode of millable cane (Table 2)

A marked influence on sulphur fertilization on number of internodes of sugarcane was observed. The mean values ranged from 12.60 to 28.60. Application of STCR based N, P_2O_5 and K_2O with sulphur @ 100 kg ha^{-1} as $FeSO_4$ (T_{11}) recorded the maximum number of internodes (28.60) which was on par with T_{12} (27.20). Similarly the treatment T_5 (22.50) and T_9 (21.70) were onpar with each other. The least number of internodes of 12.60 was observed in T_1 (absolute control). Similar to the girth, length of internodes in millable cane was also found to be significant and varied between 7.80 and 13.70 cm. Conjoint incorporation of STCR based N, P_2O_5 and K_2O with sulphur @ 100 kg ha^{-1} as $FeSO_4$ (T_{11}) recorded the maximum length of internodes per millable cane (13.70 cm) which was on par with T_{12} (13.30cm). Shinde, [15] registered high intermodal length while applying 80 kg S ha^{-1}. Vijay kumar et al., [11] reported that application of sulphur increases the number of internodes and length of internode in sugarcane crop.

3.2 Cane Yield

A profound influence on the application of sulphur on cane yield was recorded irrespective of its levels and sources. The cane yield varied from 50.00 to 162.00 t ha^{-1} (Table 3). Among the treatment combination, application of sulphur @ 100 kg ha^{-1} as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O (T_{11}) recorded the maximum cane yield of 162.00 t ha^{-1} followed by T_{12} (157 t ha^{-1}) However, they were statistically onpar with each other. As the experimental field was deficient in sulphur (9 mg kg^{-1}), application of external sources of sulphur made a higher impact on cane yield. Aneg Singh et.al. [10] reported that application of sulphur @80 kg ha^{-1} increased the sugarcane yield significantly. The positive response for the application of sulphur on cane yield could be due to increased uptake of N, P & K as evidenced from the present study because of synergistic relationship between sulphur and N, P and K. Application of sulphur increases the photosynthetic rate and carbohydrate assimilation which would have helped in improving the yield attributes and ultimately cane yield [6]. Johnson and Richard, [16] reported a strong positive relationship between sulphur application and sugarcane yield and quality.

3.3 Effect of Sulphur Fertilization on Nutrient Content of Leaf and Cane of Sugarcane (Table 4)

3.3.1 Nitrogen content

The highest nitrogen content of cane and leaf (0.122 and 1.12%) was registered in the treatment which received 100 kg ha^{-1} S as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O (T_{11}) and it is onpar with the T_{12} (0.119 and 1.09%). The lowest nitrogen content of cane and leaf (0.053 and 0.77%) was recorded in the T_1 (absolute control). The result further showed that the N content decreased with advancement of growth stage. This might be due to dilution effect of N with growth period. Verma et al., [17] reported that application of sulphur @ 40 kg ha^{-1} along with recommended dose of NPK significantly increased the N content in rice crop.

3.3.2 Phosphorus content

The phosphorus content in cane and leaf of sugarcane at harvest stage varied from 0.042 to 0.025 and 0.161 to 0.108 per cent, respectively. Application of 100 kg sulphur ha^{-1} as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O (T_{11}) recorded the highest value of 0.042 and 0.161 in cane and leaf respectively. Sudhir Kumar et al., [18] reported that application of sulphur @ 60 kg ha^{-1} along with recommended dose of NPK resulted in highest content of P. Sulphur 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 would have been the possible reason for increased P content in sugarcane. These findings are in corroboration with earlier work of Bokhtiar et al. [19] and Kumar et al. [20].

3.3.3 Potassium content

The potassium content of cane and leaf at harvest stage is depicted in Table 4. Application of 100 kg S ha^{-1} as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O (T_{11}) recorded the highest K content in both cane and leaf (0.141 and 0.970%). The treatments T_5 (0.135 and 0.95%) and T_9 (0.126 and 0.90%) were onpar with each other in registering the K content of leaf and cane. Similar synergistic effect of S on K content was reported by Teotida et al. [21] on mung bean. Caldwell et al. [22] reported that application of sulphur maintain the electro neutrality or ionic balance with in the plant system which would have helped to increase the extracting ability and higher K content.

3.3.4 Sulphur content

The sulphur content in the leaf and cane of sugarcane at harvest stage clearly indicates that sulphur fertilisation significantly increased the sulphur content. A linear increase in sulphur content was observed with sulphur fertilisation. The S content was the highest with application of 100 kg S ha^{-1} as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O (T_{11}) which accounted for 0.024 and 0.113 per cent in cane and leaf respectively. The lowest sulphur content in cane and leaf (0.009 and 0.070%) was recorded in the T_1 (absolute control). Joshi and Amodkar [23] reported that application of 60 kg S ha^{-1} increased the S content in leaves (0.238%) as compared to the treatments which had not received sulphur (0.188%).

3.4 Effect of Sulphur Fertilization on Uptake of Nutrients of Sugarcane (Table 5)

3.4.1 Total nitrogen uptake

The results exhibited that a positive influence of application of sulphur on N uptake of sugarcane crop. It varied between 305.6 and 95.2 kg ha^{-1}. The application of 100 kg ha^{-1} as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O (T_{11}) significantly recorded the maximum N uptake 305.6 kg ha^{-1} which is onpar with T_{12} (295.10 kg ha^{-1}). The lowest N uptake 95.2 kg ha^{-1} was recorded in T_1 (control). The positive effect of application of sulphur on N uptake might be due to synergistic relationship of sulphur on N absorption. The sulphate being developed anion (SO_4^{2-}) would have released the monovalent anion (NO_3^-) from the colloidal complex and brought to the labile pool which would have enhanced the N uptake. Verma et al. [17] reported that application of sulphur @ 40 kg ha^{-1} along with recommended dose of NPK significantly increased the total uptake of N in rice crop which may be due to increased biomass by the enhanced uptake of nitrogen.

3.4.2 Total phosphorus uptake

The effect of sulphur fertilization of sugarcane on total P uptake at harvest varied between 17.75 and 59.14 kg ha^{-1}. The application of sulphur 100 kg ha^{-1} as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O (T_{11}) significantly recorded the maximum P uptake 59.14 kg ha^{-1} which is onpar with T_{12} (56.80 kg ha^{-1}). The addition of SO_2^- would have replaced the $H_2PO_4^-$ from the sesquioxide through anion exchange mechanism and released to the labile pool which would have favoured for the higher uptake of P by the crop. The lowest P uptake of 95.2 kg ha^{-1} was recorded in T_1 (absolute control). Sudhir Kumar et al. (2014) reported that application of sulphur @ 60 kg ha^{-1} registered the highest content and uptake of phosphorus. This may be due to synergistic effect of S on P.

3.4.3 Total potassium content and uptake

The effect of sulphur fertilization on total K uptake of sugarcane at harvest stage varied between 97.08 and 289.33 kg ha^{-1}. The application of sulphur @ 100 kg ha^{-1} as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O (T_{11}) recorded the maximum total K uptake of 289.33 kg ha^{-1}. Higher K uptake due to application of sulphur may be due to the formation of K_2SO_4 which is highly soluble and favoured the uptake of K. Dharmesh Verma and Harendra Singh [24] reported that maximum uptake of K was registered while adding at S @ 60 kg ha^{-1}.

3.4.3 Total sulphur uptake

The sulphur uptake in sugarcane at harvest stage is exhibited in Table 5 the result showed that a positive influence of sulphur uptake by sugarcane crop due to application of various levels of sulphur. The highest sulphur uptake of 47.4 kg ha^{-1} was registered in the treatment receiving a conjoint incorporation of 150 kg S ha^{-1} as $FeSO_4$ and STCR based N, P_2O_5 & K_2O (T_{11}). The lowest S uptake was observed in the T_1 (10.20 kg ha^{-1}). Shaheen et al. [25] who found the favorable positive effect of sulphur on plant growth parameters, consequently increasing the uptake of sulphur by improved rooting system and also sulphur application at higher doses exerted positive influence on uptake of sulphur thereby increasing the cell activities and ultimately contributed for the higher yield attributes and cane yield in sulphur deficit soil.

Table 1. Effect of sulphur on yield attributes of sugarcane in *Typic Ustropept*

Treatment	Number of millable cane ('000 ha^{-1})	Cane weight (kg $cane^{-1}$)	Length of millable cane (cm)
T_1	52.63	0.95	182.40
T_2	91.68	1.01	193.50
T_3	88.44	1.09	201.20
T_4	90.81	1.24	217.40
T_5	99.29	1.41	233.50
T_6	102.04	1.47	240.10
T_7	88.03	1.17	209.50
T_8	94.74	1.33	224.60
T_9	103.57	1.40	231.40
T_{10}	103.85	1.30	225.20
T_{11}	104.52	1.55	248.70
T_{12}	101.82	1.54	247.30
Mean	93.45	1.29	221.23
SEd	2.16	0.03	2.93
CD(P=0.05)	4.51	0.06	6.11

Table 2. Effect of sulphur on girth, number and length of internode of sugarcane in *Typic Ustropept*

Treatment	Girth of millable cane (cm)	Number of internodes per millable cane	Length of internode in millable cane (cm)
T_1	6.50	12.60	7.80
T_2	6.80	13.80	7.90
T_3	6.90	14.10	8.20
T_4	7.80	16.30	9.30
T_5	9.50	22.50	11.60
T_6	9.90	24.90	12.40
T_7	7.30	14.20	9.10
T_8	8.30	18.70	10.20
T_9	9.40	21.70	11.20
T_{10}	8.90	19.20	10.30
T_{11}	10.90	28.60	13.70
T_{12}	10.50	27.20	13.30
Mean	8.56	19.48	10.42
SEd	0.54	1.19	0.34
CD (P=0.05)	1.12	2.47	0.71

Table 3. Effect of sulphur on sugarcane on cane yield (t ha^{-1}) in *Typic Ustropept*

Treatment No.	Cane yield (t ha^{-1})
T_1	50.00
T_2	92.00
T_3	96.00
T_4	113.00
T_5	140.00
T_6	150.00
T_7	103.00
T_8	126.00
T_9	145.00
T_{10}	135.00
T_{11}	162.00
T_{12}	157.00
Mean	122.45
SEd	2.73
CD(P=0.05)	5.68

Table.4. Effect of sulphur fertilization on nutrient content (%) of leaf and cane at harvest stage in sugarcane in *Typic Ustropept*

Treatment	Typic Ustropept							
	N (%)		P (%)		K (%)		S (%)	
	Cane	Leaf	Cane	Leaf	Cane	Leaf	Cane	Leaf
T_1	0.053	0.77	0.025	0.108	0.087	0.710	0.009	0.070
T_2	0.069	0.85	0.027	0.109	0.097	0.82	0.010	0.076
T_3	0.075	0.90	0.029	0.111	0.107	0.77	0.011	0.078
T_4	0.092	0.94	0.033	0.114	0.116	0.79	0.012	0.091
T_5	0.111	1.04	0.039	0.148	0.130	0.92	0.018	0.104
T_6	0.116	1.05	0.040	0.147	0.135	0.95	0.021	0.112
T_7	0.085	0.91	0.031	0.112	0.112	0.78	0.012	0.086
T_8	0.096	0.95	0.034	0.118	0.120	0.83	0.014	0.097
T_9	0.111	1.01	0.036	0.135	0.126	0.90	0.018	0.105

Treatment	Typic Ustropept							
	N (%)		P (%)		K (%)		S (%)	
	Cane	Leaf	Cane	Leaf	Cane	Leaf	Cane	Leaf
T_{10}	0.107	1.00	0.035	0.131	0.123	0.84	0.016	0.098
T_{11}	0.122	1.12	0.042	0.161	0.141	0.97	0.024	0.113
T_{12}	0.119	1.09	0.040	0.158	0.140	0.97	0.023	0.110
Mean	0.10	0.97	0.03	0.13	0.12	0.85	0.02	0.09
SEd	0.002	0.017	0.001	0.003	0.003	0.018	0.003	0.003
CD=0.05	0.004	0.036	0.002	0.006	0.007	0.037	0.006	0.007

Table.5. Effect of sulphur fertilization on total uptake (kg ha $^{-1}$) of macro nutrients in sugarcane in *Typic Ustropept* soil

Treatment	Typic Ustropept			
	N	P	K	S
T_1	95.2	17.75	97.08	10.20
T_2	159.1	28.66	167.03	17.69
T_3	187.3	32.18	178.53	19.90
T_4	220.6	38.80	207.38	27.40
T_5	264.9	50.83	251.17	35.50
T_6	293.1	55.24	283.10	41.21
T_7	179.0	31.63	172.40	21.09
T_8	228.6	40.04	218.24	28.84
T_9	271.9	49.41	258.23	36.96
T_{10}	253.1	45.23	232.35	33.27
T_{11}	305.6	59.14	289.33	47.41
T_{12}	295.1	56.80	282.85	45.01
Mean	279.46	41.15	219.81	30.37
SEd	4.58	0.66	5.09	0.83
CD=0.05	9.56	1.38	10.62	1.74

4. CONCLUSION

From the above results, it can be concluded that the STCR based application of NPK along with sulphur fertilization is extremely important for improving the productivity of sugarcane crop and also for maintaining the soil fertility. Hence application of 100 kg sulphur as $FeSO_4$ in combination with STCR based N, P_2O_5 and K_2O can be recommended district to harvest the maximum yield in sugarcane in the sulphur deficient soils of Sivagangai district.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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