DOI : 10.5958/0974-0112.2021.00045.1

Indian J. Hortic. 78(3), September 2021: 311-316

Effect of different sources and levels of sulphur on soil available nutrients and yield of Jasmine

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ABSTRACT

A field experiment was conducted to study the effect of different sources and levels of sulphur on the available nutrient status and yield of jasmine in 2018. The treatments comprised three levels of sulphur (20, 40 and 60g sulphur/plant/year) from three sources viz., pressmud, gypsum and sulphate of potash along with T1-control (no fertilizer source) and T2 - farmers fertilizer practice (70:110:100g of NPK / plant/year). The recommended dose of fertilizers (RDF) for jasmine at 60:120:120g of N: P_2O_5: K_2O/plant/ year was applied in the form of suphala, urea, single super phosphate and muriate of potash to the treatments T3, T4, T5, T6, T7 and T8. The soil samples collected at different growth stages of the crop were analyzed for soil available N, P, K and S. The mean available sulphur status of 9.2mg kg^{-1} and mean water soluble sulphur content of 7.9mg kg^{-1} was significantly higher in the treatment (T8) that received gypsum as sulphur source @ 60g sulphur/plant/year along with RDF. The same treatment recorded the highest flower yield plant-1 of 2406g and flower yield of 15.4 tonnes per hectare. This treatment was followed by RDF along with Pressmud @ 60g sulphur/plant/year, emphasizing the need for application of 60g sulphur/plant/year for the jasmine crop equivalent to the tune of 2 tonnes gypsum ha^{-1} or 5 tonnes pressmud ha^{-1}.

Keywords: *Jasminum sambac* L., Sulphur, Gypsum, Pressmud, Flower yield

INTRODUCTION

Jasmine (*Jasminum sambac* L.) is one of the most popular and the oldest of fragrant flowers cultivated in India. Tamil Nadu is the leading producer with an annual production of 2.2 lakh tonnes and an average productivity of 8.25 tonnes ha^{-1}(NHB, 7). In Tamilnadu, the jasmine flowers from Madurai district popularly called as "Madurai Malli" is known for its powerful, mysteriously attractive and seductive fragrance and differs from other jasmine flowers in the pattern of transformation of petal colours from harvest to utilization and it has also acquired special status with geographical indication (Vandhana, 13). The favourable climatic condition with high summer temperature, mild winter, high relative humidity and scanty rainfall makes Madurai district an ideal location for Jasmine cultivation. The fragrance of these jasmine flowers is superior because of heavy accumulation of the alkaloids *'Jasmone'* and '*Alpha Terpineol'* (Aravindan, 1). The laterite and red soils of this geographical area are rich in sulphur which is the precursor of these alkaloids. However nutrient survey reveals that Sulphur deficiencies in Indian soils vary from 5 to 83 % with an overall mean of 41 % (Singh, 11) and the nutrient database generated by TNAU clearly established that only 5% of the cultivable area of Madurai district exhibited sufficiency status of available sulphur (Raja Rajeshwaran, 8).The decreasing status in the availability of sulphur is being reflected in the sharp decline of productivity of jasmine flowers, its quality and concrete content. Hence, the present investigation was taken up to evaluate the effects of different levels and sources of sulphur on soil available nutrients contributing to yield and quality of jasmine flowers.

MATERIALS AND METHODS

The experiment was laid out in O. Alangulam village which is located at 9°60'N latitude and 78°06'E longitude in Thiruparankundram block of Madurai district, Tamil Nadu during 2018 The characteristics of initial soil registered sandy loam texture, pH-7.56, EC-0.23 $dSm^{-1}$and an organic carbon content of 6.2g kg^{-1}(Table 1). The status of available N (273 kg ha^{-1}) and K (267 kg ha^{-1}) were medium, available P status (28.1kg ha^{-1}) was high and available S (6.4mg kg^{-1}) was low. The experiment was carried out in Randomized Block Design replicated thrice with eleven treatments *viz*., T_1 Control, T_2-Farmers Fertilizer Practice (70 : 110 : 100 g of N:P_2O_5:K_2O / plant / year), T_3, T_4, T_5 treatments received Pressmud @ 20 g,40 g and 60 g of S/plant/year respectively, T_6, T_7, T_8 treatments received Gypsum at20g 40 g and

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Table 1. Properties of the Experimental soil

S. No.	Parameters	Value
	Physical parameters	
1.	Bulk density (mg m^{-3})	1.25
2.	Particle density (mg m^{-3})	2.31
3.	Percent Pore space	46.0
Physico-chemical properties		
4.	Soil reaction	7.56
5.	Electrical conductivity	0.23
6.	Organic carbon (g kg^{-1})	6.2
Chemical properties		
	Macro nutrients	
7.	Available Nitrogen (kg ha^{-1})	273
8.	Available Phosphorus (kg ha^{-1})	28.1
9.	Available Potassium (kg ha^{-1})	267
10.	Available Sulphur (mg kg^{-1})	6.4
11.	Exchangeable calcium (cmol (p+) kg^{-1}l)	4.5
12.	Exchangeable magnesium (cmol (p+) kg^{-1})	2.8
	DTPA extractable micronutrients	
13.	Fe (mg kg^{-1})	31.4
14.	Mn (mg kg^{-1})	8.86
15.	Zn (mg kg^{-1})	3.31
16.	Cu (mg kg^{-1})	3.09
Biological properties		
i. Enzyme activities		
17.	Dehydrogenase (μg of TPF g^{-1} day^{-1})	3.0
18.	Aryl sulphatase (μg of PNP g^{-1} hr^{-1})	10.1
ii. Microbial population		
19.	Bacteria (× 10^6 CFU g^{-1})	62
20.	Fungi (× 10^3 CFU g^{-1})	3
21.	Actinomycetes (× 10^4 CFU g^{-1})	7

60 g of S/plant/year T_9, T_{10} and T_{11} received Sulphate of Potash @ 20g,40g and 60g of S/plant/year. The recommended dose of fertilizers were applied at 60:120:120g of N:P_2O_5:K_2O/plant/ year in the form of urea, SSP and MOP to the treatments T_3, T_4, T_5, T_6, T_7 and T_8. The treatments T_9, T_{10} and T_{11} received RDF in the form of Sulphala, SSP and MOP. 20 g S/plant corresponds to 108, 267 and 115g, 40 g S/plant 215, 533 and 227g, 60g S/plant corresponds to 324, 800 and 340g of Gypsum, Pressmud and Sulphate of Potash respectively (Table 2).

Soil samples collected during current season shoot initiation, flowering and harvest stages of the crop were assessed for available N, P, K following the standard procedures outlined by Jackson (4) Sulfate was determined in the soil extract by the turbidity method using spectrophotometer on transmittance at a wave length of 420nm (Williams and Steinbergs, 15). The data were statistically analyzed as suggested by Gomez and Gomez (2) by using AGRES and SPSS software packages.Whenever the treatment differences were found significant, critical differences were worked out at five per cent probability level.

RESULTS AND DISCUSSION

The influence of various sources and levels of sulphur on soil pH was found to be non-significant. However the highest pH of 7.46 at current season shoot initiation and 7.56 at post flowering was observed in the treatment that received recommended dose of fertilizer along with gypsum at 60g sulphur/plant/year. Similar non significant reduction in soil pH with the application of sulphur at 125kg ha^{-1} was reported in chickpea by Velarda *et al.* (14). The Electrical Conductivity (EC) values of soil were significantly higher in the plots treated with recommended dose of fertilizers along with sulphur sources compared to untreated control. This might to be due to the increase in soluble salt contents in soil due to the addition of nutrient sources. Among the treatments, gypsum application at 60g sulphur/plant/year recorded significantly higher values of 0.49 and 0.35dSm^{-1} at current season, shoot initiation and post flowering stages respectively. This may be due to the water soluble sulphate form of sulphur in gypsum that becomes readily available in soil. The influence of pressmud application, gypsum and sulphate of potash on soil organic carbon content was found to be significant. RDF along with pressmud at 60g sulphur/plant/year recorded significantly higher soil organic carbon contents of 7.4 and 7.5 g kg^{-1} in current season shoot initiation and post flowering stages respectively. This might be due to the increase in soil microbial activity and substantial increase in soil organic matter aided by improvement in the soil physical conditions due to the pressmud application. Similar reports on the improvement in soil organic carbon with integrated application of fertilizers and organic manures were reported by Tariq Aziz *et al*. (12).

The available nitrogen status of soil was significantly influenced by the application of sulphur along with recommended dose of fertilizers (Table 3). The mean soil available nitrogen status of 311kg ha^{-1} and 237kg ha^{-1} during the current season shoot initiation and post flowering stages respectively were significantly higher in the treatment that received RDF along with gypsum at 60g sulphur/plant/year. Sulphur is not only a growth limiting plant nutrient but

Table 2. Influence of treatments on soil pH, EC and Organic Carbon at various stages of Jasmine

Treatments	pH		EC		OC(g kg^{-1})	
	Current season shoot initiation	Post flowering	Current season shoot initiation	Post flowering	Current season shoot initiation	Post flowering
T_1	7.40	7.51	0.21	0.19	5.8	5.3
T_2	7.45	7.55	0.24	0.21	6.4	6.5
T_3	7.42	7.51	0.26	0.22	6.8	7.0
T_4	7.41	7.49	0.29	0.24	7.1	7.2
T_5	7.39	7.46	0.31	0.26	7.4	7.5
T_6	7.42	7.54	0.42	0.30	6.6	6.7
T_7	7.43	7.55	0.46	0.32	6.7	6.9
T_8	7.46	7.56	0.49	0.35	6.8	7.0
T_9	7.44	7.52	0.35	0.25	6.5	6.7
T_{10}	7.44	7.53	0.37	0.26	6.6	6.8
T_{11}	7.45	7.55	0.41	0.28	6.7	6.9
Mean	7.43	7.52	0.35	0.26	6.7	6.9
SEd	0.15	0.13	0.01	0.009	0.13	0.14
CD (p=0.05)	NS	NS	0.02	0.02	0.27	0.29

T_1 – Control; T_2 - Farmer's Fertilizer Practice; T_3 - RDF + Pressmud (20g of S/plant/year); T_4 - RDF + Pressmud (40g of S/plant/year); T_5 - RDF + Pressmud (60g of S/plant/year); T_6 - RDF + Gypsum (20g of S/plant/year); T_7 - RDF + Gypsum (40g of S/plant/year); T_8 - RDF + Gypsum (60g of S/plant/year); T_9 - RDF + SOP (20g of S/plant/year); T_{10} - RDF + SOP (40g of S/plant/year); T_{11} - RDF + SOP (60g of S/plant/year)

also indirectly influence the use efficiency of other plant nutrients, such as N. Hence the combined application of recommended dose of nitrogen through urea and sulphur through gypsum has improved the efficiencies of these nutrients recording significantly higher available nitrogen than the other treatments. The significant increase in available nitrogen with the application of sulphur through gypsum at 40kg ha^{-1} was earlier reported by Yadav *et al*. (16). Pressmud application at 60g sulphur/plant/year along with RDF recorded the second highest mean available nitrogen content of 299 kg ha^{-1}. The organic matter content of pressmud provides a congenial environment for soil organisms involved in nitrogen transformation and when combined with application of N as urea enhanced the available N status. The available nitrogen status decreased progressively from current season shoot initiation (300kg ha^{-1}) to post flowering stage (247kg ha^{-1}) which might be due to the uptake of nitrogen by the crops for its growth and development.

The available phosphorus status of soil was significantly influenced by the application of sulphur during various growth stages of jasmine crop (Table 3). Application of recommended dose of fertilizers along with organic manures or inorganic materials as sulphur sources recorded significantly higher values of available phosphorus compared to that of farmers fertilizer practice (NPK alone) and unfertilized control. Among the treatments, the available phosphorus status of 30.8kg ha^{-1} was significantly recorded in the treatment that received pressmud at60g sulphur/plant/year followed by gypsum at 60g sulphur/plant/year along with recommended dose of fertilizers (29.3kg ha^{-1}). Organic matter decomposition of pressmud in soils releases carbonic acid which dissolute native P minerals and fixed phosphorus (Mengal and Kirkby, 5) thereby increasing the phosphorus mobility in soil. Hence, in this experiment soil applied with organic manures *viz*., pressmud recorded more available phosphorus than the other sources like gypsum and sulphate of potash indicating the necessity for balanced and integrated use of organics and inorganic nutrient sources to improve the nutrient availability in soils. The unfertilized control plots recorded the lowest values of available phosphorus indicating the depletion of the native soil P as most of the farmers use only nitrogenous fertilizers.

Application of RDF along with sulphate of potash (SOP) at 60 g sulphur/plant/year recorded significantly higher value of available potassium (290 kg ha^{-1}) followed by SOP at40 g sulphur/plant/year (280kg ha^{-1}). SOP with 41.5 % K and 17 % S provides both potassium and sulphur in soluble forms thus increasing their availability in soil rather than the other sources. However, the farmers fertilizer

Table 3. Influence of treatments on soil available nitrogen, phosphorus, potassium (kg ha^{-1}) and sulphur (mg ha^{-1})at various stages of Jasmine crop

Treatments	Current season shoot initiation				Bud forming stage				Peak flowering stage				Post flowering			
	Availability ((kg ha^{-1}))			mg/ ha	Availability ((kg ha^{-1}))			mg/ ha	Availability ((kg ha^{-1}))			mg/ ha	Availability ((kg ha^{-1}))			mg/ ha
	N	P	K	S	N	P	K	S	N	P	K	S	N	P	K	S
T_1	251	20.5	19.8	2.5	241	19.8	222	2.1	236	19.2	214	1.7	220	18.3	208	1.2
T_2	263	23.3	21.2	3.9	252	21.2	237	3.3	238	20.7	228	2.7	227	19.4	224	1.8
T_3	302	27.5	26.3	8.2	284	26.3	248	6.4	244	26.4	239	5.3	234	24.3	229	3.1
T_4	318	30.7	28.9	9.6	298	28.9	254	8.2	261	27.1	243	6.2	253	25.1	236	4.1
T_5	334	35.8	31.4	10.5	316	31.4	260	9.3	287	28.8	249	7.8	260	27.3	243	5.6
T_6	311	27.2	25.2	8.9	282	25.2	262	7.2	271	24.8	251	6.4	255	23.5	239	4.6
T_7	327	28.8	26.9	10.2	307	26.9	266	9.7	279	26.2	259	7.1	258	24.8	241	5.0
T_8	346	33.4	30.1	11.5	327	30.1	274	10.5	298	27.6	262	8.6	272	26.2	251	6.3
T_9	272	24.6	22.5	7.5	260	22.5	270	6.3	250	21.9	258	4.8	241	20.3	245	3.7
T_{10}	281	25.1	24.8	8.1	267	24.8	285	7.1	254	23.9	272	5.5	247	22.4	258	4.2
T_{11}	293	26.3	25.4	9.0	274	25.4	296	7.9	260	24.6	281	6.1	251	23.3	265	4.9
Mean	300	27.6	25.7	8.2	283	25.7	261	7.1	262	24.7	251	5.7	247	23.2	240	4.0
SEd	5.67	0.62	0.59	0.33	5.53	0.59	4.53	0.31	5.41	0.54	4.45	0.28	5.34	0.48	3.68	0.23
CD (p=0.05)	11.83	1.29	1.24	0.73	11.54	1.24	9.56	0.65	11.29	1.13	9.29	0.60	11.16	0.99	7.69	0.48

T_1 – Control; T_2 - Farmer's Fertilizer Practice; T_3 - RDF + Pressmud (20g of S/plant/year); T_4 - RDF + Pressmud (40g of S/plant/year); T_5 - RDF + Pressmud (60g of S/plant/year); T_6 - RDF + Gypsum (20g of S/plant/year); T_7 - RDF + Gypsum (40g of S/plant/year); T_8 - RDF + Gypsum (60g of S/plant/year); T_9 - RDF + SOP (20g of S/plant/year); T_{10} - RDF + SOP (40g of S/plant/year); T_{11} - RDF + SOP (60g of S/plant/year)

practice without the addition of sulphur source and unfertilized control plots recorded lesser values of available K. The significant increase in available potassium when integrated with sulphur sources was reported by Rongzhong *et al*. (9).

In recent years, sulphur deficiencies have become more frequent and the importance of sulphur as the "fourth macronutrient" in crop production is becoming more and more recognized. Sulphur availability in red and laterite soils of Madurai district is considered as precursor of smell causing alkaloids (Jasmone and alpha terpenol) but is reported to be deficient in the soils. Thus the need for standardizing the source and level of sulphur application for Jasmine was considered for this study. The treatment that received gypsum at 60 g sulphur/plant/year recorded significantly higher value of 9.2mg kg^{-}followed by pressmud application at 60g sulphur/plant/year (8.3mg kg^{-1}). Gypsum containing 22% calcium and 18.5% sulphur might have efficiently increased the availability of sulphur. The critical level of sulphur being 10mg kg^{-1} soil, treatment with gypsum or pressmud at 60g sulphur/ plant/year increased the available S content from initial levels of 6 mg kg^{-1} to 9.2 and 8.3mg kg^{-1} respectively..

The increase in available sulphur due to the application of pressmud may be attributed to the positive effect of microorganisms and growth promoting substances on soil conditions, thereby increasing the availability of nutrients like sulphur. By virtue of its nutrient composition especially Ca @ 2.4 % and S @ 2.5 % and high content of organic carbon, the usefulness of pressmud as a potential source of sulphur for jasmine is well established in this study.

The decreasing trend in the water soluble sulphur content values of 5.8, 5.3, 4.8 and 3.2mg kg^{-1} during the current season shoot initiation, bud forming, peak flowering and post flowering stages respectively might be due to the increased uptake of S by the crop with its advancing growth and developmental stages. The mean water soluble sulphur content was significantly higher in the treatment that received maximum level of sulphur in the form of gypsum (60g sulphur/plant/year) followed by pressmud @ 60g sulphur/plant/year. The increase in water soluble fraction of sulphur with the increase in sulphur levels is ensured from the results emanated from various sources of sulphur. Similar results were reported by Shubhangi Dhage *et al*. (10) who also observed that sulphur transformation and its availability depends on its various forms which get influenced by the application of graded levels of sulphur.

The flower yield $plant^{-1}$ of 2406 g $plant^{-1}$ was significantly higher in the treatment that received gypsum as a source of sulphur @ 60g sulphur/plant/year along with RDF (Table 4). The increased nutrient supply through sulphur application can affect the plant growth by its effect on cell growth and cell elongation leading to increased number of flowers and flower weight and ultimately enhanced the flower yield. The yield $plant^{-1}$ ranged from 587 to 2406 g $plant^{-1}$ with the lowest yield per plant in unfertilized control. From the results of the field experiment, it is well established that sulphur application obviously improves the yield of jasmine flowers. Similar findings were reported by Hugar and Nalawadi (3) in *Jasminum auriculatum* where the fertilizer treatments gave significantly higher flower yield than control.

RDF along with gypsum @ 60 g sulphur/plant/year recorded significantly higher yield of 15.4 t ha^{-1} followed by RDF along with Pressmud @ 60 g sulphur/plant/year (13.3t ha^{-1}). Exclusion of S application in control and farmers fertilizer practice recorded lower yield values of 3.8 and 5.1 t ha^{-1} indicating that application of sulphur irrespective of levels and sources increased the flower yield significantly over these treatments (Table 4). Similar yield improvement was reported by Motior *et al*. (6) who emphasized the necessity of sulphur application for better crop growth and good fruit quality of cucumber.

Finally, the rising scarcity of accessible sulphur is a cause for concern in terms of impacting Jasmine flower yield. Results of the experiment emphasized the need for application of gypsum or pressmud as sulphur sources at 60g sulphur/ plant/year that increased the soil available nutrient status of N, P, K and S which in turn had a significant positive influence on the yield of jasmine crop. It can be concluded that sulphur application of 60g sulphur/plant/year equivalent to the tune of 2t gypsum ha^{-1} or 5t pressmud ha^{-1} along with fertilizers at 60:120:120g of $N:P_2O_5:K_2O$/plant/ year can be recommended for improving the availability of nutrient status in the soils and thereby the yield of jasmine flowers. Further, conformity trials can be taken up in soils of sulphur deficiency and sufficiency status alike in jasmine growing regions of the state and the country by including the results of the present study so as to standardize the sulphur recommendation towards maximizing the yield and quality parameters of jasmine flowers.

Table 4. Influence of treatments on yield attributes of *Jasminum sambac*

Treatments	No. of flowers per plant	Yield per plant (g)	Yield per hectare (tonnes)
T_1	289	587	3.8
T_2	367	804	5.1
T_3	621	1497	9.6
T_4	689	1723	11.0
T_5	803	2072	13.3
T_6	665	1649	10.6
T_7	731	1857	11.9
T_8	891	2406	15.4
T_9	456	1008	6.4
T_{10}	502	1140	7.3
T_{11}	557	1298	8.3
Mean	597	1458	9.0
SEd	35.6	51.69	0.60
CD (p=0.05)	80.1	107.82	1.31

T_1 – Control; T_2 - Farmer's Fertilizer Practice; T_3 - RDF + Pressmud (20g of S/plant/year); T_4 - RDF + Pressmud (40g of S/plant/year); T_5 - RDF + Pressmud (60g of S/plant/year); T_6 - RDF + Gypsum (20g of S/plant/year); T_7 - RDF + Gypsum (40g of S/plant/year); T_8 - RDF + Gypsum (60g of S/plant/year); T_9 - RDF + SOP (20g of S/plant/year); T_{10} - RDF + SOP (40g of S/plant/year); T_{11} - RDF + SOP (60g of S/plant/year)

AUTHORS' CONTRIBUTION

Conceptualization of research (BS); Designing of the experiments (BS, PS); Execution of field/lab experiments and data collection (BS, PS); Analysis of data and interpretation (PS, RS); Preparation of manuscript (BS, RS, PS).

DECLARATION

The authors declare no conflict of interest

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Received : November, 2020; Revised : August, 2021; Accepted : September, 2021