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Study of Soil Microbial Population and Enzyme Activities under Jasmine Cultivation as Influenced by Nutrient Sources

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Authors' contributions

This work was carried out in collaboration among all authors. Author BBS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript All authors read and approved the final manuscript. . Authors BB and PB managed the analyses of the study. Author RI managed the literature searches.

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ABSTRACT

Multi nutrient deficiencies in soil have been reported with increasing frequency over the past two decades on a worldwide scale, is considered as an important factor that reduces yield and affects the quality of harvested products. Nutrient cycling and transformation of in soil is influenced by microbes and the availability of organic and inorganic nutrients to plants and microbes can both be controlled through enzyme activities. Keeping this in view a field experiment was conducted at O. Alangulam village of Thiruparankundram block, Madurai district, Tamil Nadu during 2016-18 to evaluate the influence of organic and inorganic sources of nutrients on soil microbial population and enzyme activities and optimize the sulphur requirement of Jasmine (*Jasminum sambac*) which plays a key role in enhancing the yield and quality of flowers. The significantly higher bacterial population of 124 × 10^6 CFU g^{-1} was observed in the treatment that received pressmud as sulphur source @ 60 g sulphur/plant/year along with RDF (recommended dose of fertilisers were applied @ 60:120:120 g of N:P_2O_5:K_2O/plant/ year in the form of urea, SSP and MOP).This was followed by the treatment

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that received pressmud @ 40 g sulphur/plant/year along with RDF (111 × 10^6 CFU g^{-1}). Application of inorganic NPK fertilizers without organics decreased the activities of dehydrogenase and aryl sulphatase enzymes. The flower yield hectare^{-1} ranged from 3.8 to 15.4 tonnes ha^{-1}as influenced by various nutrient sources. Application of RDF along with Gypsum @ 60 g sulphur/ plant/year recorded significantly higher yield followed by the treatment that received RDF along with Pressmud @ 60 g sulphur/plant/year.

Keywords: Aryl sulphatase; bacterial population; dehydrogenase; gypsum; jasmine.

1. INTRODUCTION

Nutrient Management in floricultural crops is very important to enhance the production, productivity, quality and shelf life of flowers. One of the factors affecting the productivity of most of the floricultural crops is improper use of nutrients. To improve productivity, an adequate amount of organic manures and inorganic fertilizers in a balanced proportion should be used which has been given less attention by the flower growers. The most adorable among floricultural crops which is highly esteemed for its attractive and fragrant flowers is Jasmine because of the heavy accumulation of the smell causing alkaloids 'Jasmone' and 'Alpha Terpineol' [1] which is correlated with the sulphur content of soil. Tamil Nadu is the leading producer of jasmine in the country with an annual production of 1,20,750 tonnes from an area of 15,581 hectares and a productivity of 7.75 tonnes ha^{-1} (2016-17). The plants, have long woody stem and bold buds with pinkish tinge, which blooms into snow white star shaped flower with 10 petals which are leaner, longer and spread out [2]. Due to the increasing demand for fresh flowers and concrete, the area under jasmine has increased in recent years and efforts are being made to increase the yield by adopting improved cultural practices. Among the several factors, nutrition is the major component that decides the yield and quality of the crop [3]. Like other plants, *Jasminum samba* requires well balanced dose of nutrients for better growth and quality flower production. Hence there is a need to develop sustainable production system, wherein chemical fertilizers can be minimized by using alternative sources of nutrients. Use of organic manures as a source of nutrients especially for sulphur requirement of jasmine is one of the untapped means and can supplement the nutritional requirement of Jasmine crop [4].

From the literature available, it is presumed that very little research work has been done in evaluating the effect of S nutrition on microbes and enzymes which play key role in inter conversion of organically bound sulphur to inorganic sulphate for the uptake of crops which in turn contributes for higher yield and quality of Jasmine flowers.Among all the enzymes in the soil environment, dehydrogenase is one of the most important indicator of overall soil microbial activity [5-6], because they occur intracellular in all living microbial cells [7-8]. Hence the present investigation was taken upto study the dynamics of soil microbes (bacteria, fungi, actinomycetes)and enzymes (dehydrogenase and arylsulfatase) as influenced by nutrient sources at various levels for improving the yield of Jasmine(*Jasminum sambac*).

2. MATERIALS AND METHODS

The experiment was laid out in O. Alangulam village which is situated at 9□ 60' N latitude and 78□ 06' E longitude in Thiruparankundram block of Madurai district, Tamilnadu.The altitude of the farm is 127 m above MSL and relatively flat with a uniform slope. The experimental field belongs to Palaviduthi soil series, well drained, sandy loam in texture comprising sand, silt and clay at 56.5, 25.0 and 18.4 per cent, respectively with neutral pH of 7.56 and classified under *TypicHaplustalf.* The field 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 and T_5 received pressmud @ 20 g,40 g and 60 g of S/plant/year respectivel.T_6 , T_7 and T_8 treatments received gypsum @ 20 g, 40 g and 60 g of S/plant/year. T_9 ,T_{10} and T_{11} received sulphate of potash @ 20 g,40 g and 60 g of S/plant/year. Regarding the application of fertilisers, the treatments T_3, T_4, T_5, T_6, T_7 and T_8 received the recommended dose of fertilisers(RDF) @ 60:120:120 g of N:P_2O_5:K_2O/plant/ year as urea, single super phosphate(SSP) and muriate of potash (MOP) respectively. The treatments T_9, T_{10} and T_{11} received RDF in the form of Suphala, SSP and MOP. N was applied in three equal splits during October, December and February. Full dose of P

was applied in basal at the time of planting, K in two equal splits during October and February. 20 g S/plant corresponds to 108, 267and 115 g, 40 g S/plant 215, 533 and 227g, 60 g S/plant corresponds to 324, 800 and 340g of gypsum, pressmud and sulphate of potash respectively.

The surface and sub surface soil samples were collected from the depth of 15 cm and 30-45 cm respectively before imposing the treatments. The collected soil samples were processed and sieved through 2.0 mm sieve before placing in sealed and clean polythene bags. Samples were also collected during different growth stages viz., current season shoot initiation, flowering and harvest. The processed soil samples were subjected for analysis of physico - chemical and chemical properties by adopting standard analytical methods (Jackson,1973) and organic carbon estimation by chromic acid wet digestion method (Walkley and Black, 1934). Soil microbial population was enumerated by using standard serial dilution plate techniques as given by Waksman and Fred [9]. Soil dehydrogenase activity was determined by Colorimetry as proposed by Cassida*et al*. [10] and arylsulphatase activity by Colorimetric estimation of Tabatabai and Bremner [11]. The net flowers produced from all the treatments were collected, weighed and treatment-wise yield was expressed in kg ha^{-1}.The experimental data were statistically analyzed as suggested by Gomez and Gomez [12] by using AGRES and SPSS software packages. Whenever the treatment differences were found significant, critical differences were worked out at five percent probability level.

3. RESULTS AND DISCUSSION

3.1 Characteristics of the Experimental Soil

The experimental soils belonged to the taxonomical class *Typic Haplustalf* as per the soil taxonomy [13].The soil had a pH of 7.56, EC of 0.23 dSm^{-1} and organic carbon content of 6.2 g kg^{-1}. (Table 1). The low organic carbon content in the soils may be attributed to the application of inorganic fertilizers (NPK) alone by the farmers without sufficient focus on sulphur, micronutrients and organic manure application. The texture of the soil was sandy loam that ensures better aeration, infiltration, percolation and hydraulic conductivity and root penetration [14].The available N (273 kg ha^{-1}) and K status (267 kg ha^{-1})were moderate, the available P status (28.1 kg ha^{-1})was high and available S (6.4 mg kg^{-1}) was low. The reduced sulphur availability is attributed to the low organic matter content of soil and other factors discussed elsewhere. Organic S as the dominant form of S in soils has already been reported by Eriksen et al. [15] who indicated that the organic S compounds in soils are derived from plant and animal residues and lack of supply of this organic residue will result in sulphur deficiency. The biological properties *viz.*, microbial population and enzyme activities recorded the values that changed with the stages of crop growth. The initial bacterial, fungal and actinomycetes population were 62 x 10^6, 3 x 10^3 and 7 x 10^4 CFU g^{-1} of dry soil. The dehydrogenase and arylsulphatase enzyme activities were 3.0 µg of TPF g^{-1} of soil day^{-1} and 10.1 µg of PNP g^{-1} of soil hr^{-1}respectively.The biological properties of soil changed with the supply of inorganic and organic manures. These values were influenced by the quantity and quality of organic manures applied and the fertilizer management practices adopted as reported by Pascual et al. [16].

3.2 Nutrition Effect on Soil Organic Carbon

The influence of pressmud application and other nutrient sources viz., gypsum and sulphate of potash on soil organic carbon was found to be statistically significant (Table 2).The mean organic carbon content in soil was 6.7 g kg^{-1} and 6.9 g kg^{-1} during the current season shoot initiation and post-flowering stages respectively. The treatments that received recommended dose of fertilisers (RDF) along with pressmud @ 60 g sulphur/plant/year recorded significantly higher soil organic carbon content of 7.4 and 7.5 g kg^{-1} in both the stages respectively closely followed by the application of pressmud @ 40 g sulphur/plant/year recording 7.1 and 7.2 in the above stages. 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 application of chemical fertilizer along with organic manures were reported by Xu et al. [17] and Tariq Aziz et al. [18].

3.3 Nutrition Effect on Soil Microbial Population

The population of bacteria, fungi and actinomycetes in soil were significantly

influenced by the application of nutrient sources at varying levels at various stages of crop growth (Tables.3,4 and 5). The mean bacterial population of 124 x 10^6 CFU g^{-1} was significantly higher in the treatment that received RDF along with pressmud @ 60 g sulphur/plant/year. The reason may be attributed to enhanced organic carbon content of soil as a result of organic manure application compared to inorganic sulphur sources. The high organic carbon content in soil applied with manures might have stimulated the microorganisms by serving as source of carbon, energy and other nutrients essential for their growth and development. Further, the microorganisms occurring naturally in the organic manures could have also contributed to the enhanced bacterial activity in soil applied with pressmud. The treatments that received RDF along with Pressmud @ 40 g sulphur/plant/year (111 x 10^6 CFU g^{-1}) and RDF along with Pressmud @ 20 g sulphur/plant/year (100 x 10^6 CFU g^{-1}) were found to be on par in influencing the bacterial population of soil. Improvement in the bacterial population with addition of sulphur through organic source was reported by Premanandarajah and Shanika [19].

The significantly low bacterial population of 54 x 10^6 CFU g^{-1} was recorded in the control plots. Among the growth stages, significantly highest mean bacterial population of 92 x 10^6 CFU g^{-1} was recorded in current season shoot initiation stage while significantly lower bacterial population of 69 x 10^6 CFU g^{-1} was recorded in post flowering stage. Statistically significant differences were observed for the fungi and actinomycetes population in the soil treated with various sources and levels of nutrients. The lowest mean fungal population of 2 x 10^3 CFU g^{-1} was recorded in the control plots. Among the crop growth stages, the highest mean fungal population of 8 x 10^3 CFU g^{-1} was recorded in current season shoot initiation stage while the mean lowest fungal population of 5 x 10^3 CFU g^{-1} was recorded in post-flowering stage. The mean actinomycetes population of 8 x 10^4 CFU g^{-1} was observed in unfertilized control. The mean highest and lowest actinomycetes population of 16 x 10^4 CFU g^{-1} and 12 x 10^4 CFU g^{-1} were recorded in the current season shoot initiation stage and post-flowering stage respectively. The lowest mean microbial population in control plots may be due to the unavailability of carbon source for microbes. The lesser microbial load of bacteria, fungi and actinomycetes in inorganic fertilized plots might be due to the inhibitory nature of chemical fertilizers on the growth and development of microbes.

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

Table 2. Influence of treatments on OC at various stages of Jasmine crop

Treatment details	OC (gkg^{-1})	
	Current season shoot initiation	Post flowering
T_1 – Control	5.8	5.3
T_2 - Farmer's Fertilizer Practice	6.4	6.5
T_3 - RDF + Pressmud (20g of S/plant/year)	6.8	7.0
T_4 - RDF + Pressmud (40g of S/plant/year)	7.1	7.2
T_5 - RDF + Pressmud (60g of S/plant/year)	7.4	7.5
T_6 - RDF + Gypsum (20g of S/plant/year)	6.6	6.7
T_7 - RDF + Gypsum (40g of S/plant/year)	6.7	6.9
T_8 - RDF + Gypsum (60g of S/plant/year)	6.8	7.0
T_9 - RDF + SOP (20g of S/plant/year)	6.5	6.7
T_{10} - RDF + SOP (40g of S/plant/year)	6.6	6.8
T_{11} - RDF + SOP (60g of S/plant/year)	6.7	6.9
Mean	6.7	6.9
SEd	0.13	0.14
CD (p=0.05)	0.27	0.29

Table 3. Effect of nutrient sources on bacterial population (x 10^6 CFU / g of dry soil) at various stages of Jasmine crop

Treatment details	Current season shoot initiation	Bud forming stage	Peak flowering stage	Post flowering	Mean
T_1 – Control	65	58	51	41	54
T_2 - Farmer's Fertilizer Practice	78	69	57	48	63
T_3 - RDF + Pressmud (20g of S/plant/year)	98	111	102	89	100
T_4 - RDF + Pressmud (40g of S/plant/year)	109	121	114	98	111
T_5 - RDF + Pressmud (60g of S/plant/year)	122	131	126	118	124
T_6 - RDF + Gypsum (20g of S/plant/year)	84	76	68	60	72
T_7 - RDF + Gypsum (40g of S/plant/year)	92	86	77	68	81
T_8 - RDF + Gypsum (60g of S/plant/year)	96	89	80	71	86
T_9 - RDF + SOP (20g of S/plant/year)	80	72	58	51	65
T_{10} - RDF + SOP (40g of S/plant/year)	85	67	63	55	68
T_{11} - RDF + SOP (60g of S/plant/year)	91	80	71	63	76
Mean	92	87	79	69	
SEd	5.8	5.3	5.2	4.8	
CD (p=0.05)	13.2	12.1	11.1	10.1	

Table 4. Effect of nutrient sources on fungal population (x 10^3 CFU / g of dry soil) at various stages of Jasmine crop

Treatment details	Current season shoot initiation	Bud forming stage	Peak flowering stage	Post flowering	Mean
T_1 – Control	3	2	2	2	2
T_2 - Farmer's Fertilizer Practice	5	4	4	3	4
T_3 - RDF + Pressmud (20g of S/plant/year)	10	11	7	6	9
T_4 - RDF + Pressmud (40g of S/plant/year)	11	12	8	7	10
T_5 - RDF + Pressmud (60g of S/plant/year)	13	14	10	9	12
T_6 - RDF + Gypsum (20g of S/plant/year)	7	6	5	4	6
T_7 - RDF + Gypsum (40g of S/plant/year)	8	6	5	5	6
T_8 - RDF + Gypsum (60g of S/plant/year)	9	7	6	5	7
T_9 - RDF + SOP (20g of S/plant/year)	6	5	5	4	5
T_{10} - RDF + SOP (40g of S/plant/year)	7	6	6	5	6
T_{11} - RDF + SOP (60g of S/plant/year)	8	7	6	6	7
Mean	8	7	6	5	
SEd	0.51	0.49	0.40	0.39	
CD (p=0.05)	1.09	1.02	0.84	0.83	

Table 5. Effect of nutrient sourceson actinomycetes population (X 10^4 CFU / g of dry soil) at various stages of Jasmine crop

Treatment details	Current season shoot initiation	Bud forming stage	Peak flowering stage	Post flowering	Mean
T_1 – Control	9	8	8	6	8
T_2 - Farmer's Fertilizer Practice	11	10	9	8	10
T_3 - RDF + Pressmud (20g of S/plant/year)	18	21	19	16	19
T_4 - RDF + Pressmud (40g of S/plant/year)	22	23	21	17	21
T_5 - RDF + Pressmud (60g of S/plant/year)	24	26	24	21	24
T_6 - RDF + Gypsum (20g of S/plant/year)	13	11	12	10	12
T_7 - RDF + Gypsum (40g of S/plant/year)	16	14	15	12	14
T_8 - RDF + Gypsum (60g of S/plant/year)	19	18	17	14	17
T_9 - RDF + SOP (20g of S/plant/year)	11	10	10	9	10
T_{10} - RDF + SOP (40g of S/plant/year)	13	12	11	10	12
T_{11} - RDF + SOP (60g of S/plant/year)	16	15	13	11	14
Mean	16	15	14	12	
SEd	0.77	0.88	0.76	0.48	
CD (p=0.05)	1.61	1.83	1.58	1.00	

3.4 Nutrition Effect on Soil Enzyme Activities

A high level of enzyme activity is essential for maintaining soil health. Enzyme activities are an important index of the biological activity of a soil because they are involved in the dynamics of soil nutrient cycling and energy transfer. Statistically significant differences were observed for soil dehydrogenase activity (Table 6) and aryl sulphatase activity (Fig.1) in soil influenced with the application of nutrient sources at varying levels The treatment that received RDF along with pressmud @ 60 g sulphur/plant/year recorded the highest mean dehydrogenase activity of 7.2 µg of TPF g^{-1} day^{-1} and was significantly higher over other treatments. The treatments that received RDF along with pressmud @ 40 g sulphur/plant/year (6.8 µg of TPF g^{-1} day^{-1}) and RDF along with pressmud @ 20 g sulphur/plant/year (6.6 µg of TPF g^{-1} day^{-1}) were on par in influencing the dehydrogenase enzyme activity. The significantly lower dehydrogenase enzyme activity of 3.3 µg of TPF g^{-1} day^{-1} was observed in the control plots. These treatments influenced the arylsulphatase activity in a similar pattern. The bud forming stage recorded the highest mean dehydrogenase enzyme activity of 5.9 µg of TPF g^{-1} day^{-1} while post flowering stage recorded the lowest mean dehydrogenase activity of 5.5 µg of TPF g^{-1} day^{-1}. Dehydrogenase activity with application of organic sources like pressmud might be linked to more substrate availability in the soil. This reflects the greater biological activity in the soil and the stabilization of extracellular enzymes through complexation with humic substances [20].

Application of Ca and S through gypsum at various levels was found to influence the dehydrogenase activity next to pressmud which might be attributed to better soil aggregation and aeration. However, farmers fertilizer practice and control which did not receive sulphur either through organic or inorganic sources registered the lower values of dehydrogenase activity in soil [21]. The treatment that received pressmud as sulphur source @ 60 g sulphur/plant/year recorded significantly higher aryl sulphatase enzyme activity of 38.2 ug of PNP g^{-1} hr^{-1} followed by the application of pressmud @ 40 g of sulphur/plant/year (36.1 ug of PNP g^{-1} hr^{-1}) .Close relationships between microbial biomass and arylsulfatase activities in all the plots supported the hypothesis that organic carbon content and enzyme activities should be related to each other via microbial biomass. Arylsulfatase activity was found to be a good indicator of microbial population. The decrease in aryl sulphatase activity with application of inorganic NPK coincides with the results of LadislavHolik et al [22]. The farmer's fertilizer practice and control plots where there was no external application of sulphur either through organic or inorganic sources recorded the significantly lesser activity of aryl sulphatase. The bud forming stage recorded the highest mean aryl sulphatase activity of 20.9 µg of PNP g^{-1} hr^{-1} whereas the current season shoot initiation stage registered the lowest mean aryl sulphatase activity of 19.5 µg of PNP g^{-1} hr^{-1}.

3.5 Nutrition Effect on Yield of Jasmine

Statistically significant difference was obtained for yield per hectare by the application of sulphur sources and levels (Fig 2). The highest flower yield per hectare of 15.4 tonnes was registered with the treatment that received application of RDF along with gypsum @ 60 g of S/plant/year followed by the application of RDF along with pressmud @ 60 g of S/plant/year (13.3 tonnes ha^{-1}). The lowest yield of 3.8 tonnes ha^{-1} was registered in control plots followed by farmers fertilizer practice (5.1 tonnes ha^{-1}). The flower yield $hectare^{-1}$ ranged from 3.8 to 15.4 tonnes ha^{-1} . The highest yield was found in the treatment that received RDF along with gypsum @ 60 g sulphur/plant/year followed by the application of RDF along with Pressmud @ 60 g sulphur/plant/year. The maximum number of flowers $plant^{-1}$ and yield $plant^{-1}$ in these treatments has resulted in higher yield per hectare. Application of sulphur at all levels and from all sources increased the flower yield significantly over the control. Similar yield improvement with sulphur application was reported in many other crops also. Motior*et al*. [23] emphasized the necessity of sulphur application for better crop growth and good fruit quality of cucumber. while Ercoli et al. [24] reported that S applications at both levels (60 and 120 kg/ha S) increased theyield of durum wheat.

Table 6. Influence of treatments on soil dehydrogenase activity (ug of TPF / g of dry soil / day) at various stages of Jasmine crop

Treatment details	Current season shoot initiation	Bud forming stage	Peak flowering stage	Post flowering	Mean
T_1 – Control	3.2	3.4	3.3	3.1	**3.3**
T_2 - Farmer's Fertilizer Practice	4.3	4.6	4.4	4.2	**4.4**
T_3 - RDF + Press mud (20g of S/plant/year)	6.5	6.7	6.6	6.4	**6.6**
T_4 - RDF + Press mud (40g of S/plant/year)	6.8	7.0	6.9	6.6	**6.8**
T_5 - RDF + Press mud (60g of S/plant/year)	7.1	7.4	7.2	7.0	**7.2**
T_6 - RDF + Gypsum (20g of S/plant/year)	5.7	6.0	5.8	5.5	**5.8**
T_7 - RDF + Gypsum (40g of S/plant/year)	6.2	6.5	6.4	6.0	**6.3**
T_8 - RDF + Gypsum (60g of S/plant/year)	6.4	6.8	6.7	6.3	**6.6**
T_9 - RDF + SOP (20g of S/plant/year)	4.9	5.2	5.0	4.7	**5.0**
T_{10} - RDF + SOP (40g of S/plant/year)	5.3	5.6	5.5	5.0	**5.4**
T_{11} - RDF + SOP (60g of S/plant/year)	5.6	5.9	5.7	5.3	**5.6**
Mean	**5.6**	**5.9**	**5.8**	**5.5**	
SEd	**0.14**	**0.18**	**0.16**	**0.12**	
CD (p=0.05)	**0.30**	**0.38**	**0.34**	**0.25**	

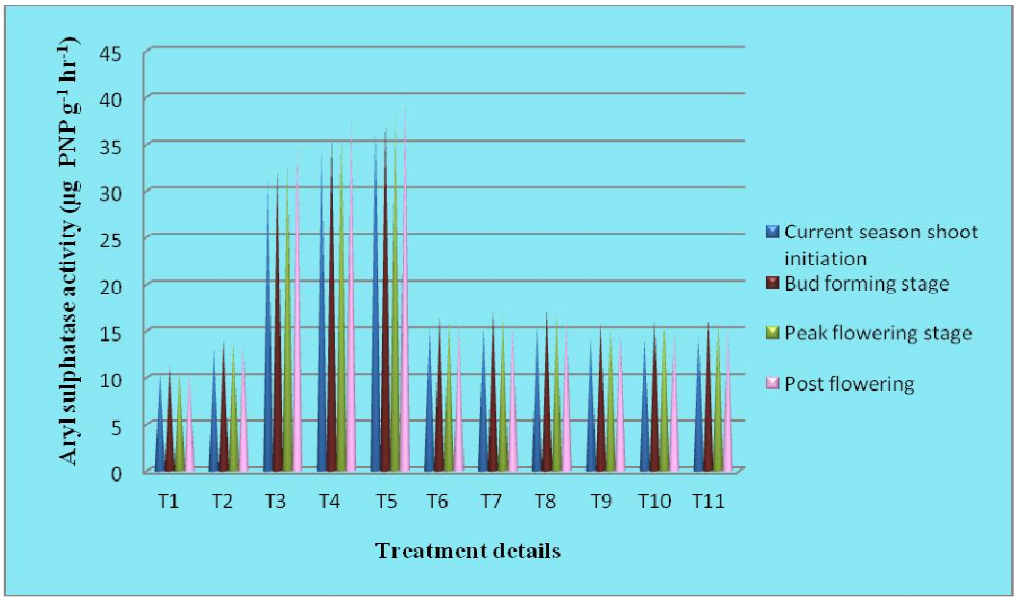

Fig. 1. Effect of treatments on aryl sulfatase activity

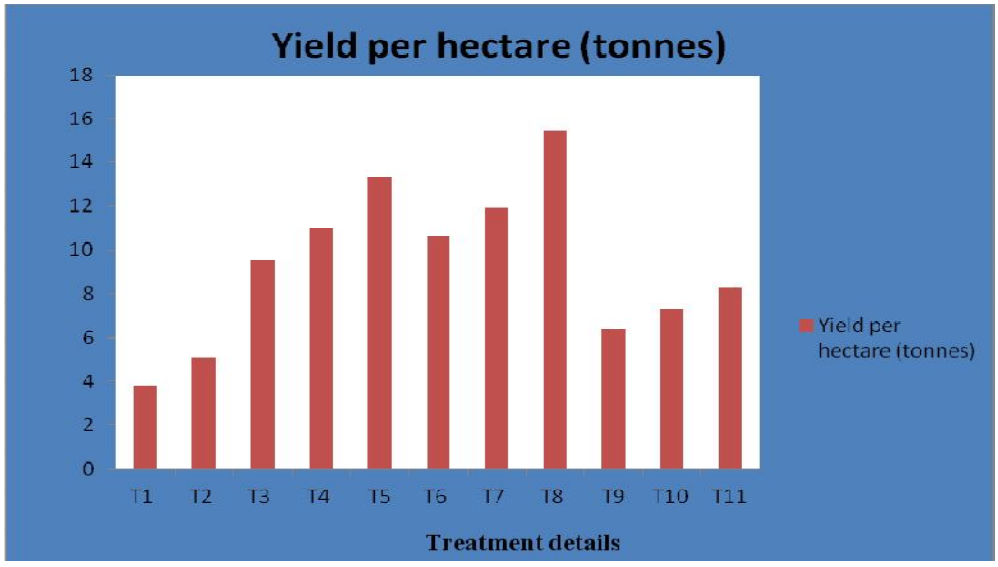

Fig 2. Influence of treatments on yield (tonnes ha^{-1}) of *Jasminum sambac*

4. CONCLUSIONS

Application of pressmud source @ 60 g sulphur/plant/year recorded significantly higher organic carbon content in the soil. The highest microbial population of 124 x 10^6 CFU g^{-1} (bacteria), 12 x 10^3 CFU g^{-1} (fungi) and 24 x 10^4 CFU g^{-1} (actinomycetes) were observed with the treatment that received pressmud @ 60 g sulphur/plant/year along with RDF followed by treatment that received pressmud @ 40 g sulphur/ plant/year along with RDF. Similar influence of these treatments were observed on the dehydrogenase and aryl sulphatase enzyme activities. However, the farmers fertilizer practice of non-inclusion of S source and control without application of NPKS recorded the minimum values for the above parameters. Hence it can be concluded that application of gypsum or pressmud as sulphur source @ 60 g sulphur/ plant/year enhanced the yield attributes of jasmine crop emphasizing the need for

application of 60 g sulphur/plant/year for the jasmine crop equivalent to the tune of 2 tonnes gypsum ha^{-1} or 5 tonnes pressmud ha^{-1}.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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