

Original Research Article

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Nutritional Significance of Sulphur on Growth, Yield and Quality of Blackgram in Major Contrasting Soil Series of Tamil Nadu, India

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ABSTRACT

Sulphur is an essential element for plant growth because it is present in major metabolic compounds such as amino acids (methionine and cysteine), glutathione, proteins, and sulpho lipids in oil seeds and pulses. Pulses are particularly sensitive to S deficiency, which imparts the low quality of seeds and yield. Therefore, the investigation was assessed with three different S sources as Gypsum, Ammonium sulphate and Potassium sulphate were tried at two levels (S @ 10 and 20 kg ha⁻¹). Field experiment were conducted during rabi season of 2014 to study the effect of yield and quality of irrigated blackgram as influenced by the sulphur application in Peelamedu (TypicHaplustert) and Vylogam series (TypicRhodustalf). The result revealed that, the highest growth parameters such as plant height (54.7 cm, 55.9 cm), Number of leaves plant⁻¹ (54.8, 58.8), Number of pods plant⁻¹ (34.7, 38.8), Number of seed pod⁻¹ (7.4, 8.4) like yield parameters such as grain (1145, 1275 kg ha⁻¹) and straw yield (1645, 1990 kg ha⁻¹) and quality parameters viz., protein (23, 24.2 %) and methionine (8.92, 8.97 mg g⁻¹) were significantly increased by the different S sources when compared to control in Vylogam and Peelamedu series. Irrespective of the different S sources, S @ 20 kg ha⁻¹ as K₂SO₄ coupled with recommended dose of fertilisers plus 0.5 % K₂SO₄ foliar spray at 30th and 45th DAS were significantly registered better response in blackgram at both the series. The synergistic effect of sulphur with NPK fertilisers on blackgram growth, yield and quality characters in alfisols and vertisols of Tamil Nadu.

Keywords

Blackgram, Sulphur, Alfisols, Vertisols, Vylogam and Peelamedu series.

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Introduction

Blackgram (*Vigna mungo*) is one of the most important pulse crops grown in India, particularly Tamil Nadu. It is mainly grown for human consumption but also used as fodder for cattle and green manure for soil fertility. Seeds are mainly cooked, as 'Dal' in our country. Being a legume crop, blackgram has the ability to fix atmospheric nitrogen symbiotically with the nodule producing bacteria *Rhizobium* sp. Responses of blackgram to added fertilizers such as

nitrogen and phosphorus have been found to vary with soil conditions. Increase of pulse production is urgently needed to meet up the demand of the people to reduce import, to save foreign currency and to increase pulse consumption for maintaining good health. Increase of pulse production can also minimize the scarcity of fodder because the whole plant or it is by products can be used as good animal feed. Pulses in India have long been considered as the poor man's meat and

important diet due to rich in protein that nutritionally imbalances the protein from cereal grain, supply minerals and vitamins and provide an abundance of energy. But protein deficiency is a chronic problem in the developing countries like India. The World Health Organization recommends a per capita consumption of pulses at 80 g per day and the Indian council of Medical Research has a recommended a minimum consumption of 47 grams but at present the per capita availability of pulses is only 40g per day in India (Chaturvedi and Masood Ali, 2002). Modern intensive farming has resulted in higher demand for fertilizer because of removal of all the essential nutrients in higher proportions by the crops. Most of our attention for fertilizer use has been restricted to the use of N, P and K, the three primary nutrients required by the crops in large quantities. Sulphur is an important secondary nutrient elements and it is indispensable for the synthesis of certain amino acids like cysteine, cystine and methionine besides being involved in various metabolic and enzymatic processes of plants (Schnug, 1991; McGrath *et al.*, 1996 and Zhao *et al.*, 1999). It is a constituent of protein and glutathione, a compound that play an important role in plant respiration and synthesis of essential oils. In countries like India, vitally concerned with increasing of food production, S is one element that must not be overlooked. Low S levels in Indian soils is regularly the main reason for low yield of cereals, pulses, oilseeds and commercial crops due to its involvement in the assimilation of nitrogen, photosynthesis, in synthesis of proteins and S containing amino acids. The widespread S deficiency in Indian soils depends more on climate, vegetation, parent material, soil texture, and management practices. Sulphur and nitrogen both are required for the synthesis of protein; therefore, the ratio of total N to total S in plant tissue can reflect the ability of N and S in protein synthesis

(Brunold and Suter, 1984). Singh and Aggarwal (1998) found that among the sources of sulphur, gypsum produced significantly higher pods per plant and seed per pod of black gram. Singh *et al.*, 1999 reported that potassium sulphate was significantly better than elemental sulphur and pyrite but remained on par with gypsum in production of pods per plant and seeds per pod of Lentil. Sharma and Singh (1997) reported that application of sulphur at the rate of 40kg ha⁻¹ enhanced plant height, branches, pod per plant and 1000 gram weight in green gram. Application of S @ 40 kg ha⁻¹ may be regarded as beneficial dose of sulphur application from the point of view of more protein content in seed of black gram. Information on sulphur with blackgram in vylogam and peelamedu series is rather limited. Bearing this background, the present study was undertaken to evaluate the effect of sulphur on yield and quality of blackgram in Typic Haplustert of Madurai district.

Materials and Methods

A field experiment was conducted in private fertiliser firm (BG crop sciences) at Thenamallur village, T.Kalligudi block, Madurai district with the test crop of Black gram during the year and the experimental site is located at 9° 41' 17.6" N latitude and 77° 55' 50.6"E longitude at an elevation of 127 meters above mean sea level. The soils of the experimental site belonged to Vylogam series and according to USDA soil taxonomy it is classified as Sandy clay loam, fine loamy mixed isohyperthermic Typic Rhodustalf. Initial nutrient status and characteristics of the experimental site of this series was low in KMnO₄ – N (234 kg ha⁻¹), high in Olsen – P (24.8 kg ha⁻¹), medium in NH₄OAc- K (244 kg ha⁻¹), deficient in CaCl₂ extractable S (9.9 mg kg⁻¹), medium status in organic carbon (5.43 g kg⁻¹), deficient in DTPA extractable Zn (0.92 mg kg⁻¹), sufficient DTPA

extractable Fe (9.10 mg kg^{-1}), moderate in DTPA extractable Cu (1.64 mg kg^{-1}) and high in DTPA extractable Mn (34.8 mg kg^{-1}) of sandy clay loam.

The second field experiment was conducted at farmer's field of Annaikaripatti village, T. Kallupatti block, Madurai district with the test crop of Black gram (VBN4) during 2014. The experimental site is located at $9^{\circ}40' \text{ N}$ latitude and $77^{\circ}35' \text{ E}$ longitude at an elevation of 215 meters above mean sea level. The soils of the experimental site belonged to Peelamedu series and according to USDA soil taxonomy it has been classified as clay loam, fine montmorillonitic isohyperthermic Typic Haplustert. The characteristics of the both experimental soil are presented in Table 1. In Peelamedu series, the soils were clay loam with the neutral pH of 7.40 and non-saline electrical conductivity of 0.30 dSm^{-1} . The total sesquioxides and AEC were recorded as low of 4.50 per cent and $2.40 \text{ c mol}_c \text{ kg}^{-1}$ respectively. The available N, P and K status of the soils were low, high and medium of 261, 25.4 and 298 kg ha^{-1} respectively. The available $\text{CaCl}_2 - \text{S}$ was low of 9.30 mg kg^{-1} .

Blackgram (*Vigna mungo L.*) variety VBN 4 was used as a test crop in both the field experiments to evaluate the efficacy of sulphur on growth, yield and quality of blackgram. We sow two seeds per hill and thinned after 6 days after germination. Spacing was $45 \times 15 \text{ cm}$. Irrigation was scheduled at every ten days interval after the life irrigation was given. The experimental design used was randomised block design with three replications. Recommended dose of fertilizer as NPK @ 25: 50: 25 kg ha^{-1} . Three S fertilizer sources [Gypsum (Ca SO_4), ammonium sulphate ($\text{NH}_4 \text{ SO}_4$) and potassium sulphate (K_2SO_4)] and two levels (S @ 10, 20 kg ha^{-1}) and soil application (as basal dose), foliar spray (only 0.5% K_2SO_4) and combined application along with control

a total 14 treatments were used for the experiment during 2014. All the experimental data were statistically analysed as per the procedure outlined by Gomez and Gomez (1984).

Results and Discussion

Effect of sulphur application on growth parameters of blackgram

Plant height (cm)

Sources and levels of sulphur significantly influenced the plant height at harvest stage of blackgram which varied from 45.4 to 54.7 cm and 44.8 to 55.9 cm in Vylogam and Peelamedu series respectively (Table 2). The highest plant height of 54.7 cm in the treatment receiving S @ 20 kg ha^{-1} as Potassium sulphate plus 0.5 per cent K_2SO_4 foliar spray plus 100 per cent RDF (T_9) and this was on par with S @ 20 kg ha^{-1} as potassium sulphate plus 100 per cent RDF (T_8) (54.5 cm). Regarding Peelamedu series, the treatment T_9 recorded highest plant height of 55.9 cm followed by T_8 (55.3 cm) in blackgram. This was ascribed due to the increasing levels of sulphur could have increased the ferridoxin content which is responsible for nodulation activity. Ferridoxin are rich in sulphur and contain Fe-S clusters which play vital role in N_2 fixation. These nodulation encourage the activity of rhizosphere region increases the nutrient retention in root zone which in turn increased the nutrient absorption and translocation from assimilate to shoot encourage the plant height of blackgram. In both locations S application increases the plant height augmented to synergism of sulphur with N and other macro and micro nutrients which has increased the plant height of blackgram. This was supported by the findings of Fahmina Akter *et al.*, (2013) who revealed that among the different fertilizer doses, application of S @ 40 kg ha^{-1}

recorded the highest plant height which was statistically similar with 20 kg S ha⁻¹ this was ascribed to the favourable effects of sulphur on N-metabolism and consequently on the vegetative growth of soybean.

Number of leaves per plant

The significant influences of sulphur application on number of leaves per plant of blackgram was ranged from 37.1 to 54.8 and 38.2 to 58.8 in Vylogam and Peelamedu series respectively (Table 2). The higher number of leaves per plant was noticed at S @ 20 kg ha⁻¹ as Potassium sulphate plus 0.5 per cent K₂SO₄ foliar spray plus 100 per cent RDF (T₉) of 54.8 and this was on par with S @ 20 kg ha⁻¹ as potassium sulphate plus 100 per cent RDF (T₈) (52.8) as compared to other treatments in Vylogam series. Regarding Peelamedu series, T₉ recorded the highest number of leaves per plant (58.8) followed by T₈ (53.1).

There was significant influences of sulphur application on number of leaves per plant in blackgram and the highest number of leaves per plant was noticed in S @ 20 kg ha⁻¹ as Potassium sulphate plus 0.5 per cent K₂SO₄ foliar spray plus 100 per cent RDF (T₉) as compared to other treatments both in Vylogam and Peelamedu series. This was ascribed due to the S application leads to higher absorption and translocation of nutrients assimilates to shoot which has increased the number of leaves per plant in blackgram. This result was corroborating with the findings of Mir *et al.*, (2013) who augmented that among the sulphur levels, application of sulphur @ 40 kg ha⁻¹ significantly increased the number of leaves per plant in blackgram as compared to no sulphur application. This significant influence of sulphur application on increasing the growth and yield might be attributed to its role in chlorophyll synthesis.

Effect of sulphur on yield and yield attributes

Number of pods per plant

Application of treatment influenced number of pods per plant and it ranged from 24.7 to 34.7 and 28.9 to 38.8 in Vylogam and Peelamedu series respectively (Table 2). Among the treatments, the number of pods per plant recorded the highest in the treatment receiving S @ 20 kg ha⁻¹ as Potassium sulphate plus 0.5 per cent K₂SO₄ foliar spray plus 100 per cent RDF (T₉) of 34.7 followed by T₈ (S @ 20 kg ha⁻¹ as Potassium sulphate plus 100 per cent RDF) (33.2) in Vylogam series. In Peelamedu series, the highest number of pods per plant was noticed in T₉ (38.8) followed by T₈ (37.4). This was augmented that application of S increases the yield by increasing the S from source (assimilate) to sink (seed) which would have increased the number of pods per plant. Besides, S application increases the photosynthetic activity over all growing environment (rhizosphere region of roots) and greater partitioning of metabolites and adequate translocation of nutrients to developing structure leads to increase the number of pods per plant in blackgram.

This result was corroborated with the findings of Kokani *et al.*, (2014) who found that application of S @ 20 kg ha⁻¹ had registered significantly higher number of pods per plant which had been attributed that sulphur improve overall nutritional environment of the rhizosphere as well as in the plant system, which in turn enhanced the plant metabolism and photosynthetic activity resulting in better growth and yield attributes of plant.

Number of seeds per pod

The result envisaging the number of seeds per plant of blackgram arranged from 5.1 to 7.4

and 6.1 to 8.4 in Vylogam and Peelamedu series respectively (Table 2). The highest number of seeds per pod was registered in the treatment receiving S @ 20 kg ha⁻¹ as Potassium sulphate plus 0.5 per cent K₂SO₄ as foliar spray plus 100 per cent RDF (T₉) of 7.4 followed by S @ 20 kg ha⁻¹ as Potassium sulphate plus 100 per cent RDF (T₈) of 7.1 in Vylogam series. In the case of Peelamedu series, T₉ recorded the highest number of seeds per pod (8.4) closely followed by T₈ (8.1) as compared to other treatments in

blackgram. This might be due to synergism between S and most of nutrients which was responsible for higher growth, yield and also leads to encourage the nutrient availability and assimilation. This result was in concurrence with the findings of Vaiyapuri *et al.*, (2010) who revealed that application of S @ 30 kg ha⁻¹ increases all yield attributing characters viz., no. of branches plant⁻¹, no. of pods plant⁻¹, no. of seeds pod⁻¹ and 100 seed weight of soybean due to better plant metabolism.

Table.1 Initial physico – chemical properties of the experimental site I & II

S. No.	Soil Parameters	Vylogam	Peelamedu
A.	Particle size distribution		
1.	Textural class	Sandy clay loam	Clay loam
B.	Physical properties		
1.	Bulk density (Mg m ⁻³)	1.37	1.30
2.	Particle density (Mg m ⁻³)	2.71	1.96
3.	Water holding capacity (%)	31.9	41.4
4.	Pore space (%)	36.4	47.6
C.	Physico- chemical properties		
1.	Soil reaction (pH)	7.17	7.89
2.	EC (dSm ⁻¹)	0.43	0.3
3.	CEC (c mol(p ⁺) kg ⁻¹)	12.3	19.8
4.	AEC (c mol _c kg ⁻¹)	4.20	2.40
D.	Chemical properties		
1.	Total Sesquioxides (%)	12.6	4.50
2.	Organic carbon (g kg ⁻¹)	5.43	4.10
3.	Total nitrogen (%)	0.052	0.043
4.	Total phosphorus (%)	0.047	0.051
5.	Total potassium (%)	0.283	0.55
6.	Alk- KMnO ₄ - N (kg ha ⁻¹)	234	261
7.	Olsen - P (kg ha ⁻¹)	24.8	25.4
8.	NH ₄ Oac - K (kg ha ⁻¹)	244	298
9.	CaCl ₂ - S (mg kg ⁻¹)	9.9	9.30
10.	Exchangeable Ca (c mol(p ⁺) kg ⁻¹)	7.80	11.6
11.	Exchangeable Mg (c mol(p ⁺) kg ⁻¹)	2.92	5.89
12.	DTPA extractable Zn (mg kg ⁻¹)	0.92	1.78
13.	DTPA extractable Fe (mg kg ⁻¹)	9.10	4.10
14.	DTPA extractable Cu (mg kg ⁻¹)	1.64	3.14
15.	DTPA extractable Mn (mg kg ⁻¹)	34.8	16.5

Table.2 Effect of sulphur on growth and yield attributes of blackgram (VBN 4) in Vylogam (Typic Rhodustalf) and Peelamedu (Typic Haplustert) series

Vylogam (Typic Rhodustalf)						Peelamedu (Typic Haplustert)				
Treatment	Plant height (cm)	No. leaves plant ⁻¹	No of pods plant ⁻¹	No of seeds pod ⁻¹	100 grain weight (g)	Plant height (cm)	No. leaves plant ⁻¹	No of pods plant ⁻¹	No of seeds pod ⁻¹	100 grain weight (g)
T ₁	45.4	37.1	24.7	5.1	4.75	44.8	38.2	28.9	6.1	4.76
T ₂	45.9	43.4	27.2	5.2	4.76	47.4	42.8	31.3	6.3	4.77
T ₃	46.3	45.3	28.1	5.4	4.76	47.9	45.9	31.9	6.5	4.77
T ₄	46.4	46.2	28.4	6.3	4.77	48.5	47.8	32.8	7.2	4.78
T ₅	47.2	46.4	29.1	6.5	4.78	49.0	48.3	34.2	7.4	4.79
T ₆	52.3	49.3	30.9	5.5	4.79	53.8	52.7	35.3	6.4	4.80
T ₇	53.2	50.9	32.8	6.4	4.80	54.2	50.2	36.9	7.3	4.81
T ₈	54.5	52.8	33.2	7.1	4.80	55.3	53.1	37.4	8.1	4.81
T ₉	54.7	54.8	34.7	7.4	4.81	55.9	58.8	38.8	8.4	4.82
T ₁₀	47.3	47.2	27.4	5.3	4.78	49.3	48.4	31.4	6.2	4.79
T ₁₁	47.5	47.9	30.2	5.5	4.79	49.7	49.2	33.2	6.5	4.80
T ₁₂	47.7	48.9	30.9	6.2	4.79	50.1	51.1	35.1	7.3	4.80
T ₁₃	51.7	49.2	32.1	6.5	4.80	52.9	52.9	35.9	7.2	4.81
T ₁₄	45.3	39.9	26.3	5.1	4.76	45.7	41.4	30.1	6.4	4.77
Mean	48.9	47.1	29.7	6.0	4.78	50.3	48.6	33.8	7.0	4.79
SEd	1.02	0.95	1.51	0.1	0.10	1.02	1.11	0.68	0.2	0.10
CD(p=0.05)	2.09	1.96	3.02	0.3	0.20(NS)	2.10	2.28	1.40	0.4	0.21(NS)

Table.3 Effect of sulphur application on grain and haulm yield (kg ha⁻¹) of blackgram in Vylogam (TypicRhodustalf) and Peelamedu (Typic Haplustert) series

Treatment	Vylogam (TypicRhodustalf)		Peelamedu (TypicHaplustert)	
	Grain Yield (kg ha ⁻¹)	Haulm Yield (kg ha ⁻¹)	Grain Yield (kg ha ⁻¹)	Haulm Yield (kg ha ⁻¹)
100% recommended dose of fertilisers(RDF)	807	982	825	1098
T ₁ + S (10 kg ha ⁻¹)as Gypsum	858	1089	983	1187
T ₂ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	879	1107	1008	1221
T ₁ + S (20 kg ha ⁻¹) as Gypsum	899	1132	1025	1290
T ₄ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	921	1221	1033	1356
T ₁ + S (10 kg ha ⁻¹)as Potassium sulphate	1049	1332	1142	1435
T ₆ +Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	1098	1411	1167	1553
T ₁ + S (20 kg ha ⁻¹) as Potassium sulphate	1101	1598	1217	1878
T ₈ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	1145	1645	1275	1990
T ₁ + S (10 kg ha ⁻¹) as Ammonium sulphate	945	1288	1075	1389
T ₁₀ +Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	953	1394	1100	1493
T ₁ + S (20 kg ha ⁻¹) as Ammonium sulphate	986	1476	1200	1623
T ₁₂ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	999	1520	1208	1765
T ₁ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	825	1012	907	1136
Mean	962	1301	1083	1458
SEd	23	36	26.4	29.7
CD (p=0.05)	48	74	54.3	61.1

Table.4 Effect of sulphur application on quality parameters of black gram (VBN 4) in Vylogam (Typic Rhodustalf) and Peelamedu (Typic Haplustert) series

Treatments	Vylogam (TypicRhodustalf)		Peelamedu (TypicHaplustert)	
	Protein (%)	Methionine (mg g ⁻¹)	Protein (%)	Methionine (mg g ⁻¹)
100% recommended dose of fertilisers(RDF)	18.1	6.76	18.9	6.79
T ₁ + S (10 kg ha ⁻¹)as Gypsum	18.9	7.12	19.8	7.17
T ₂ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	19.3	7.52	20.4	7.58
T ₁ + S (20 kg ha ⁻¹) as Gypsum	19.9	7.60	21.3	7.67
T ₄ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	21.1	7.76	22.2	7.82
T ₁ + S (10 kg ha ⁻¹)as Potassium sulphate	21.9	8.36	22.8	8.39
T ₆ +Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	22.2	8.40	23.4	8.45
T ₁ + S (20 kg ha ⁻¹) as Potassium sulphate	22.5	8.76	23.7	8.78
T ₈ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	23.0	8.92	24.2	8.97
T ₁ + S (10 kg ha ⁻¹) as Ammonium sulphate	20.2	7.96	21.5	8.02
T ₁₀ +Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	20.5	8.00	21.7	8.08
T ₁ + S (20 kg ha ⁻¹) as Ammonium sulphate	20.7	8.32	22.0	8.37
T ₁₂ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	21.0	8.60	22.3	8.68
T ₁ + Foliar spray 0.5 % K ₂ SO ₄ at 30 th and 45 th DAS	18.6	6.88	19.2	6.94
Mean	20.6	7.93	21.7	7.98
SEd	0.46	0.14	0.39	0.16
CD (p=0.05)	0.94	0.30	0.79	0.34

Effect of sulphur on grain and haulm yield of blackgram

The grain and haulm yield of blackgram was significantly influenced by the application of S (Table 3). The grain and haulm yield ranged from 807 to 1145, 982 to 1645, 825 to 1275 and 1098 to 1990 kg ha⁻¹ in Vylogam series and Peelamedu series respectively. Among the treatments, T₉ registered significantly highest grain yield of 1145 and 1275 kg ha⁻¹ and haulm yield of 1645 and 1990 kg ha⁻¹ in Vylogam series and Peelamedu series and this was on par with T₈ (S @ 20 kg ha⁻¹ as Potassium sulphate plus 100 % RDF) the grain and haulm yield of 1101 and 1598 kg ha⁻¹, 1217 and 1878 kg ha⁻¹ in Vylgam and Peelamedu series respectively. The lowest grain and haulm yields were noted in control of 807 and 982 kg ha⁻¹, 825 and 1098 kg ha⁻¹ in Vylogam series and Peelamedu series respectively. It is an established fact that photosynthesis together with availability of assimilates (source) and storage (sink) exert an important regulative function on the complex process of yield formation. Application of sulphur could have improved the nitrate recovery and diversion of greater proportion of assimilation to developing pods. This result was in close association with the findings of Shubhangi *et al.*, (2014) and Kokani *et al.*, (2014) who reported that the grain (1153 kg ha⁻¹) and haulm (2548 kg ha⁻¹) yields of blackgram produced significantly higher with S @ 20 kg ha⁻¹ over control.

Effect of sulphur application on quality parameters of blackgram

Protein content

The protein content of blackgram varied from 18.1 to 23.0 and 18.9 to 24.2 per cent in Vylogam and Peelamedu series respectively (Table 4). Among the treatments, application of S @ 20 kg ha⁻¹ as Potassium sulphate plus

0.5 per cent K₂SO₄ foliar spray plus 100 per cent RDF (T₉) recorded the highest protein content of 23.0 per cent in which was on par with application of S @ 20 kg ha⁻¹ as Potassium sulphate plus 100 per cent RDF (T₈) (22.5 %) in Vylogam series. In Peelamedu series, the same treatment T₉ recorded the highest protein content of 24.2 per cent followed by T₈ (23.7 %) in blackgram. Application of S serves for several structural, regulation of secondary metabolites and catalytic functions in the sense of proteins, tripeptide glutathione (redox buffer) and certain proteins such as thioredoxin, glutaredoxin and protein disulphide isomerase. This attributing to regulation activity, involved in light reaction (CO₂ fixation) of photosynthesis, which will increase the assimilation of N and S responsible for S containing amino acids, viz., methionine and cysteine.

In both the sites, the soil organic matter was found to be low to medium in status which would have showed less competition to sorption sites, which leads to SO₄²⁻ concentration higher in solution phase. High tenacity of SO₄²⁻ induced higher NO₃⁻ and SO₄²⁻ absorption and translocation in tissues. Sulphur and nitrogen both are required for the synthesis of protein and indeed the ratio of total N to total S in plant tissue can reflect the ability of N and S in protein synthesis. Thus, a change in the ratio of reduced-N to reduced-S (NR/SR), which is a reflection of the amount of S in amino acids, suggests that protein metabolism has been significantly altered which has important implications in maintain protein quality. This result was corroborating with the findings of Singh and Sarkar (2013) who revealed that sulphur applied to these low S soils not only increase the crop yields, but also affect crop quality such as oil content of oilseeds and protein content of pulses. As S is an important constituent of some essential amino acids (e.g., cysteine, cystine and

methionine), soil S deficiency can lower protein quality.

Methionine content

As in the case of protein, the methionine content of blackgram was also significantly influenced by S application and it varied from 6.76 to 8.92 and 6.79 to 8.97 mg g⁻¹ in Vylogam and Peelamedu series. While comparing the treatments, application of S @ 20 kg ha⁻¹ as Potassium sulphate plus 0.5 per cent K₂SO₄ as foliar spray plus 100 per cent RDF (T₉) recorded significantly the highest methionine content of 8.92 mg g⁻¹ in Vylogam series and this was on par with application of S @ 20 kg ha⁻¹ as Potassium sulphate plus 100 per cent RDF (T₈) (8.76 mg g⁻¹). In Peelamedu series the highest methionine content was recorded in T₉ (8.97 mg g⁻¹) followed by T₈ (8.78 mg g⁻¹). The lowest methionine content was registered in control (6.79 mg g⁻¹). This was ascribed by application of S regulating nitrate reductase enzyme (Nitrate assimilation pathway), these leads to maintain the N: S (15:1) ratio in blackgram plant tissues. Nitrogen is found to be responsible for regulation of SO₄²⁻ assimilation in ATP-sulphurylase.

In both the locations SO₄²⁻ adsorption were higher leads to higher NO₃⁻ retention in solution phase of soil. Application of sulphur increases sulphur availability which has a role in regulating nitrate reductase, in addition to its role in regulating ATP-sulphurylase. Moreover, nitrogen availability has a role in regulating ATP-sulphurylase as well as in regulating nitrate reductase. The synthesis of cysteine as a result of the incorporation of sulphide moiety into O acetylserine appears to be the meeting point between N-and S metabolism. This result was corroborating with the findings of Josefsson (1970) who found that S fertilization had increased the S-containing amino acids in rapeseed and

Jarvan *et al.*, (2008) reported an increase in cysteine and methionine content in wheat grain due to S fertilization.

It could be concluded that, in Tamil Nadu most of the soils are red soils with higher free iron and aluminum oxides, low CEC and low to medium organic carbon status which was less fertile compared to black soils. Application of sulphur in Vylogam series increases the adsorption of S leads to increase the macro and micro nutrient availability in soil. Sulphur showed synergism with macro nutrients (N, P, K and S) and micro nutrients (Zn, Fe, Mn and Cu) in soil. The availability criteria have increased the assimilation of nutrients from source to sink which encourages the content, uptake and yield of blackgram. In Peelamedu series, sesquioxides content was low when compared to Vylogam series but this series had high amount of Ca and Mg leads the chemisorption of some anions leads to deficiency of phosphorus, sulphur and micro nutrients due to higher pH. Application of sulphur in this series has improved the overall soil rhizosphere environment which leads to improve the nutrient status of this series. In both the locations Potassium sulphate (20 kg ha⁻¹ and 0.5 % foliar spray) is found as a best source as compared to ammonium sulphate and gypsum. Hence in order to improve the productivity of blackgram in pulses growing soils of Madurai district in addition to recommended dose of N, P₂O₅ and K₂O, soil application of 20 kg ha⁻¹ as Potassium sulphate plus foliar spray of 0.5 per cent K₂SO₄ on 30 DAS and 45 DAS is essential to reduce the sub optimal yield.

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