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Screening groundnut (*Arachis hypogaea*) genotypes for sulphur efficiency

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ABSTRACT

A field experiment was conducted on a sandy clay soil to screen eighteen groundnut genotypes for their sulphur (S) efficiency and to know its effect on growth, yield and sulphur availability and uptake. There were two levels of sulphur (0 and 40 kg ha^{-1}) applied as gypsum basally and replicated thrice in a randomized block design. Results revealed that inclusion of 40 kg S ha^{-1} as gypsum significantly improved the growth and yield attributes of all the groundnut genotypes besides increasing the kernel and haulm yield. Soil available sulphur and sulphur uptake by the genotypes were also considerably improved by sulphur addition which differs widely among them. Several indices were computed for assessing the sulphur efficiency and found that, the genotypes, VRI 6, CO 7, TMV 7, TMV 13, VRI 5, VRI 3, CO2 and CO 6 were found efficient and responsive for sulphur application while VRI 8, and TMV 10 were inefficient but found responsive. However the varieties such as Local, VRI 4, CO 3, VRI 2, VRI 7, TMV 2, ALR 3 and BSR 1 were highly non-responsive and inefficient in utilizing the applied sulphur.

Key words: Groundnut, Sulphur availability, Sulphur efficiency, Uptake, Yield.

INTRODUCTION

Oil seeds are one of the major sources of fat and protein for human diet and groundnut is the major source of protein (25%) and oil (48%). In India, groundnut is grown in an area of 39.19 lakh ha with the average production of 71.78 lakh tones. In Tamil Nadu, it is cultivated in an area of 346 lakh ha with the production of 8.92 lakh tones. Globally, 50% of the groundnut is used for oil extraction, 37% for confectionary and 12% for seed purpose (Nurezannat *et al,* 2019). Application of sulphur to all crops particularly to oilseeds increased the pod yield and quality besides the oil content. It is essential for many physiological processes such as synthesis of sulphur containing amino acids *viz*., cystine, cystein and methionine, vitamins, chlorophyll and few co-enzymes (Coates and Howe, 2007; Tejeswara Rao *et al.,* 2013; Sisodiya *et al.,* 2017; Mahipal Choudhary *et al*., 2019).

It also helpful for the synthesis of glycosides in oilseed crops, promotes nodulation in legumes, N fixation and seed development hence sulphur addition is essential for improving the yield and quality of oilseed crops (Hossain *et al.,* 2006; Jamal *et al*., 2010). Many researchers reported the positive role of sulphur in increasing the pod yield, nutrient absorption and its availability in soils (Jamal *et al.,* 2006; El-Kader and Mona, 2013; Sisodiya *et al*., 2017; Abdul Manaf *et al.,* 2017). Wider variability for the application of various sources of sulphur like single super phosphate, sulphate of potash and gypsum was observed in many crops and concluded that all were equally effective in increasing the pod yield, sulphur content and uptake, protein and oil content, oil yield in groundnut (Ramdevputra *et al*., 2010; Chattopaddhyay, 2012; Abdul Manaf *et al.*, 2017).

Sulphur availability to crops more specifically depends on free $CaCO_3$, pH and organic matter content (Hilal and Abd-Elfattah, 1987; Ramdevputra *et al.,* 2010; Assefa *et al.*, 2014) in the soils. Further the gap between supply and demand for sulphur requirement of crop is also widening due to intensive farming practices with high yielding and high analysis fertilizers, inadequate supply of organic manures and imbalanced application of nutrients which leads to sulphur deficiencies in soils and crops. Applied sulphur also turns into unavailable forms due to unfavourable soil conditions and the use efficiency of applied S hardly exceeds 8-12% in different crops. In this context, screening and selection of sulphur efficient groundnut genotypes having higher yield and sulphur utilization potentials is of practical significance. The S efficient crops posses the ability to utilize applied S effectively and maintain better growth even under sulphur deficient situations while the inefficient genotypes are not able to utilize the applied sulphur sufficiently and resulted in yield loss. It was reported that S content in plants showed 6 to 8 fold differences among the genotypes (Ahmad *et al.,* 2005; Balint *et al.,* 2008; Halil Erdem and Mustafa Bulent Torun, 2017). The differential

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ability of the crop genotypes to extract sulphur from soil can be exploited for increasing the sulphur use efficiency hence, the present paper deals with how the groundnut genotypes differs in utilizing the applied sulphur and to identify sulphur efficient genotypes by assessing the variation in growth, yield, S efficiency, S content and uptake.

MATERIALS AND METHODS

A field experiment was conducted with 19 groundnut genotypes to screen sulphur efficient genotypes on a sandy clay loam soil with two levels of sulphur as gypsum (0 and 40 kg S). The seeds of groundnut genotypes *viz*., VRI 2, VRI 3, VRI 4, VRI 5, VRI 6, VRI7, VRI 8, CO1, CO2, CO3, CO 6, CO7, TMV 2, TMV 7, TMV 10, TMV 13, BSR 1, ALR3, Local were sown and grown with and without sulphur application. The treatments were replicated thrice in a randomized block design with a plot size of 5 m x 3 m. The recommended NPK fertilizers (25:50:75 kg NPK ha^{-1}) were applied as urea, DAP and muriate of potash. The experimental soil was neutral in reaction (7.33) with low salt status (0.36 dS m^{-1}) and organic carbon content (3.8 g kg^{-1}). The available major nutrient status showed low N (188 kg ha^{-1}), medium P (13 kg ha^{-1}) and K (211 kg ha^{-1}) availability. The soil was deficient in sulphur (8.18 mg kg^{-1}) and Zn (0.48 mg kg^{-1}) availability while rests of the nutrients were sufficient in status (Table 1). Necessary plant protection and production measures were carried out, grown to maturity and harvested. Plant growth and yield parameters such as plant height, root length, number of pods $plant^{-1}$ and 100 kernal weight were recorded besides registering pod and haulm yield.

The post-harvest soil samples were collected and analyzed for 0.15 % $CaCl_2$ extractable S availability using $BaCl_2$ turbidity method outlined by Williams and Steinbergs (1959). The plant samples collected after the harvest were washed, shade dried then oven dried at 70°C for 48 hours and the dry weight was determined. The dried samples were powdered using Willey mill and digested with 15 ml acid mixture (Nitric acid: Perchloric acid at 5:2 ratio) and used for S analysis spectrophotometrically. The sulphur uptake was computed by multiplying sulphur content in plants and DMP. The sulphur efficiency indices were also calculated using the following formula:

Sulphur efficiency (SE %) =

[Pod yield at S_0 conditions /Pod yield at S_{40} conditions] x100

Yield efficiency index =

[Pod yield in S_0 conditions /Mean pod yield at S_0] x
[Pod yield at S_{40} conditions / Mean pod yield at S_{40}]

S uptake efficiency index =

[S uptake at S_0 conditions / S uptake S_{40} conditions] x100

S harvest index =

[S content in kernal / S content in plant]

(Ahmad *et al.,* 2005; Halil Erdem and Mustafa Bulent Torun, 2017).

Based on various indices computed, the genotypes were grouped as S efficient and inefficient responsive and non responsive genotypes. The data generated for all the parameters were subjected to analysis of variance to find out the significance as suggested by Gomez and Gomez (1984). The statistical differences between the means were tested using the least significance differences (LSD) at 0.05 level of probability. Simple relationship between various parameters were also studied and presented.

RESULTS AND DISCUSSION

Growth and yield attributes

The response of groundnut genotypes for sulphur addition in terms of growth and yield attributes were recorded at harvest stage and furnished in Table 2. Addition of sulphur increased the plant height, root length, number of pods / plant and 100 kernel weight of all the groundnut genotypes. The values varied from 46.3 to 66.8 cm, 12.5 to 22.7 cm, 12 to 27 nos. and 35.3 to 54.7 g respectively for plant height, root length, number of pods / plant and 100 kernel weight. Higher growth and yield attributes were associated with VRI 6 = CO7 > TMV 7 while the lowest values of all the attributes were observed with local variety. Application of 40 kg sulphur as gypsum along with recommend dose of fertilisers increased the growth and yield attributes of all the groundnut genotypes. Better response of the genotypes for the sulphur application might be due to its involvement in photosynthesis and translocation of photosynthetic products from source to sink. Further increase in root traits with sulphur addition might have also facilitated the absorption of nutrients and improved the metabolic activity within the plants (Subhendu *et al.,* 2005; Patel *et al*., 2009; Taejeswara Rao *et al.,* 2013; Lali *et al.,* 2017; Sisodiya *et al*., 2017).

Pod and haulm yield

Significant and positive pod and haulm yield responses for the addition of sulphur were observed with all the eighteen groundnut genotypes which differed widely (Table 3). The mean pod and haulm yield of genotypes varied from 1269

Table 1: Initial physico chemical properties of the experimental soil.

Selected soil properties	
pH	7.33
Electrical conductivity (dS m^{-1})	0.36
Organic carbon (g kg^{-1})	3.8
Available Nitrogen (kg ha^{-1})	188
Available Phosphorus (kg ha^{-1})	13
Available Potassium (kg ha^{-1})	211
Available Sulphur (mg kg^{-1})	8.18
Available Micronutrients (mg kg^{-1})	
DTPA Zn	0.48
DTPA Fe	4.00
DTPA Cu	1.20
DTPA Mn	8.22
HWS-B	0.50

Table 2: Effect of sulphur on the growth and yield attributes of groundnut genotypes.

Genotypes	Plant height (cm)			Root length (cm)			No. of Pods / plant			100 kernal weight (g)		
	S_0	S_{40}	Mean	S_0	S_{40}	Mean	S_0	S_{40}	Mean	S_0	S_{40}	Mean
VRI 2	46.7	57.8	52.3	12.5	15.4	14.0	12.7	16.0	14.4	46.7	52.0	49.4
CO 7	50.7	64.8	57.8	16.1	21.9	19.0	19.7	24.3	22.0	48.0	54.7	51.4
VRI 7	49.3	55.2	52.3	14.0	15.7	14.9	14.0	16.7	15.4	42.7	48.0	45.4
CO2	47.0	53.5	50.3	13.9	17.6	15.8	17.7	21.3	19.5	47.3	50.7	49.0
VRI 8	47.8	56.3	52.1	13.6	17.3	15.5	15.0	17.0	16.0	44.7	49.3	47.0
VRI 6	58.0	66.8	62.4	15.8	19.8	17.8	19.0	24.7	21.9	40.0	44.0	42.0
TMV 7	54.0	59.8	56.9	17.1	22.7	19.9	23.7	27.3	25.5	39.3	45.3	42.3
VRI 3	48.7	54.8	51.8	14.4	18.6	16.5	16.0	16.3	16.2	36.7	44.0	40.4
VRI 5	47.0	56.2	51.6	14.1	18.2	16.2	17.0	18.3	17.7	46.0	52.0	49.0
ALR 3	51.3	58.8	55.1	13.0	18.4	15.7	15.3	19.0	17.2	40.7	47.3	44.0
TMV 10	50.7	59.5	55.1	14.1	18.3	16.2	15.0	16.3	15.7	43.3	47.3	45.3
TMV 2	51.0	57.2	54.1	13.9	18.6	16.3	14.0	17.7	15.9	36.7	41.3	39.0
BSR 1	51.3	53.3	52.3	14.3	19.3	16.8	15.0	18.0	16.5	40.0	46.0	43.0
CO3	47.7	53.5	50.6	13.4	17.8	15.6	17.0	20.7	18.9	48.7	52.7	50.7
TMV 13	48.0	59.5	53.8	15.1	19.4	17.3	16.3	22.0	19.2	44.0	50.7	47.4
CO 6	50.0	56.8	53.4	16.7	18.4	17.6	15.3	20.3	17.8	43.3	50.0	46.7
CO 1	50.3	52.8	51.6	13.6	17.6	15.6	18.7	21.0	19.9	43.3	48.0	45.7
VRI 4	54.0	62.8	58.4	14.4	18.6	16.5	16.7	19.0	17.9	44.0	48.0	46.0
LOCAL	46.3	49.4	47.9	12.5	15.5	14.0	11.7	14.0	12.9	35.3	39.3	37.3
Mean	50.0	57.3	53.7	14.3	18.4	16.4	16.3	19.5	17.9	42.7	47.9	45.3
	SEd	CD (P=0.05)		SEd	CD (P=0.05)		SEd	CD (P=0.05)		SEd	CD (P=0.05)	
V	2.36	4.80		1.34	2.72		1.53	3.12		3.35	6.80	
S	0.55	1.13		0.28	0.57		0.33	0.68		0.43	0.87	
V×S	2.43	NS		1.60	NS		1.85	NS		3.60	NS	

V-Groundnut genotypes; S-Sulphur; NS-Non significant.

Table 3: Effect of Sulphur on the pod and haulm yield, available sulphur and S uptake by groundnut genotypes.

Genotypes	Pod yield (kg ha^{-1})			Haulm yield (kg ha^{-1})			Available sulphur (mg kg^{-1})			S uptake (kg ha^{-1})		
	S_0	S_{40}	Mean	S_0	S_{40}	Mean	S_0	S_{40}	Mean	S_0	S_{40}	Mean
VRI 2	1942	2214	2078	2415	2735	2575	8.66	11.9	10.3	4.54	8.20	6.37
CO 7	2702	2912	2807	2748	3060	2904	9.15	14.3	11.7	9.38	14.86	12.12
VRI 7	1844	2158	2001	2204	2897	2551	7.97	12.3	10.1	5.00	9.22	7.11
CO2	1847	2268	2058	2369	2586	2478	8.25	13.1	10.7	5.80	9.28	7.54
VRI 8	2010	2353	2182	2396	2705	2551	8.25	12.8	10.5	5.99	9.99	7.99
VRI 6	2299	2545	2422	2433	3292	2863	9.25	13.6	11.4	12.64	16.67	14.66
TMV 7	1754	1962	1858	2079	3049	2564	9.45	14.8	12.1	10.03	14.94	12.49
VRI 3	1678	1968	1823	2253	2684	2469	8.17	12.6	10.4	5.24	8.22	6.73
VRI 5	1881	2185	2033	2223	2566	2395	8.90	11.9	10.4	5.76	8.75	7.26
ALR 3	2047	2335	2191	2375	2737	2556	8.22	10.9	9.56	5.22	8.83	7.03
TMV 10	1594	1880	1737	2316	2828	2572	8.25	11.1	9.68	5.79	9.37	7.58
TMV 2	1894	2246	2070	2242	2721	2482	8.14	10.5	9.32	4.86	8.51	6.69
BSR 1	1931	2313	2122	2281	2613	2447	7.32	10.8	9.06	5.40	9.34	7.37
CO3	2184	2479	2332	2478	2704	2591	8.59	11.4	10.0	3.75	7.20	5.48
TMV 13	2401	2624	2513	2545	2906	2726	9.00	13.2	11.1	8.20	13.07	10.64
CO 6	1756	2070	1913	2442	2869	2656	8.02	11.7	9.86	3.99	6.63	5.31
CO 1	2003	2371	2187	2530	2780	2655	8.25	12.8	10.5	4.31	8.03	6.17
VRI 4	1676	2031	1854	2075	2382	2229	8.00	12.2	10.1	3.22	6.19	4.71
LOCAL	1079	1459	1269	2258	2662	2460	7.48	11.4	9.44	1.73	3.69	2.71
Mean	1922	2230	2076	2351	2778	2565	8.39	12.3	10.3	5.83	9.53	7.68
	SEd	CD (P=0.05)		SEd	CD (P=0.05)		SEd	CD (P=0.05)		SEd	CD (P=0.05)	
V	130	265		209	NS		0.55	1.12		1.00	2.03	
S	21.7	44.0		32.8	66.5		0.18	0.36		0.14	0.30	
V×S	147	NS		143	290		0.78	NS		1.10	NS	

V- Groundnut genotypes; S- sulphur; NS- Non significant.

to 2807 kg and 2229 to 2904 kg ha^{-1} respectively. Higher mean pod and haulm yield was recorded with CO7 (2807 and 2904 kg ha^{-1}) followed by TMV 13 (2513 and 2726 kg ha^{-1}) and VRI 6 (2422 and 2863 kg ha^{-1}). Application of 40 kg sulphur as gypsum significantly increased the pod and haulm yield of groundnut genotypes by 16.0 and 18.2 per cent respectively over no sulphur addition. Improvement in both pod and haulm yield of genotypes might be attributed to the positive effect of sulphur on growth, partitioning and translocation of metabolites to reproductive structures (Tathe *et al.,* 2008; Badawy *et al.,* 2011 and Sarangi and Lama, 2013; Abdul Manaf *et al.,* 2017). The lowest pod yield was noted in the local variety (1269 kg ha^{-1}) and haulm yield was registered with VRI 4 (2229 kg ha^{-1}), which might be due to lesser photosynthetic rate as well as poor nutrient acquisition and utilization by these genotypes. The variations among different genotypes might be due to genetic makeup as well as the environmental conditions.

Yield efficiency indices

The yield and S uptake efficiency indices were worked out for all the genotypes to identify the S efficient genotypes and furnished in Fig 1 and Table 4. The yield efficiency varied from 71.7 to 97.1 per cent and more than 90 per cent yield efficiency was noticed with the genotypes: VRI 6 > TMV 7 > CO7. With regard to sulphur uptake efficiency, higher uptake efficiency was recorded with VRI 6> TMV 7 > VRI 5 which varied from 62.8 to 82.2 per cent and the lowest yield and S uptake efficiency was registered with the local variety. The relationship between sulphur content in kernals, yield and uptake efficiency of groundnut genotypes also varied significantly and showed 75.9 per cent variation in yield and 65.3 per cent variation in sulphur uptake by the genotypes (Fig 2).

Based on higher yield and S uptake efficiencies, the genotypes *viz*., VRI 6, CO 7, TMV 7, TMV 13 were grouped as efficient and responsive to sulphur fertilization, CO2, VRI 8, VRI 3, VRI 5, ALR 3, BSR 1, CO 6 were inefficient but responsive to S addition and local, CO 1, VRI 4, CO3, VRI 7, TMV 2, TMV 10 were inefficient and non-responsive genotypes for S addition. The efficient genotypes miight have

Table 4: Yield and sulphur uptake efficiency of groundnut genotypes.

Genotypes	Yield efficiency Indices		Sulphur efficiency indices	
	% Efficiency	Yield Index	Harvest index	Uptake efficiency
VRI 2	81.8	1.04	0.90	0.54
CO 7	89.1	1.59	1.11	0.63
VRI 7	81.7	0.88	1.12	0.56
CO2	87.2	1.05	0.95	0.61
VRI 8	80.8	1.03	1.05	0.60
VRI 6	97.1	1.51	1.32	0.75
TMV 7	93.7	1.43	1.16	0.68
VRI 3	85.6	0.83	1.13	0.63
VRI 5	86.9	0.88	1.09	0.66
ALR 3	80.0	0.87	1.07	0.59
TMV 10	83.5	0.82	1.06	0.62
TMV 2	82.2	0.91	0.96	0.58
BSR 1	80.0	1.05	0.96	0.57
CO3	81.7	1.06	0.86	0.52
TMV 13	85.5	1.35	1.10	0.63
CO 6	84.6	0.77	0.80	0.60
CO 1	85.4	0.95	0.89	0.54
VRI 4	78.1	0.80	0.81	0.52
LOCAL	71.7	0.47	0.75	0.47
Mean	**84.0**	**1.02**	**1.00**	**0.60**

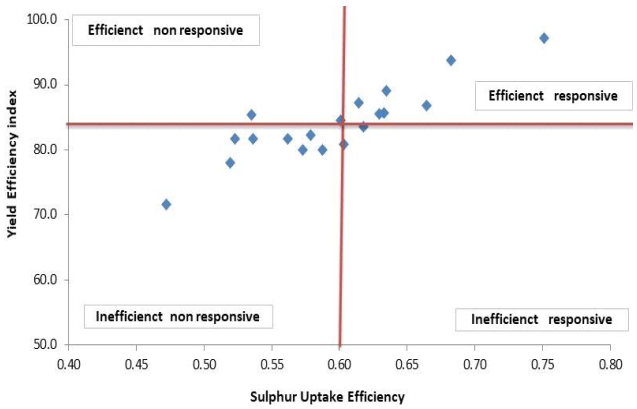

Fig 1: Grouping of groundnut genotypes for sulphur efficiency.

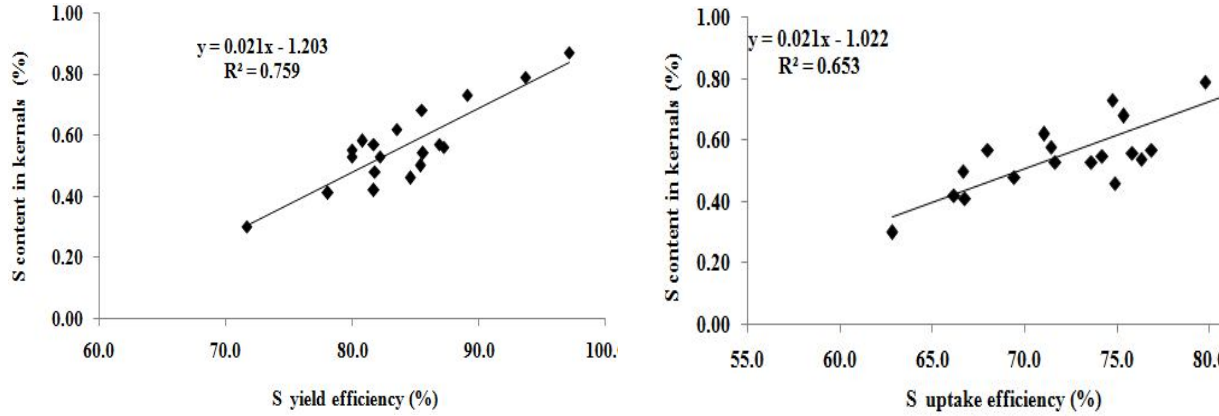

Fig 2: Relationship between sulphur content in kernals and yield and uptake efficiency of groundnut genotypes.

modified their root environment by the secretion of root exudates to utilize the soil sulphur which depends mainly on sulphur use efficiencies, its absorption, transport and concentration in kernals. Similar response was reported by Ahmad *et al.,* (2005) in mustard, Abdul Manef *et al.,* (2017) in groundnut and by Halil Erdem and Mustafa Bulent Torun (2017) in wheat genotypes.

Sulphur uptake and availability

Application of sulphur as gypsum significantly increased the S content and uptake by all the genotypes and reported in Table 3. The sulphur content varied from 0.19 to 0.87 per cent in kernel and 0.23 to 0.67 per cent in haulm while the S uptake values ranged from 1.73 to 14.9 kg ha^{-1} in kernel and 5.10 to 22.1 kg ha^{-1} in haulm. The highest sulphur content and uptake was observed in the genotypes: VRI 6 > TMV 7 > CO 7 > TMV 13 for kernel and TMV 7 > VRI 6 > CO 7 > TMV 13 for haulm. The lowest sulphur content and uptake in kernel and haulm was registered in local variety followed by VRI 4. This trend might be due to increased growth and yield attributes, total dry matter production and yield due to sufficient supply of sulfur which helped in better absorption and translocation (Singh and Chaudhari, 1995,1997; Sisodiya *et al*., 2017). The increased sulphur availability might have also influenced the photosynthetic rate, increased protein content which leads to greater synthesis of sulphur containing amino acids and might have resulted in more uptake of sulphur and higher sulphur use efficiency (Abd EL-Kader and Mona, 2013; Assefa *et al.,* 2017; Mahipal Choudhary *et al,* 2019).

The post- harvest soil samples were also analyzed for available sulphur status and reported in Table 3. Application of 40 kg S as gypsum increased the sulphur availability in soil and the values varied from 7.32 to 14.8 mg kg^{-1}. Higher S availability was observed with TMV 7 (9.45 and 14.8 mg kg^{-1}) in the soils applied with and without sulphur which was on par with CO 7 (9.15 and 14.3 mg kg^{-1}) and VRI 6 (9.25 and 13.6 mg kg^{-1}). The increased soil availability of sulphur might be due to external S supply through gypsum and concurrent increase in soil which was observed by Pandya and Bhatt (2008), Ramdevputra *et al.,* (2010) and Humair Ahmed (2017) in groundnut. The lowest S availability was noted in control plots.

CONCLUSION

Screening of groundnut genotypes for sulphur efficiency on a sandy clay soil showed considerable variation in growth, yield, sulphur uptake and use efficiency. Based on higher kernel yield, sulphur absorption and uptake efficiency, VRI 6, CO 7, TMV 7, TMV 13, VRI 5, VRI 3, CO 2 and CO6 were categorized as sulphur efficient and responsive genotypes while the genotypes Local, VRI 4, CO 3, VRI 2, VRI 7, TMV 2, ALR 3, BSR 1 were found inefficient and non responsive. The efficiency was confirmed with the positive and significant relationship exists between sulphur absorption and translocation efficiency and higher kernel yield. From the results, it can be concluded that, the genotypes VRI6, CO7, TMV7, TMV13, VRI5, VRI3, CO2 and CO6 were categorized as sulphur efficient and responsive hence can be used for low S soils and S bio-fortification.

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