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Establishing critical limits of sulphur for groundnut (*Arachis hypogaea*)

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ABSTRACT

Sulphur is essential for growth and development of groundnut (*Arachis hypogaea* L.). Deficiency of S is widespread in soils of India, and is becoming a major concern for the quality and yield of groundnut crop. Therefore, a study was conducted to investigate the response of groundnut to S application in alluvial Inceptisols of West Bengal with four levels of S, i.e. 0, 15, 30 and 45 kg/ha. The critical limits of Sulphur in soil and plant for deficiency, adequacy and toxicity were determined from Bray percent yield (BPY). The amount of $CaCl_2$ extractable S in soils varied from11.90–29.17 mg/kg while the critical level for deficiency of S in groundnut was graphically 18.6 mg/kg and statistically 19.58 mg/kg in soils. Application of S increased groundnut yield significantly, concentration of S in plant and its uptake by groundnut parts. The critical limit was determined to be 3.0 g/kg for groundnut plants and 4.42 g/kg for groundnut nuts at harvest.

Key words: Critical limit, Groundnut, Inceptisols, S uptake

Sulphur is a structural constituent of organic compounds, some of which are uniquely synthesized by plants, providing human and animals with essential amino acids (methionine and cysteine). Sulphur involved in chlorophyll formation, activation of enzymes and is a part of vitamins such as biotin and thiamine (B1) (Hegde and Sudhakarababu 2007). It is a master nutrient for oilseed production as each unit of fertilizer S generates 3-5 units of edible oil (Ramdevputra *et al.* 2010). Role of S in Indian agriculture is now gaining importance because of the recognition of its role in increasing crop production, not only of oilseeds, pulses, legumes and forages but also of many cereals (Singh *et al*. 2000). Sulphur deficiency is extensive particularly in the areas where crop is intensively cultivated with the use of S free fertilizers (Basak *et al*. 2002). At present, deficiency in soils of various Indian states varies from 5–83% with an overall mean of 41% (Singh 2001). Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crops of India occupying 2/3rd area under oilseeds. The high-energy value, protein content and minerals make groundnut a rich source of nutrition at a comparatively affordable price. Besides, it's a valuable source of vitamins E, K and B. It is the richest plant source of thiamine and is also rich in niacin, which is low in cereals. The groundnut grown on light textured soils generally suffers from S deficiency due to leaching of sulphate. The crop responds significantly to the application of S in the light textured soil (Giri *et al*. 2014). Because of the increasing area under groundnut cultivation and emerging S deficiency, judicious application of S fertilizer is required. To attend to this issue, it is important to evaluate the critical concentration of this nutrient in soils and plants for optimum crop nutrition. In this context, the present investigation was done to study the response of groundnut to different rates of S application and to establish the critical limit of sulphur in soils as well as in plants in alluvial Inceptisols of West Bengal.

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MATERIALS AND METHODS

Twenty surface soil samples (0-15cm) were collected from different locations of seven districts (Coochbehar, Jalpaiguri, Uttar Dinajpur, Burdhawan, Bankura, Hoogly and Nadia) under the different agroclimatic zones of West Bengal, India during 2016. Samples were air-dried, ground and passed through a 2 mm nylon sieve. The soil samples were analyzed for *p*H (Jackson 1973), clay content (Bouyoucos 1962) and organic carbon (Walkley and Black 1934), Available S (Chesin and Yien 1951). A pot culture experiment was conducted on smaples collected from twenty different locations at Central Research Farm, BCKV, Gayeshpur (Latitude 22°58'°N, Longitude 88°29'E, Altitude 9.75 m amsl) using groundnut as test crop during 2016. Ten kg of soil was transferred into each pot. Recommended doses of N, P_2O_5 and K_2O @20, 60 and 60 kg/ha, were applied as Urea, SSP and KCl respectively. The N was applied 1/3 at sowing time and 2/3 by top dressing; P and K were applied as full basal dose. Sulphur was applied as per treatments @ 0, 15, 30 and 45 kg/ha of soil through gypsum ($CaSO_4 . 2H_2O$) at the time of sowing and replicated thrice in completely randomized design. Groundnut crop was sown with five healthy seeds (cv. Tag-50) in each pot. The seedlings were thinned to 3 in each pot after 15 days of sowing. Each pot was watered as and when required with de-ionized water. The dried plant samples were ground and digested with di-acid mixture as outlined by Tandon (1993). Concentration of S in extract was determined using standard procedure (Chesin and Yien 1951). The critical levels of S for deficiency and adequacy were determined from the relationships between nut yield and plant S concentration or extractable soil S. Deficient level of S was calculated using both the graphical and statistical procedures as proposed by Cate and Nelson (1965). Only the highest value of relative yield for each soil was chosen to determine deficient S levels in soil and plant. Yield of nut, haulm, shell concentration and uptake of sulphur were considered for determination of critical S levels.

RESULTS AND DISCUSSION

Physico-chemical properties and extractable S content of the experimental soils: The amount of clay content varied from 130 to 460 g/kg with a mean value of 245 g/kg. The *p*H of soils varied from 4.19 to 7.72 with a mean value of 5.38. Soils collected from different location were mostly in acidic range, except the soils from Nadia district that showed neutral to alkaline reaction with a mean value of 7.40. The organic C content ranged from 0.48% to 1.29% with a mean value of 0.87%. The amount of S extracted by $CaCl_2$ varied from 11.90 to 29.17 mg/kg with a mean value of 18.27 mg/kg (Table 1). Pearson correlation was computed between the extractable S content and the physiochemical properties of soil. It was found that the extractable S content was not significantly correlated with pH (r = -0.002; P = 0.831), clay (r = +0.043; P = 0.390), organic C (r = +0.083; P = 0.461) of the soils. This indicated that the available S content of Gangetic alluvial soils was not influenced by physico-chemical parameters of soils since the parameter varied within a limited range and also the quality of organic matter and their different decomposition rate might be the reason for this non significant relationship. The correlations of available S with *p*H and organic carbon were in accordance with earlier reports (Srinivasrao *et al.* 2004).

Dry matter yield: Application of S increased the dry matter yield (DMY) of haulm, shell and nut of groundnut. The analysis of variance showed that yield of groundnut haulm, shell and nuts were significantly influenced by the application of different doses of S (Fig 1a). However, the highest dry matter yield of haulm and nuts of groundnut were recorded with S application @45 kg/ha and found significantly superior over rest of the S levels but shell

Table 1 Physico-chemical properties and $CaCl_2$ extractable S of experimental soils

District	Location	Latitude (°)	Longitude (°)	Agro-climatic zones	Clay (g/kg)	pH	O.C (%)	Ext. S (mg/kg)
Cooch Behar	North Kalaerkuthi	26º26'249"	89°22'359"	Terai-Teesta Alluvial	220	4.65	0.72	20.8
	Panisala	26º16'652"	89°30'967"		250	6.89	0.75	13.1
	Kusharbadi	26º27'722"	89°14'610"		210	4.42	1.11	15.2
Jalpaiguri	PurbaKanthalbari	26º30'635"	89°18'700"		180	4.19	1.02	14.8
	Mayradanga	26º34'70"	89°14'100"		160	4.53	1.29	17.8
	Taluktari	26º35'526"	89°14'184"		190	4.51	0.51	16.4
North Dinajpur	Lohatara	25º38'169"	88°23'576"		300	4.85	0.87	13.1
	Narayanpur	25º37'716"	88°10'408"		200	5.04	0.78	21.4
	Rampur	25º41'802"	88°6'806"		160	5.31	1.08	19.0
Bankura	Muidara	22º59'353"	87°36'981"	Undulating Red and Laterite	130	4.66	0.96	18.0
	Damodarbati	23º7'641"	87°14'483"		180	5.54	1.17	29.1
	Janta	23º6'972"	87°20'234"		240	4.29	0.72	15.2
Hoogly	Ochai	22º56'548"	88°18'322"	Gangetic Alluvial	300	4.69	0.75	16.4
	Mollai	23º5'639"	88°18'723"		260	6.15	0.99	12.3
	Hoira	23º0'584"	88°21'693"		450	5.34	1.14	24.8
Nadia	Kastadanga	22º58'337"	88°39'554"		320	7.45	0.78	16.8
	Magurkhali	23º10'70"	88°33'309"		460	7.72	0.9	22.2
	Hariyakhi	23º2'756"	88°38'941"		160	7.05	0.48	11.9
Burdhawan	Charul	23º27'621"	87°80'482"		230	5.4	0.72	22.0
	Kajidanga	23º25'401"	88°14'102"		300	4.89	0.72	24.4
			Mean		245	5.38	0.87	18.2
			Range		130-460	4.19-7.72	0.48-1.29	11.9-29.1

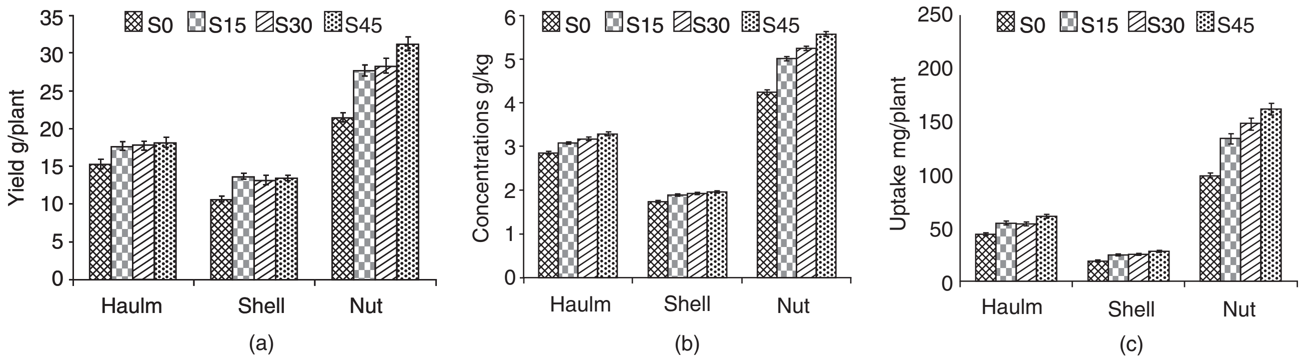

Fig 1 Effect of different levels of S application on (a) average dry matter yield (g/plant), (b) S concentration (g/kg), (c) S uptake (mg/plant) of haulm, shell and nut at harvesting stage of groundnut.

yield of groundnut was recorded highest with S application of 15 kg/ha as compared to other S treatments. Average of the 20 location soils showed an increase in relative yield of groundnut with sulphur application. Higher yield of haulm, shell and nut was recorded with application of 45 kg/ha S than that with lower S rates. Such lower response with application of 15 and 30 kg/ha S may be due to deficiency of S in soil. Response of groundnut to applied S had also been reported by (Reddy *et al.* 1993) from different soil types of India.

Sulphur concentration: Different level of S application significantly affected the S concentration in different parts of groundnut, i.e. haulm, shell and nut at harvest. The concentration of S in haulm, shell and nut increased due to S application. The highest value of S concentration in groundnut parts was recorded with applied S @45 kg/ha. (Fig 1b). The result also indicated that the mean S concentration in haulm and nut was 39.4 and 62.5% higher over shell respectively. In control treatment, the concentration of S in different parts of groundnut was lowest. The sulphur concentration in haulm, shell and nut of groundnut also increased with increasing rate of S application. The highest S concentration in nut than the shell and haulm was due to translocation of S from root to the nut that continues during the entire nut formation which leads to the accumulation of S in that portion of groundnut (Tejeswara Rao *et al*. 2013). Similar result reported earlier by Singh and Chaudhari (1996).

Sulphur uptake: The sulphur uptake by groundnut haulm, shell and nut significantly increased with increasing levels of S over the control (Fig 1c). This indicates that on an average, the plant response to S application increasing with increase the rate of S application up to 45 kg/ha. The uptake of S was recorded highest with application of 45 kg/ha S and lowest with control treatment. This is obviously due to the increased biomass yield as well as the tissue S concentration with increasing S application rate in soils. Tejeswara Rao *et al.* (2013) also reported increase in haulm, shell and nut uptake in groundnut with the application of sulphur.

Critical limit of sulphur for groundnut crop in alluvial soil: Results showed that critical value of $CaCl_2$ extractable S in soil for the S nutrition of groundnut from statistically and graphically was 18.6 and 19.58 mg/kg respectively, considering BPY (Fig 2a). Critical limit of S in groundnut haulm and nut as computed by statistically was 2.94 and 4.28 g/kg while through graphically 3.0 and 4.42 g/kg respectively (Fig 2b and 2c). Athokpam *et al*. (2005) also followed the same technique of Cate and Nelson in mustard to find out the critical value of Sulphur. In this study, we tried to find out the response of groundnut towards the application of S and to estimate the critical value for groundnut plant following the same footsteps. Extraction of S with $CaCl_2$ in soil still being the most recognized and

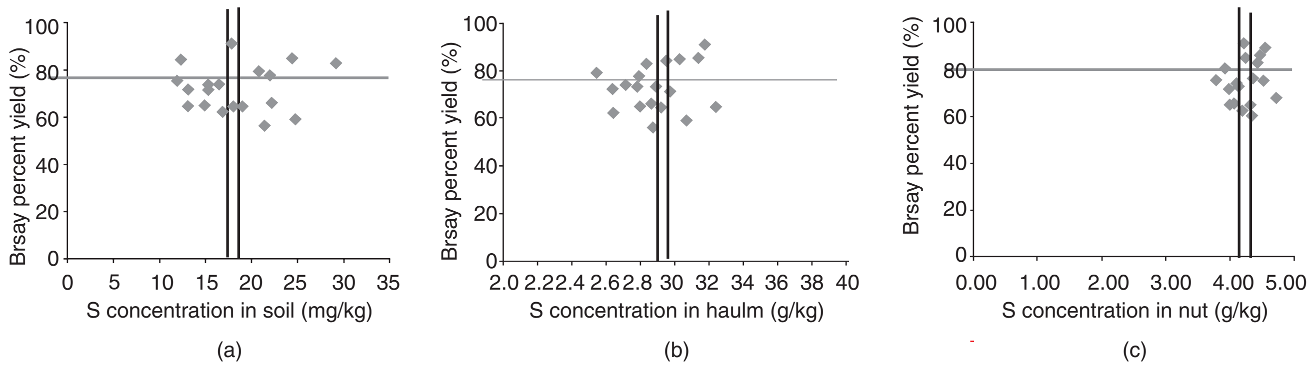

Fig 2 Vertical lines intercepting X axis indicating the values of statistically and graphically critical limit of S concentration in (a) soil, (b) haulm and (c) nut of groundnut

widely followed and generally synchronized method. It was also found that the critical value obtained in graphical method was 2% to 5.3% greater than those obtained through statistical method. The result indicates that for the considered soil, if the content of available S in soil be lower than 18.6 (graphical method) or 19.58 (statistical method) mg/kg, the test plant show visual deficiency symptoms and would respond to the application of S. The critical value in different plant parts also indicated some important information about S nutrition in groundnut. However, Alam (2003) reported 15.2 mg/kg as critical value in 16 soil series of Bangladesh using mustard as test crop.

Application of S fertilizer significantly increased the yield, concentration and uptake of sulphur by groundnut and a higher response was associated with application of 45 kg/ha S than with lower (15 and 30 kg/ha) S rates. The critical level of $CaCl_2$ extractable S for deficiency in groundnut was 18 mg/kg. The results also suggest application of fertilizer S @30-45 kg/ha for optimum S nutrition and yield of groundnut in alluvial Inceptisols of different agro-climatic zone of West Bengal, India.

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