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Sulphur and Micronutrient Nutrition of Groundnut in a Calcareous Soil

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With 5 tables

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Abstract

Field experiments conducted on a calcareous soil have shown that application of elemental sulphur reduced the chlorosis of groundnut leaves and increased the dry matter, nodule biomass, pod, haulms, and oil yields, and concentration of nutrients in leaf tissue and their uptake by groundnut. The application of iron (Fe), zinc (Zn) and manganese (Mn) further helped in recovering the chlorosis of groundnut and increased the above parameters. On average, application of 20 kg S ha^{-1} as elemental sulphur (S) increased pod yield by 8.6–9.8% and oil yield by 8.8–15%. However, application of 10, 2, and 4 kg ha^{-1} of Fe, Zn and Mn, increased pods by 19.5, 13.6, and 11.7% and oil yield by 20.1, 13.9 and 12.2%, respectively.

Elemental S increased the concentrations of N, P, K, S, Fe, Mn and Zn, but brought down the excess Ca levels of groundnut leaves, at pegging stage (45 DAE), from high to its sufficiency level. The uptake of all the macro- and micro-nutrients by groundnut, however, increased due to S application. Application of Fe, Mn and Zn reduced Ca and increased S concentrations in groundnut leaves, but increased the uptake of all the nutrients. Of the two varieties tested, JL 24 was found to be more efficient in mining the calcareous soil for nutrients and showed less chlorosis and lower Ca content in leaves, but higher pod, haulm and oil yields and nutrient uptake than J 11.

Key words: Calcareous soil — chlorosis — groundnut (*Arachis hypogaea* L.) — micronutrient — sulphur — yield

Introduction

Recently, sulphur has become a major limiting plant nutrient due to continuous use of high analysis NPK fertilizers (Biswas and Tewatia, 1986; Hilal and Abd-Elfattah, 1987; Singh and Chaudhari, 1995). Groundnut, due to its underground pod bearing habit, is mainly grown on light-textured soils generally deficient in sulphur and micronutrients (Kanwar et al., 1983; Dwivedi, 1988; Supakamnerd et al., 1990; Singh and Chaudhari, 1995). When grown on a calcareous soil, the groundnut shows chlorosis mainly due to the lime-induced deficiencies of sulphur and micronutrients such as Fe, Zn, and Mn causing considerable yield reductions (Hartzook, 1975; Houng, 1984; Singh and Dayal, 1992; Singh et al., 1990, 1993, 1995; Singh and Chaudhari, 1995). In groundnut, these deficiencies occur mainly in young and developing leaves as interveinal to complete leaf blade chlorosis which sometimes may turn pale yellow or white causing death of leaflets and plants (Hartzook, 1975; Hago and Salama, 1987; Dwivedi, 1988; Supakamnerd et al., 1990; Singh et al., 1990, 1995; Singh and Chaudhari, 1995). These deficiencies are so intermingled that it is very difficult to single them out in field-grown crops, especially in calcareous soil. However, they can easily be detected through their correction by applying S and those micronutrients either in soil, seed or through foliar applications (Hartzook, 1975; Singh et al., 1993, 1995). The soil application of sulphur-containing fertilizers is the main remedy to overcome chlorosis caused by S and micronutrients deficiencies and a number of sulphur-containing fertilizers have been tested for groundnut (Biswas and Tewatia, 1986; Hago and Salama, 1987; Singh and Chaudhari, 1995; Singh et al., 1990, 1993, 1995), but information on the mixed application of S and micronutrients and their effectiveness in fields in calcareous soils is scarce. Therefore, field experiments were conducted to study the effects of sulphur with and without application of Fe, Zn, and Mn on the growth, nodulation, pod, and haulm yields and nutrient concentrations and uptake by groundnut in calcareous soil.

Materials and Methods

Field experiments were conducted for two consecutive years during the wet season at the Research Farm of

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Table 1: Details of the treatments and application modes

Treatments Symbol	Chemicals used and their chemical formulae	Application rate (kg nutrients ha^{-1}) Soil	Seed	Foliar	Total
Control	—	—	—	—	—
Fe	Iron chloride ($FeCl_3 \cdot 6H_2O$)	8.0	—	2.0*	10.0
Zn	Zinc chloride ($ZnCl_2$)	—	1.5	0.5	2.0
Mn	Manganous chloride ($MnCl_2 \cdot 4H_2O$)	—	3.0	1.0	4.0
S_0		—	—	—	
S_{20}	Elemental sulphur	20	—	—	20

* For the foliar spray of iron, iron citrate was used. The iron citrate and chloride salts of zinc and manganese at 0.44, 0.1, and 0.2 % aqueous suspension containing 0.1, 0.05 and 0.05 % of Fe, Zn and Mn, respectively were applied on the foliage thrice at a rate of 500, 500, 1000 l ha^{-1} at 30, 50 and 70 DAE, respectively.

the National Research Centre for Groundnut, Junagadh, India in a medium black, calcareous, clayey soil (35% sand and 44% clay) containing 18.4% calcium carbonate, 0.71% organic carbon, 590 mg kg^{-1} total N, 4.5 mg kg^{-1} available P (Olsen P), 10 mg kg^{-1} heat soluble S (available S), 2.2, 4.5 and 0.45 mg kg^{-1} DTPA extractable Fe, Mn, and Zn, respectively, and pH 7.6. The experiment was laid out in a factorial-randomized block design and the factors tested were: Sulphur (S_0, no sulphur and S_{20}, elemental sulphur at a rate of 20 kg S ha^{-1} applied before sowing); groundnut varieties (JL 24, a high yielding iron-efficient variety released for cultivation in the 1980s and J 11, an iron-inefficient variety released in the 1970s); and micronutrient treatments (Control, Iron (Fe), Zinc (Zn), and Manganese (Mn)). Other details of the treatments are summarized in Table 1. There were three replications.

The field was prepared and divided into 48 small plots of 20 m^2 (5 m × 4 m) by raising bunds. A basal dose of 20 kg N and 22.5 kg P ha^{-1} as diammonium phosphate and 40 kg K ha^{-1} as muriate of potash were mixed in the soil before sowing. The major portion of the micronutrients was applied in the soil either directly in furrows or through seed dressing and some portion as foliar spray as detailed in Table 1. The elemental S at 20 kg S ha^{-1} and ferric chloride at 8 kg Fe ha^{-1} were mixed with the soil before sowing in the respective sulphur and iron treatments. Manganese and Zn at 3 and 1.5 kg ha^{-1} were mixed with the seed and sown in their respective treatments.

The groundnut varieties were sown at 30 cm × 10 cm spacing by placing the seed 2–4 cm below soil surface. As there was adequate moisture in the soil the seed germinated within a week. The crop was grown under the recommended package of practices and proper care was taken to protect it from weeds, insects, pests, and diseases during the entire cropping season. The micronutrient solutions in water as detailed in Table 1 were sprayed on the foliage thrice at a rate of 500, 500, and 1000 l ha^{-1} at 30, 50 and 70 DAE, respectively. Five plants from each plot were uprooted randomly both at pegging stage (45 DAE) and at maturity, washed, separated into leaves, stems and nodules, weighed after drying in an oven at 60 °C for about a week, and subjected to nutrient analyses.

The crop was harvested at maturity, dried in the sun for a week and pod and fodder yields were recorded. The percentage oil content of the kernel was determined taking NMR observations. The oven-dried plant tissues were ground to a fine powder and analysed for N by auto analyser, S by turbidimetry (Chaudhary and Cornfield, 1966), P by colorimetry, Ca by titrimetry, K by flame photometry and Fe, Mn, Zn and Cu by atomic absorption spectrophotometry following Jones et al. (1991). The uptake was calculated by multiplying the nutrient concentration with the respective weight of dry matter. All these data were analysed statistically following Gomez and Gomez (1984) using a factorial-randomized block design, and the LSD ($P < 0.05$) values were used to compare means of different groundnut varieties, micronutrients and sulphur doses.

Results and Discussion

Growth, nodulation, dry matter production and yields

Application of sulphur and micronutrients caused significant increases in the dry matter and nodule biomass at 45 days after emergence (DAE) as well as plant height, pod, haulm, and oil yields at harvest during both years (Table 2). Though iron was more effective in increasing nodulation and pod yield than Mn and Zn, the other parameters did not vary significantly among these micronutrients (Table 2). However, all the three micronutrients increased these parameters over control significantly. As the nodule requires iron for the synthesis of nitrogenase, it was obvious that the iron application increased nodulation in this study which also caused regreening of the chlorotic leaves. O'Hara et al. (1988) observed that Fe-deficient groundnut grown on cal-

Table 2: Influence of micronutrient and sulphur on the dry matter production and nodulation at 45 DAE; and pod, haulm, and oil yields of groundnut varieties at harvest

Treatment	At 45 DAE: Dry matter ($g\ m^{-2}$)	Nodule wt. ($g\ m^{-2}$)	At harvest: Plant height (cm)	Yield ($kg\ ha^{-1}$): Pod	Haulm	Oil
			First year			
Groundnut varieties						
JL 24	434	4.15	67	1339	1934	463
J 11	391	3.20	74	974	1998	322
LSD 0.05	23	0.22	2.1	25	NS	29
Micronutrient						
Control	375	3.11	63	1040	1779	352
Fe	435	3.92	74	1243	2100	422
Zn	419	3.80	73	1179	1997	400
Mn	423	3.88	72	1164	1990	395
LSD 0.05	32	0.31	2.9	35	116	42
Sulphur doses						
S_0	390	3.30	68	1109	1911	376
S_{20}	435	4.05	73	1204	2022	409
LSD 0.05	23	0.22	2.1	25	82	29
			Second year			
Groundnut varieties						
JL 24	368	3.22	43	1439	2296	534
J 11	329	2.85	42	1276	2163	411
LSD 0.05	16	0.14	1	38	NS	36
Micronutrient						
Control	332	2.52	42	1221	1925	423
Fe	353	3.30	44	1459	2233	509
Zn	355	3.23	41	1390	2417	483
Mn	354	3.09	43	1360	2342	475
LSD 0.05	25	0.20	NS	54	199	51
Sulphur doses						
S_0	340	2.94	42	1294	2154	439
S_{20}	357	3.14	43	1421	2304	505
LSD 0.05	16	0.14	1	38	141	36

NS = non-significant.

careous soil in Central Thailand failed to nodulate unless plant received foliar application of Fe. With the application of sulphur, nodule weight at 45 DAE increased which is in accordance with our earlier study (Singh and Chaudhari, 1995). However, Hago and Salama (1987) found that application of elemental S at 50 kg S ha^{-1} increased the nodule number per plant but not the nodule dry weight. Though in our earlier study iron sulfate was found to be best (Singh et al., 1990), the chloride salts of Fe, Mn, and Zn were used in this study to differentiate the effects of sulphur from micronutrients and the individual effects of these micronutrients were found promising.

As flower production is improved when a considerable portion of S is applied in soil as basal and early flowering caused more peg formation (Singh and Chaudhari, 1995), elemental S applied at 20 kg S ha^{-1} as basal dressing in this study increased the nodule biomass and pod yield.

On average, application of 10, 2, and 4 kg ha^{-1} of Fe, Zn and Mn increased pod yield by 19.5, 13.6, and 11.7%, and oil yield by 20.1, 13.9, and 12.2%, respectively. However, application of 20 kg S ha^{-1} as elemental S increased pod yield by 8.6–9.8% and oil yield by 8.8–15.0% (Table 2). The increase in yield with application of these micronutrients was mainly due to corrections of the deficiencies of these micronutrients in groundnut which is very common in this soil (Singh and Dayal, 1992; Singh et al., 1990, 1993). The combined application of Fe, Mn, and Zn, however, has been reported to increase pod yield of JL 24 and J 11 groundnut varieties by 8.9–21.2 and 13.6–50%, respectively, in this calcareous soil (Singh et al., 1993). Application of these micronutrients in this study overcame the chlorosis and increased yield. Depending upon the field condition, the chlorosis due to deficiencies of Fe and S has been found to reduce 15.9–32.5% pod yield in calcareous soil and application of Fe and S sources could offset these losses (Singh et al., 1995). Moreover the presence of lime in the soil causes leaching of SO_4^{2-} S from the soil leading to S deficiency (Bolan et al., 1988). Thus S is a limiting nutrient for groundnut in this soil and hence the responses to the element were significant in this study.

No significant interaction of micronutrients, sulphur and groundnut varieties was noticed on any of the above parameters. Though the S application is reported to increase oil content (Sahu et al., 1991), in this study such an effect was not observed but the increase in oil yield was observed due to higher seed yield (Table 2).

Nutrient concentration and uptake

The nutrient concentrations of leaves, observed at 45 DAE, are given in Table 3. Application of Fe, Mn, and Zn did not affect the concentrations of N, P, and K, but these all reduced Ca and increased S contents in leaf tissues. Application of Fe, Mn, and Zn in the soil as well as foliar spray increased the availabilities of these elements and hence increase in the Fe, Mn and Zn concentrations of leaves were obtained in the respective treatments (Table 3). Elemental S on the other hand increased the concentrations of N, P, K, S, Fe, Mn, and Zn, but reduced Ca in leaves during both the years. Elemental S is a slow-releasing fertilizer and in calcareous soil it is first oxidized to SO_4^{2-} and then becomes available to the plant. Besides release of S, the biological oxidation of the added S produces sulphuric acid in the soil (Hilal and Abd-Elfattah, 1987) which might have increased the solubility of most of the nutrients in this calcareous soil and hence the increase in concentration and uptake of these elements was obvious.

The sufficiency levels of Ca concentration in upper leaves is in between 1.2–2.0% (Nicholaide and Cox, 1970). But in this study, conducted in calcareous soil, the Ca content of groundnut leaf was in excess (2.1–2.5%) in control plot (without S and micronutrients) which came down to its sufficiency level with application of S. The S also increased the concentrations of other elements. This increase was more pronounced for those elements whose absorption is restricted due to high soil Ca. In our earlier study also, S fertilizer increased N, S and Fe concentrations of leaves (Singh and Chaudhari, 1995; Singh et al., 1990). Here the effect of S was more pronounced on increasing the Fe concentrations of leaves. The recovery of iron deficiency through sulphur fertilizer is well established (Houng, 1984; Singh and Chaudhari, 1995; Singh et al., 1990, 1995) but in this study S also increased the concentrations of Zn and Mn in leaf tissues which resulted in overcoming the groundnut plants from Zn and Mn deficiencies in the calcareous soil.

Of the two varieties JL 24 was more efficient in mining the calcareous soil for micronutrients as the concentrations of Fe, Mn, and Zn were higher in this variety than J 11. The JL 24 also maintained lower Ca concentration in leaves than J 11 which is a desirable character as high Ca content in plant tissues causes low uptake of most of the nutrients. Based on the visual symptoms the JL 24 has been identified as an iron-efficient variety and J 11 as iron-inefficient one for calcareous soil (Singh and Chaudhari, 1991) hence JL 24 could perform better than J 11 in this study also. However, these two varieties did not differ in their N, P, K, and S concentrations in leaves (Table 3).

Though the nutrient concentration of leaves showed different trends, the uptake of all the macro- and micro-nutrients at harvest increased due to application of elemental S, and micronutrients (Table 4). This increase in uptake was either due to the higher concentration of these nutrients in the plant tissues or higher yields and biomass production. Chlorosis due to the deficiencies of Fe, Mn, and Zn is the main problem of groundnut grown in calcareous soil (Singh et al., 1990, 1993, 1995) and application of these micronutrients in this study recovered the plants from chlorosis, and resulted in greater nutrient removal. Although no significant interaction of micronutrients, sulphur,

Table 3: Influence of micronutrient and sulphur on the nutrient concentrations of groundnut leaf tissues at 45 DAE

Treatments	N	P	K	Ca	S	Fe	Mn	Zn	Cu
	Nutrient concentration in leaves								
	%					mg/kg			
First year									
Groundnut varieties									
JL 24	3.44	0.28	1.86	1.90	0.20	305	188	36	20
J 11	3.40	0.26	1.83	2.09	0.19	274	182	32	20
LSD 0.05	NS	NS	NS	0.11	NS	21	NS	3	NS
Micronutrient									
Control	3.39	0.25	1.85	2.15	0.18	205	133	25	19
Fe	3.47	0.28	1.83	2.00	0.21	372	156	28	20
Zn	3.41	0.27	1.90	1.93	0.21	285	172	55	21
Mn	3.41	0.28	1.8	1.90	0.19	295	278	27	19
LSD 0.05	NS	NS	NS	0.15	0.02	30	26	4.3	NS
Sulphur doses									
S_0	3.33	0.25	1.77	2.06	0.19	261	173	31	19
S_{20}	3.51	0.29	1.92	1.93	0.21	318	197	37	21
LSD 0.05	0.16	0.04	0.14	0.11	0.014	21	18	3	1.4
Second year									
Groundnut varieties									
JL 24	3.50	0.30	1.62	1.83	0.25	370	143	39	26
J 11	3.45	0.29	1.53	1.92	0.22	343	130	34	24
LSD 0.05	NS	NS	NS	0.09	NS	28	12	4.2	NS
Micronutrient									
Control	3.44	0.28	1.46	2.30	0.22	297	107	29	21
Fe	3.50	0.31	1.54	1.71	0.24	465	128	33	27
Zn	3.48	0.30	1.70	1.90	0.23	318	135	50	28
Mn	3.47	0.30	1.59	1.62	0.24	345	176	34	25
LSD 0.05	NS	NS	0.20	0.13	NS	40	17	6	3.7
Sulphur doses									
S_0	3.40	0.28	1.46	1.97	0.19	315	127	32	23
S_{20}	3.55	0.31	1.69	1.78	0.28	398	146	41	27
LSD 0.05	0.11	0.02	0.14	0.09	0.04	28	12	4.2	2.6

NS = non-significant.

and groundnut varieties was observed on the nutrient concentration of leaf tissues at 45 DAE, the uptake of N, P, S, and Zn by groundnut during first year, and N and Zn during second year showed significant interaction with sulphur and micronutrients (Table 5). In these, the uptake of N, P, S and Zn by groundnut was higher with S than without S in all the treatments, except Mn during second year. In both with and without S treatments, the N uptake by groundnut was higher in Fe treatment than Mn and Zn during first year, but during second year the various micronutrients did not show variation in N uptake by groundnut. Similarly, irrespective of S application, the P and S uptakes by groundnut during first year were higher in Fe treatment than Mn and Zn, but this effect was more pronounced with S than without S. The Zn uptake by groundnut increased due to application of all the three micronutrients, but the more pronounced effect was noticed in Zn treatments.

Conclusions

As chlorosis, due to the deficiencies of S, Fe, Zn and Mn, is of common occurrence in groundnut in

Table 4: Influence of micronutrient and sulphur on the uptake of macro- and micronutrient by groundnut varieties at harvest

Treatments	Nutrient uptake kg ha^{-1} N	P	K	Ca	S	Nutrient uptake g ha^{-1} Fe	Mn	Zn	Cu
First year									
Groundnut varieties									
JL 24	94	11.5	44	37	9.2	793	356	168	60
JL 11	83	10.7	43	38	8.7	718	344	153	53
LSD 0.05	1.6	0.11	NS	NS	0.14	25	NS	4	1.5
Micronutrient									
Control	82	10.7	38	34	8.5	638	293	122	51
Fe	94	11.6	49	41	9.3	954	346	145	61
Zn	90	11.3	45	39	9.1	717	329	238	58
Mn	89	11.1	44	38	9.0	713	432	137	57
LSD 0.05	2.7	0.16	2.3	2.2	0.19	35	18	6	2.2
Sulphur doses									
S_0	85	10.8	43	37	8.6	684	324	149	55
S_{20}	92	11.4	45	39	9.3	827	376	172	58
LSD 0.05	1.6	0.11	1.6	1.6	0.14	25	12	4	1.5
Second year									
Groundnut varieties									
JL 24	98	11.3	50	58	9.0	1120	517	188	54
J 11	90	10.8	45	55	8.6	993	484	171	49
LSD 0.05	2.3	0.16	2.5	NS	0.16	47	28	5.5	2.0
Micronutrient									
Control	85	10.5	41	49	8.3	879	434	159	45
Fe	97	11.3	48	57	9.0	1228	505	188	53
Zn	98	11.3	51	61	9.1	1075	539	289	55
Mn	96	11.2	50	59	8.9	1044	723	184	53
LSD 0.05	3.2	0.22	3.6	5	0.23	66	40	7.8	2.9
Sulphur doses									
S_0	91	10.9	46	54	8.5	970	483	189	50
S_{20}	97	11.3	49	59	9.1	1144	618	220	53
LSD 0.05	2.3	0.16	2.5	3.5	0.16	47	28	5.5	2.0

NS = non-significant.

calcareous soil, the first and foremost approach of the groundnut growers should be to use nutrient efficient groundnut genotypes which are tolerant to these chlorosis. Further, to avoid occurrence of sulphur deficiency, 20 kg S ha^{-1} as elemental S should be applied in the soil before sowing, which also prevents Fe, Mn, and Zn deficiencies to a greater extent. If the deficiencies of these micronutrients occur in groundnut leaves, the Fe, Mn and Zn at 10, 4 and 2 kg ha^{-1}, respectively, need to be applied. To recover the groundnut plant from Fe-, Zn- and Mn-deficiency chlorosis in the standing crop the foliar sprays of 0.44, 0.1 and 0.2% aqueous suspension of iron citrate, zinc chloride and manganese chloride, respectively, should be used thrice at 500, 500 and 1000 l ha^{-1} and applied 30, 50 and 70 DAE, respectively.

From an economic point of view, application of S increased 4.5–7.0 kg pod and 5.0–7.5 Kg haulm kg^{-1} ha^{-1} of nutrient applied. However, application of Fe, Zn and Mn, produced 20–24, 70–85 and 31–35 kg pod kg^{-1} ha^{-1} of these nutrients, respectively.

Table 5: Interaction of micronutrient and sulphur on the harvest uptake of macro- and micronutrient by groundnut at harvest

	Nutrient uptake											
	First year								Second year			
	kg ha^{-1}						g ha^{-1}		kg ha^{-1}		g ha^{-1}	
	N		P		S		Zn		N		Zn	
Micronutrient	S_0	S_{20}	S_0	S_{20}	S_0	S_{20}	S_0	S_{20}	S_0	S_{20}	S_0	S_{20}
Control	77	87	9.3	10.0	8.1	8.8	113	132	80	91	145	173
Fe	91	97	11.3	11.9	8.9	9.7	141	150	95	99	182	193
Zn	87	93	11.0	11.6	8.8	9.5	211	265	95	101	249	330
Mn	86	91	10.8	11.4	8.6	9.4	131	141	94	97	180	187
LSD 0.05	3.8		0.23		0.27		5.9		4.5		15.7	

Depending upon the season the Fe-efficient groundnut genotype produced 160–365 kg ha^{-1} more pod over the Fe-inefficient one.

Zusammenfassung

Schwefel- und Mikronährstoffernährung von Erdnuß in einem kalkhaltigen Boden

Es wurden Feldexperimente, die auf einem kalkhaltigen Boden durchgeführt, die zeigten, daß die Anwendung von elementarem Schwefel, Chlorose von Erdnußblättern reduzierte und die Trockensubstanz, die Knöllchenbiomasse, die Hülsen, die Stengel und den Ölertrag sowie die Konzentration der Nährstoffe in den Blattgeweben und ihre Aufnahme durch die Erdnußpflanzen erhöhte. Die Anwendung von Eisen (Fe), Zink (Zn) und Mangan (Mn) förderte darüber hinaus die Erholung der chlorotischen Erdnußpflanzen und erhöhte die genannten Parameter. Im Durchschnitt erhöhte eine Anwendung von 20 kg S ha^{-1} als elementarer Schwefel (S) den Hülsenertrag um 8,6 bis 9,8% und den Ölertrag um 8,8% bis 15%. Eine Anwendung von 10kg, 2kg und 4kg ha^{-1} von Fe, bzw. Zn und Mn erhöhte den Hülsenertrag um 19,5, 13,6 und 11,7% sowie den Ölertrag um 20,1, 19,9 und 12,2%. Elementarer S erhöhte die Konzentrationen von N, P, K, S, Fe, Mn und Zn, verringerte aber einen Überschuß an Ca-Konzentrationen in den Erdnußblättern in der Entwicklungsphase 45 DAE von einer hohen zu einer ausreichenden Konzentration. Die Aufnahme aller Makro- und Mikronährstoffe durch Erdnuß nahm als Folge der S-Anwendung zu. Die Anwendung von Fe, Mn und Zn reduzierte Ca und erhöhte die S-Konzentrationen in den Erdnußblättern; sie erhöhte darüber hinaus die Aufnahme aller Nährstoffe. Von den beiden Sorten, die untersucht wurden, erwies sich J L 24 als effizienter in der Ausnutzung an Nährstoffen in dem kalkhaltigen Boden und zeigte geringere Chlorose und geringeren Ca-Gehalt in den Blättern, aber höhere Hülsen-, Stengel- und Ölerträge sowie Nährstoffaufnahme im Vergleich zu J 11.

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References

Biswas, B. C., and R. K. Tewatia, 1986: Results of FAO sulphur trials network in India. Fert. News **36,** 11—35.

Bolan, N. S., J. K. Syder, R. W. Tilman, and D. R. Scootter, 1988: Effect of liming and phosphate addition on sulphate leaching in soil. J. Soil Sci. **39,** 493—504.

Chaudhary, T. A., and A. H. Cornfield, 1966: The determination of total sulphur in Soil and Plant material. Analyst **91,** 528—531.

Dwivedi, R. S., 1988: Mineral nutrition of groundnut. Metropolitan Book Co., New Delhi, India 135 p.

Gomez, K. A., and A. A. Gomez, 1984: Statistical Procedures for Agricultural Research, Second edn. John Wiley and Sons, Singapore.

Hago, T. M., and M. A. Salama, 1987: The effect of elemental sulphur on shoot dry weight, nodulation and pod yield of groundnut (*Arachis hypogaea*) under irrigation. Exp. Agric. **23,** 93—97.

Hartzook, A., 1975: Lime induced iron chlorosis in groundnut: Treatment and Prevention. FAO Plant Prot. Bull. **23,** 1—3.

Hilal, M. H., and A. Abd-Elfattah, 1987: Effect of $CaCO_3$ and clay content of alkaline soils on their responses to added sulphur. Sulphur Agric. **11,** 15—19.

Houng, K. H., 1984: Effect of sulphur on the chlorosis and yield of peanuts grown on calcareous soil in Hualien area of Taiwan. Problem soil in ASIA, FFTC Book Series **27,** 241—250.

Jones, Jr, J. B., B. Wolf, and H. A. Mills, 1991: Plant Analysis Handbook. Micro-Macro Publishing Inc. Georgia, U.S.A.

Kanwar, J. S., H. L. Nighawan, and S. K. Raheja, 1983:

Groundnut nutrition and fertilizer response in India. Indian Council of Agric. Res., New Delhi, India.
Nicholaide, J. J., and F. R. Cox, 1970: Effect of mineral nutrition on chemical composition and early reproductive development of Virginia type peanuts (*Arachis hypogeal* L.). Agron. J. **62,** 262—265.
O'Hara, G. W., M. J. Dilworth, N. Boonkerd, and P. Parkpian, 1988: Iron deficiency specially limits nodule development in peanut inoculation with Bradyrhizobium sp. New Phytol. **108,** 51—57.
Sahu, S. K., G. N. Mitra, and U. K. Mishra, 1991: Groundnut responses to sulphur application in Orissa. Indian Farming **41,** 2—3.
Singh, A. L., and V. Chaudhari, 1991: Screening of groundnut (*Arachis hypogeae* L) varieties tolerant of iron-chlorosis. Indian J. Agric. Sci. **61,** 925—927.
— —, — —, 1995: Source and mode of sulphur application on groundnut productivity. J. Plant Nutr. **18,** 2739—2759.
— —, — —, and V. G. Koradia, 1993: Spray schedules of multimicronutrients to overcome chlorosis of groundnut, Indian J. Plant Physiol. **34,** 35—39.
— —, — —, — —, and P. V. Zala, 1995: Effect of excess irrigation and iron and sulphur fertilizers on the chlorosis, dry matter production, yield and nutrient uptake by groundnut in calcareous soil. Agrochimica **39,** 184—198.
— —, — —, and D. Dayal, 1992: Foliar application of iron for recovering groundnut plants from lime-induced iron deficiency chlorosis and accompanying losses in yields. J. Plant Nutr. **15,** 1421—1433.
— —, Y. C. Joshi, V. Chaudhari, and P. V. Zala, 1990: Effect of different sources of iron and sulphur on leaf chlorosis, nutrient uptake and yield of groundnut. Fert. Res. **24,** 85—96.
Supakamnerd, N., B. Dell, and R. W. Bell, 1990: Diagnosis of sulphur deficiency in peanut (*Arachis hypogaea* L.) by plant analysis. In: M. L. van Beusichem (Ed.) Plant Nutrition-Physiology and applications. pp. 791—795. Kluwer Academic Publishers, Dordrecht.