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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2018; 7(4): 47-50

www.thepharmajournal.com
Received: 25-02-2018
Accepted: 26-03-2018

AR Patel
Department of Soil Science and Agricultural Chemistry, Navsari Agricultural University, Navsari, Gujarat, India

VJ Zinzala
Department of Soil Science and Agricultural Chemistry, Navsari Agricultural University, Navsari, Gujarat, India

Correspondence
AR Patel
Department of Soil Science and Agricultural Chemistry, Navsari Agricultural University, Navsari, Gujarat, India

Effect of sulphur and boron on nutrient content and uptake by summer groundnut (*Arachis hypogeal* L.)

AR Patel and VJ Zinzala

Abstract
An experiment was conducted during summer of 2016 to study the effect of sulphur and boron application on nutrient content and uptake pattern of N, P, K, S and B in groundnut. The experiment showed that increase in application of sulphur led to an increase in the concentration and in turn uptake of N, P, K, S and B in pods and haulm up to 45 Kg/ha. However, the increase in nutrient concentration and uptake parameters with the increase in sulphur from 30 Kg/ha to 45 Kg/ha showed no significance. Owing to boron application similar trend was followed in N, P, K, S and B concentration and uptake by the crop. However, it was found that higher levels of sulphur and boron showed antagonistic effect on nutrient content and uptake of summer groundnut at pod harvesting stage. The study suggested that soil application of sulphur and boron in clay loam soil in waghai, Dangs increased the availability of primary nutrients in addition to sulphur and boron causing their absorption by summer groundnut.

Keywords: Arachis hypogea, sulphur, boron, nutrient content, uptake

Introduction
Groundnut (*Arachis hypogaea* L.) is one of the most important among edible oil seed crop in the world belongs to Leguminoceae (Fabaceae) family. It is also known as earthnuts, peanuts, goobers, goober peas, pindas, jack nuts, pinders, manila nuts, and monkey nuts. The groundnut originated in South America from where it spread to Asia, Africa, Sudan, Nigeria, USA and other parts of the world. It is commercially grown in more than hundred countries like India, China, USA and West Africa. Groundnut was introduced in India in the middle of nineteenth century on east coast of the South Aricot district in Tamil Nadu. Groundnut is self pollinated, allotetraploid legume with the chromosome number (2n= 40). The name *Arachis hypogaea* L. is derived from the Greek word Arachis which means the legume and hypogaea means below ground. It contains about 50 % oil, 25 to 30 per cent protein, 20 per cent carbohydrate and 5 per cent fiber and ash which make a substantial contribution to human nutrition (Fageria *et al*. 1997) [7]. Besides, it is 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.

In India, 80 % of area under groundnut, coverage along with 84% of the production is confined to the states of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra. Among these, Gujarat ranks first in both area and production and in productivity of groundnut and it occupied an area of 1843 hectares with total production 4918 tonnes and productivity of 2668 kg ha^{-1} (Anonymous, 2016) [2]. Total area in Dangs district is 800 ha and total production 1500 MT with the productivity of 1922 kg ha^{-1} (Anonymous, 2013) [1].

Very little or negligible research work has been reported on effect of sulphur and boron on growth and yield of crop especially on summer groundnut under South Gujarat condition.

Materials and Methods
A field experiment was conducted at plot no. 24, KVK Farm, Waghai (Dangs). Dangs is the smallest district of Gujarat state and is declared by the planning commission, it is situated between the parallels of latitude 20°39' and 21°5' North, and the meridians of longitude 73°27'58" and 73°56'36" East. and mean sea level height is 147 m/km. during summer season of 2016.

According to Agro-climatic conditions, Dangs District falls under South Gujarat heavy rainfall agro-climatic zone-I. The annual average rainfall of Dang district is about 2500 mm and comes under hyperthermic temperature regime exhibiting summer, rainy and winter three seasons very prominent. The summer starts from March and lasts up to middle of June. The monsoon season starts from middle of June and lasts till the end of October. The month May is the

The month May is the hottest month in the season. The mean weekly meteorological data pertaining to maximum and minimum temperature, relative humidity, and rainfall for the period of experimentation (17-02-2016 to 17-06-2016) recorded at meteorological observatory, Hill Millets Research station, Navsari Agricultural University, Waghai, Dangs.

The soil of the experimental plot was clay loam in texture (50.2%), high in organic carbon (0.90%), low in available nitrogen (245 kg ha^{-1}), low in available phosphorus (23 kg ha^{-1}), high in available potassium (325 kg ha^{-1}), medium in available S (10.29 mg kg^{-1}) and available B (0.38 mg kg^{-1}) content. The soil reaction was neutral pH (6.9) and low soil salinity status (0.24 dS m^{-1}).

The soil of the experimental field was clayey in texture and alkaline in reaction (pH of 8.00 and EC of 0.58 dS m^{-1}). The soil was low in available nitrogen (212 kg ha^{-1}), medium in available phosphorus (28.63 kg ha^{-1}), medium in available potassium (257 kg ha^{-1}), medium in available sulphur (10.02 ppm), medium in iron (5.24 ppm), high in manganese (12.78 ppm), medium in zinc (0.74 ppm), and high in copper (1.21 ppm). The experiment comprised of total fifteen treatment combinations in which four levels of sulphur (0, 15, 30 and 45 S kg ha^{-1}) and three levels of boron (0, 1 and 2 B_0 kg ha^{-1}) were laid out in Completely Randomization Design having factorial concept with three replications. The fertilizer application was done with fixed doses of nitrogen at 25 kg ha^{-1}, phosphorus at 50 kg ha^{-1}. Sulphur and Boron application was done according to the treatments. The nutrients of N, P, S and B were applied by using sources of Urea, DAP, Boric acid and Gypsum, respectively. The Groundnut variety "Gujarat Groundnut-31" was planted in fourth week of February. A week after germination five plants per each pot were maintained under normal practices. The crop was raised with all the standard package of practices and protection measures also timely carried out as they required. The experimental data recorded for growth parameters, yield attributes and yield parameters were statistically analyzed for level of significance.

Results and Discussion

Effect of S and B on nutrients content and uptake

The results (Table 1) revealed that nitrogen content in pod and haulm was significantly influenced by increase level of sulphur application. Application of 45 kg S ha^{-1} recorded remarkably maximum nitrogen content in pod (4.42%) and haulm (1.55%) rest of the treatments. However remained at par with 30 kg S ha^{-1}. This increase in nitrogen content might be due to favorable effect on availability of nitrogen at the increase level of sulphur. The nitrogen uptake by pod, haulm and total uptake by groundnut (Table 1) remarkably increased due to application of sulphur. The maximum uptake of nitrogen by pod (37.28 kg ha^{-1}), halum (26.11 kg ha^{-1}), and total nitrogen uptake (49. 06 kg ha^{-1}) was recorded under 40 kg S ha^{-1}. The increase uptake of nitrogen by groundnut due to increase levels of sulphur might be attributed to favorable effect of sulphur application on growth and yield attributes which resulted in to higher pod and haulm yield and consequently more removal of nitrogen by the pod and haulm

Table 1: Effect of S and B on N content and uptake by groundnut

Treatments	Content (%)		Uptake (kg/ha)		
	Pod	Haulm	Pod	Haulm	Total
Sulphur (kg ha^{-1})					
S_o	3.83	1.25	59.05	22.30	81.35
S_{15}	3.98	1.39	70.40	29.21	99.61
S_{30}	4.11	1.45	85.06	35.25	120.31
S_{45}	4.17	1.49	92.17	37.28	129.44
S.Em. ±	0.09	0.05	2.57	1.35	4.53
C.D at 5 %	0.25	0.13	7.53	3.95	13.30
Boron (kg ha^{-1})					
B_0	3.85	1.32	64.96	25.99	90.95
B_1	4.10	1.41	82.57	33.14	115.71
B_2	4.12	1.46	82.48	33.90	116.37
S.Em. ±	0.07	0.04	2.22	1.17	3.93
C.D at 5 %	0.22	0.12	6.52	3.42	11.51
C.V. (%)	6.40	9.05	10.05	13.04	7.85
Interaction					
B × S	NS	NS	NS	NS	NS

Table 2: Effect of S and B on P content and uptake by groundnut

Treatments	Content (%)		Uptake (kg/ha)		
	Pod	Haulm	Pod	Haulm	Total
Sulphur (kg ha^{-1})					
S_o	0.59	0.32	8.36	5.55	13.91
S_{15}	0.62	0.38	10.09	7.61	17.70
S_{30}	0.64	0.39	13.19	9.50	22.69
S_{45}	0.67	0.39	16.22	10.38	26.60
S.Em. ±	0.02	0.01	0.44	0.35	0.86
C.D at 5 %	0.06	0.03	1.29	1.02	2.51
Boron (kg ha^{-1})					
B_0	0.59	0.35	9.25	6.51	15.76
B_1	0.65	0.37	13.68	9.15	22.83
B_2	0.64	0.38	12.96	9.13	22.08
S.Em. ±	0.02	0.01	0.38	0.30	0.74
C.D at 5 %	0.05	0.03	1.12	0.88	2.18
C.V. (%)	9.50	9.63	11.06	12.59	12.71
Interaction					
B × S	NS	NS	NS	NS	NS

Table 3: Effect of S and B on K content and uptake by groundnut

Treatments	Content (%)		Uptake(kg/ha)		
	Pod	Haulm	Pod	Haulm	Total
Sulphur (kg ha^{-1})					
S_o	0.65	0.84	11.19	16.41	27.60
S_{15}	0.73	0.94	13.06	19.56	32.62
S_{30}	0.76	0.97	15.54	22.73	38.27
S_{45}	0.77	0.96	16.61	24.41	41.02
S.Em. ±	0.02	0.02	0.62	1.07	1.20
C.D at 5 %	0.07	0.07	1.82	3.14	3.52
Boron (kg ha^{-1})					
B_0	0.69	0.89	12.48	17.59	30.08
B_1	0.74	0.95	15.01	22.60	37.61
B_2	0.76	0.96	14.81	22.14	36.95
S.Em. ±	0.02	0.02	0.54	0.93	1.04
C.D at 5 %	0.06	0.06	1.57	2.72	3.05
C.V. (%)	9.26	8.00	13.17	15.48	10.33
Interaction					
B × S	NS	NS	NS	NS	NS

Table 4: Effect of S and B on S content and uptake by groundnut

Treatments	Content (%)		Uptake (kg/ha)		
	Pod	Haulm	Pod	Haulm	Total
Sulphur (kg ha^{-1})					
S_o	0.23	0.14	3.72	2.62	6.36
S_{15}	0.27	0.16	5.10	3.64	8.67
S_{30}	0.31	0.18	6.28	4.28	10.57
S_{45}	0.33	0.19	6.96	4.66	11.67
S.Em. ±	0.01	0.00	0.16	0.11	0.22
C.D at 5 %	0.02	0.01	0.48	0.33	0.65
Boron (kg ha^{-1})					
B_0	0.25	0.15	4.65	3.18	7.81
B_1	0.29	0.17	5.78	3.93	9.80
B_2	0.31	0.18	6.11	4.28	10.36
S.Em. ±	0.01	0.00	0.14	0.10	0.19
C.D at 5 %	0.02	0.01	0.41	0.29	0.57
C.V. (%)	7.43	8.70	8.86	8.93	7.18
Interaction					
B × S	NS	NS	Sig.	Sig.	Sig.

Table 5: Effect of S and B on B content and uptake by groundnut

Treatments	Content (mg kg^{-1})		Uptake (g ha^{-1})		
	Pod	Haulm	Pod	Haulm	Total
Sulphur (kg ha^{-1})					
S_o	15.48	11.50	24.82	20.88	44.82
S_{15}	17.79	13.29	32.63	28.22	60.47
S_{30}	19.28	14.17	38.85	33.48	71.95
S_{45}	20.17	15.14	42.41	37.00	79.09
S.Em. ±	0.50	0.37	0.96	0.87	1.99
C.D at 5 %	1.47	1.08	2.81	2.54	5.83
Boron (kg ha^{-1})					
B_0	17.19	12.73	30.68	25.55	55.85
B_1	18.19	13.79	35.48	31.34	66.06
B_2	19.16	14.05	37.87	32.84	70.34
S.Em. ±	0.43	0.32	0.83	0.75	1.72
C.D at 5 %	1.27	0.93	2.43	2.20	5.05
C.V. (%)	8.25	8.14	8.28	8.69	9.30
Interaction					
B × S	NS	NS	Sig.	Sig.	Sig.

Maximum P content in pod (0.77%), haulm (0.43%) as well as total P uptake (26.60 kg ha^{-1}) was recorded with application of 45 kg S ha^{-1}. Sulphur might have shown the synergistic effect in increasing the P uptake. This was also due to increased P content in pod and haulm as well as higher pod and haulm yield.

Maximum K content and uptake by pod, haulm & total uptake by groundnut were recorded with application of sulphur @ 45 kg S ha^{-1}. Sulphur might have shown the positive effect on increasing the K uptake by plant. This was also due to increased K content in pod and haulm, as well as higher pod and haulm yield.

The results (Table 4) revealed that crop fertilized with 45 kg S ha^{-1} appreciably increased S content in pod (0.33%), haulm (0.19%). This might be due to more availability and accumulation of sulphur in pod as well as in haulm. The data presented in (Table 4) indicated that the S uptake by pod (6.93 kg ha $^{-1}$), halum (4.70 kg ha^{-1}) and total sulphur uptake (11.63 kg ha^{-1}) was increased significantly increasing levels of S up to 45 kg S ha^{-1}. The probable reason for higher uptake of S under higher application of sulphur might have increased their concentration in soil solution, which increased the availability and uptake of sulphur by plant. More over increasing trend of pod and haulm yield as well as S content in kernel and haulm by sulphur application.

Boron content and uptake by pod and haulm was significantly increased with increasing levels of sulphur. Is might be due to increasing trend of pod and haulm yield as well as B content in kernel and haulm with sulphur application resulted higher uptake of sulphur by crop.

Pal and Phogat (2005) [15] reported that application of S increased N, P, K, and S content and uptake by mustard crop. Similar findings also reported by Ismail *et al.* (2013) [9], Sakarvadiya *et al*. (2007).

Nitrogen content in pod and halum was significantly influenced by boron application maximum nitrogen content in pod and halum recorded under 2 kg B ha^{-1} followed by 1 kg B ha^{-1}. This increase in nitrogen content might be due to favorable effect of boron for producing maximum nodules per plant which fixed the availability of nitrogen in soil. The uptake of nitrogen by pod, halum and total uptake by crop increased with application of boron @ 1 kg and 2 kg ha^{-1} than control. It's might be due to favorable effect of boron on nodulation as well as higher pod and haulm yield. An appreciable increase in nitrogen uptake by groundnut due to B application was also reported by Patel and Golakiya (1986) [16] found that the application of boron at @ 2 kg ha^{-1}, increased nitrogen uptake by groundnut Application of boron caused significant increase in P content of pod and haulm and it's uptake by pod, haulm and total uptake. Maximum P content in pod and haulm as well as P uptake by pod, haulm and total uptake were recorded under 1 kg B ha^{-1}. Boron might have shown the synergistic effect in increasing the P content and uptake. This was also due to increased phosphorus content in pod and haulm yield. These results are in agreement with the work of Patel and Golakiya (1986) [16] and Tripathy *et al*. (1999) [20]. The positive effect of boron on phosphorus could be attributed to the favorable effect of the former which alters the permeability of plasma at the root surface in such way that P absorption by roots increase.

Potassium content in pod and haulm was significantly influenced by different levels of boron. Maximum potash content in pod, haulm and K uptake by pod was recorded when crop fertilized with 1 kg B ha^{-1}. Whereas maximum uptake of potassium by halum and total K uptake recorded under 1 kg B ha^{-1}. Increase in Potash uptake due to increase in levels of boron could be attributed to favorable effect of potash application at higher rate on growth and yield attributed which resulted in to higher pod and haulm yield and higher content of potassium in pod and haulm and subsequently more uptake of potassium from the soil.

Sulphur content in pod, haulm and its uptake by pod, haulm and total S uptake by groundnut were increased significantly up to 1 kg B ha^{-1}. The highest sulphur content in pod, haulm and uptake by pod, haulm as well as it's total was recorded with application of 2 kg B ha^{-1}. The increased S uptake due to increasing trend of pod and haulm yield as well as S content in pod and haulm under higher rate of boron application. Data revealed that the different sources and levels of boron significantly increased the boron content and its uptake by pod and haulm. The highest boron content in pod and haulm with 2 kg B ha^{-1}. The lowest B content in pod and halum was recorded under control

The B content and its uptake by haulm, pod increased with increasing levels of boron application. The increase in B uptake due to increasing trend of B content in pod and halum as well as higher pod and halum yield which resulted higher uptake of boron by pod, halum as well as total uptake**.** Ali *et* *al*. (2013) [3] reported that application of boron increase uptake of nutrients in fababean. Similar result also found by Mallick and Raj (2009).

Sulphur and boron uptake in pod and haulm were found significantly higher under combined application and increase level of sulphur with boron. Mumtaz *et al*. (2011) [13] found that combine application of S and B increase NPKS and B in French bean. Similar result also reported by Ismail *et al*. (2013) [9].

Conclusion

From the study it is concluded that for enhancing the nutrient content and uptake of summer groundnut on clay loam soil under temperate conditions of waghai, Dangs, the nutrient management may centre around 45 kg S and 1.0 kg B ha^{-1}, along with recommended dose of nitrogen (25 kg ha^{-1}), phosphorus (50 kg ha^{-1}).

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