The Bioscan 9(4): 1389-1393, 2014
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

GROWTH, NODULATION, PHYSIOLOGICAL INDICES AND YIELD OF SOYBEAN AS INFLUENCED BY SULPHUR AND BORON NUTRITION

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KEYWORDS
Boron
Nodulation
Soybean
Sulphur
Yield

Received on :
01.01.2014

Accepted on :
12.11.2014

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ABSTRACT

A field experiment was carried out on alluvial sandy loam soil during 2007-08 at the Indian Agricultural Research Institute, New Delhi to to study the effect of levels of sulphur (S) and boron (B) individually and in combination on the performance of soybean. The treatments consisted of 5 levels of S viz. 0, 10, 20, 30 and 40 kg S/ha and 4 levels of B viz. 0, 0.5. 1.0 and 1.5 kg B/ha. There was significant effect of levels of S and B on the performance of soybean. Application of S upto 30 kg recorded significantly higher growth parameters viz. plant height(57.62 cm), drymatter accumulation(36.66 g/plant), number of branches(3.10), leaf area index(2.89)etc. and yield attributes viz. number of pods/plant(72.00), seed/pod(2.49), seed index(9.99 g)etc. and yield of soybean(1.73 t/ha) as compared to lower levels of S. Similarly application of B@1.0 kg recorded significantly higher growth parameters viz. plant height (57.23 cm), drymatter accumulation (36.37 g/plant), number of branches/plant (3.11), leaf area index (2.70) etc. and yield attributes viz. number of pods/plant (70.47), seed/pod (2.52), seed index (9.79) etc. and yield of soybean (1.75 t/ha). Further increase in thelevels of S and B did not improve the parameters significantly. The combined application of 30 kg S and 1.0 kg B too recorded significant interaction effect on many of the growth and yield attributes and yield of soybean (1.88 t/ha). On the basis of the findings of this experiment it may concluded that there is a need for application of sulphur and boron for improving the productivity of soybean. And a combination of 30 kg S and 1.0 kg B/ha could be sufficient for realizing higher yield from the *kharif* soybean in the agro-climatic conditions of the Northern Plain Zone of the country.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is one of the most important oilseed crops in the world. It is termed as wonder crop as it contains 40 % good quality protein and 20 % oil high in essential unsaturated fatty acids. It is one of the nature's most efficient protein producers. It is a legume crop and fixes about 50 to 80 kg nitrogen per hectare.Being introduced in 1968, in India, soybean has emerged as main oil seed crop in a short span of time.In recent times there have been concerted efforts to popularize this crop with the development of new varieties and agro-techniques in other parts of the country. It has tremendous potential in the Northern Plain Zone of the country owing to emerging problems in the traditional cropping systems like rice-wheat etc. The average productivity of soybean (1.07 t/ha) recorded around 100 percent increase during the last one and half decades. But it is still very low when compared to world average productivity of 2.38 t/ha and productivity demonstrated under national demonstration programmes.

The imbalanced and inadequate nutrition is found to be one of the major limiting factors for its poor yield. Among the major nutrients, sulphur is found to be quite important now a day in many soybean-growing areas. It is the 13th most abundant element in the earth crust with an average concentration of 0.06%. It is now considered as the 4th major plant nutrient after nitrogen (N), phosphorous (P) and potassium (K)(Patel *et al.*, 2013a).Sulphur is an important part of every living cell, required for the formation of chlorophyll and for the activity of ATP-sulphurylase (the enzyme involved in sulphur metabolism). It is involved in several important physiological functions in soybean including oil synthesis and acts as precursor for many amino acids,namely cysteine (26%S), cystine (27%S) and methionine (21%S)which act as building blocks for the synthesis of protein (Patel *et al.*, 2013 b). The yield attributing characters of crops were greatly affected by sulphur application (Choudhary *et al.*, 2014). As soybean is rich in both oil and protein, the requirement of sulphur is quite high. Over the years due to intensive cultivation and use of sulphur free fertilizers, the deficiency of sulphur has begun to appear and it is slowly becoming a major constraint for realizing higher yield in soybean. Sulphur deficiencies are now widespread in Indian soil and reports of more areas found deficient in S are coming in regularly. In the early 1990s, S deficiencies in Indian soils were estimated to occur in about 130 districts (Tandon 1991). Recently, soil fertility survey by the Indian Council of Agricultural Research (ICAR) based on the analysis of 47,000 soil samples have shown S deficiencies to be a widespread problem. Besides sulphur, boron is another element, which is highly important in the physiological functions in soybean. Boron's widespread role within the plant includes cell wall synthesis, sugar transport, cell division,differentiation, membrane functioning, root elongation, andregulation of plant hormone levels (Pilbam and Kirkby, 1983; Romheld and Marschner, 1991; Marschner, 1995;). For legumes, the main impact of micronutrients may be on account of N fixed. Limitation of symbiotic N fixation decreases current crop production and will have equally significant impact on subsequent crops in the rotation due to lower residual soil N levels. B is an essential element which has received maximum attention over last 15 years. B deficiency symptoms appear especially on leaves, stems and reproductive parts. B application helps to increase the dry matter accumulation in roots, shoots and leaves.It is also often observed to bedeficit in soils causing yield reduction in soybean. Deficiencies typically resultfrom B leaching in humid areas with coarse-textured soils (Welch *et al.*, 1991; Mortvedt and Woodruff, 1993; Marschner, 1995).Further, there is synergistic interaction between sulphur and boron on the growth and yield of soybean. Keeping theses points in view, the present investigation was carried out to study the effect of levels of sulphur and boron individually and in combination on the performance of soybean.

MATERIALS AND METHODS

The experiment was conducted during *kharif* 2007-2008 at theResearch Farm of the Division of Agronomy, Indian Agricultural Research Institute and New Delhi. The field was well leveled and soil was sandy loam in texture and slightly alkaline (pH 7.6) in reaction.The treatments consisted of 5 levels of sulphur viz. 0, 10, 20, 30 and 40 kg S/ha and 4 levels of boron viz. 0, 0.5. 1.0 and 1.5 kg B/ha. Sulphur was applied in the form of gypsum while boron was applied in the form of borax. The 20 treatment combinations were tried in factorial randomized block design (FRBD) replicated thrice. Besides giving the different treatments of sulphur and boron at the time of sowing, fertilization of the crop was done @ 25 kg N/ha, 60 kg P_2O_5/ha and 40 kg K_2O /ha, all as basal application.The soil of the experimental field was medium in available nitrogen (262 kg/ha), phosphorus (14.3 kg/ha) and potassium (222.4 kg/ha) and low to medium in available sulphur (10.8 mg/kg) and boron (0.30 mg/kg). The available N, P, K, S and B were analyzed by following procedures of Subbiah and Asija (1956), Olsen *et al.* (1954), Stanford and English (1956),barium sulphateturbidimetry method of Prasad *et al.*, (2006)and azomethine-H method of Prasad *et al.* (2006), respectively. The crop was raised with recommended package of practices except for treatments. The experimental data pertaining to each character were subjected to statistical analysis by using the technique of analysis of variance (ANOVA) and their significance was tested by "F" test (Cochran and Cox, 1957).

RESULTS

Growth and physiological attributes

The plant height of soybean showed differential response to application of sulphur and boron (Table 1). Application of sulphur upto 40 kg/ha recorded the highest plant height at harvest but, it was at par with the application of sulphur upto 30 kg S/ha. The application of boron at the 1.5 kg B/ha at harvest showed the highest plant height. However both 1.0 and 1.5 kg B/ha were at par with each other. There were significant interaction effects among different levels of sulphur and boron at harvest. The combination of 40 kg S and 0.5 kg B recorded the highest plant height and it was followed by the combination of 20 kg S and 1.5 kg B.Number of branches/plant were maximum with 30 kg S at harvest being at par with 40 kg S/ha. Among the boron levels, the number of branches were higher at 1.5 kg B/ha,however it was at par with 1.0 kg B/ha. There was not any significant interaction effect among levels of sulphur and boron at any of the stages of study on the branches/plant. Application of combination of 30 kg S and

Table 1: Growth and physiological attributesof soybean as influenced by sulphur and boron application

Treatments	Plant height at harvest (cm)	Number of branches/plant at harvest	Dry matter at harvest (g/plant)	Leaf are index (90 DAS)	CGR at 60-90 DAS(g/plant/day)
Levels of sulphur (kg/ha)					
0	55.64	2.86	33.45	2.12	0.26
10	57.41	3.04	34.41	2.38	0.28
20	57.54	3.05	35.24	2.59	0.29
30	57.62	3.10	36.66	2.85	0.37
40	58.01	3.07	35.55	2.89	0.38
SEm ±	0.23	0.05	0.60	0.05	0.02
LSD (p=0.05)	0.67	0.15	1.70	0.14	0.07
Levels of boron (kg/ha)					
0	56.71	2.89	32.21	2.34	0.26
0.5	57.05	2.97	35.11	2.47	0.32
1.0	57.23	3.11	36.37	2.70	0.37
1.5	58.00	3.12	36.55	2.75	0.32
SEm ±	0.21	0.05	0.53	0.04	0.02
LSD (p=0.05)	0.60	0.13	1.52	0.13	0.06
Interaction (S × B)	*	NS	NS	*	NS

*Significant at 5% level of significance

Table 2: Nodulation pattern in soybean as influenced by sulphur and boron nutrition

Treatments	No. of nodules /plant			Nodule dry weight (mg/plant)		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
Levels of sulphur(kg/ha)						
0	34.43	43.13	38.38	280.34	519.44	347.32
10	38.13	52.87	39.75	313.52	633.29	347.29
20	40.71	55.71	39.54	334.59	670.11	346.35
30	42.42	54.65	38.75	347.86	669.25	343.58
40	40.54	54.15	39.08	333.57	676.04	343.11
SEm ±	0.55	0.80	0.47	4.42	8.71	5.79
LSD (p=0.05)	1.56	2.29	NS	12.64	24.95	NS
Levels of boron (kg/ha)						
0	36.53	47.26	38.33	300.90	567.07	347.34
0.5	38.85	52.35	39.07	319.98	625.67	338.79
1.0	40.57	54.20	39.30	330.05	670.76	346.46
1.5	41.03	54.60	39.70	336.98	671.00	349.54
SEm ±	0.49	0.72	0.42	3.95	7.79	5.17
LSD (p=0.05)	1.40	2.05	NS	11.30	22.31	NS
Interaction (S×B)	NS	*	NS	NS	*	NS

*Significant at 5% level of significance

Table 3: Yield attributes and yields of soybean as influenced by sulphurand boron nutrition

Treatments	Pods/plant	Seeds/pod	Pod yield (g/plant)	Seed yield (g/plant)	Seed index (g/100ssed)	Soybean yield(t/ha)	HI (%)
Levels of sulphur(kg/ha)							
0	65.33	2.01	6.93	4.87	9.58	1.54	32.08
10	67.58	2.22	7.30	5.18	9.54	1.61	32.95
20	69.08	2.33	8.13	5.76	9.55	1.66	34.09
30	72.00	2.49	8.52	6.08	9.99	1.73	34.81
40	71.92	2.51	8.63	6.06	9.83	1.72	34.48
SEm ±	0.42	0.07	0.10	0.08	0.08	0.16	0.34
LSD (p=0.05)	1.20	0.21	0.30	0.22	0.23	0.46	0.98
Levels of boron (kg/ha)							
0	67.00	2.03	7.00	4.96	9.50	1.51	32.78
0.5	69.53	2.31	7.59	5.39	9.68	1.64	33.37
1.0	70.47	2.52	8.49	6.04	9.79	1.75	34.33
1.5	69.73	2.39	8.52	5.96	9.83	1.71	34.24
SEm ±	0.38	0.07	0.09	0.07	0.07	0.14	0.31
LSD (p=0.05)	1.08	0.19	0.27	0.20	0.21	0.42	0.88
Interaction (S×B)	*	*	*	*	NS	*	NS

*Significant at 5% level of significance

1.0 kg B recorded the highest dry matter accumulation while the lowest dry matter accumulation was observed in the control treatment.The application of sulphur at the rate of 30 kg/ha recorded significantly higher leaf area index and it was at par with 40 kg S/ha.Among the levels of boron, 1.5 kg and 1.0 kg/ha being at par with each other recorded significantly higher leaf area index as compared to the rest of the levels of boron.At 60-90 DAS, application of 30 and 40 kg S/ha being at par recorded significantly higher CGR as compared to other levels. However there was not significant interaction effect among the levels of sulphur and boron on CGR.

Nodulation pattern in soybean

The number of nodules and nodule dry weight at 30 and 45 DAS recorded significant increase upto 20 kg S/ha and thereafter all the higher levels were at par with each other (Table 2). However at 60 DAS, all the treatments recorded number of nodules and nodule dry weight at par with each other. Among the levels of boron, application of boron upto 1.0 kg/ha recorded significantly higher number of nodules and nodule dry weight at 30 and 45 DAS and it was at par with 1.5 kg B/ha. At 60 DAS, there was significant impact of boron levels on these attributes.

Yield attributes and yield of soybean

All the yield attributes viz. pods/plant, seeds/pod, pod yield per plant, seed yield per plant and seed index were significantly affected by the levels of sulphur and boron (Table 3). All of these attributes recorded to be highest with 30 kg S/ha and 1.0 kg B/ha being at par with 40 kgS/ha and 1.5 kg B/ha respectively. The highest seed yield of soybean was recorded with the application of sulphurupto 30 kg /ha and it being at par with 40 kg S/ha was significantly superior to rest of the levels of sulphur. The application of sulphur increased seed yield by 4.8, 7.5, 12.5 and 11.5% with 10, 20, 30 and 40 kg S/ha, respectively over control. Among the boron levels, the highest seed yield was observed with 1.0 kg B/ha. It was closely followed by application of 1.5 kg B/ha. The levels of boron increased the seed yield of soybean by 8.0, 15.1 and 13.0 % with 0.5, 1.0 and 1.5 kg B/ha, respectively as compared to

Table 4: Seed yield (t/ha) in soybean as influenced by interaction effect of sulphur and boron nutrition

Treatments	Levels of S (kg/ha)					
Levels of B (kg/ha)	0	10	20	30	40	Mean
0	1.46	1.50	1.53	1.54	1.53	1.51
0.5	1.54	1.59	1.68	1.70	1.67	1.64
1.0	1.60	1.68	1.73	1.88	1.84	1.75
1.5	1.56	1.68	1.68	1.81	1.83	1.71
Mean	1.54	1.61	1.66	1.73	1.72	
SEm ±			0.03			
LSD(p=0.05)			0.09			

control. The combined application of 30 kg S/ha along with 1.0 kg B/ha recorded the highest seed yield (Table 4). The harvest index was significant increased upto 20 kg S/ha over the lower levels. Further increase in the levels of sulphurupto 30 and 40 kg S/ha recorded harvest index at par with 20 kg S/ha. Application of 1.0 and 1.5 kg B/ha being at par with each other recorded significantly higher harvest index over rest of the boron treatments. Harvest index was not influenced by the interaction effect between levels of sulphur and boron.

DISCUSSION

Sulphur and boron have varied roles to play in the growth and physiological process and act as precursor to many enzymatic activities leading to improved response to applied nutrients in the soil. The lower doses of sulphur and boron however were not conspicuous owing to smaller quantity leading inadequate supply to meet the crop requirement. Similar observations have been reported by Prasad *et al.* (1991), Gupta *et al.* (2003), Tomar *et al.* (2004) and Mohanti *et al.* (2004). Chandel *et al.* (1989) reported that boron fertilization has role in increasing the no of branches. The *Rhizobium* activity also gets boosted with the application of these nutrients. Since the nutrient need to be in optimum dose and in proportion, the above said levels of sulphur and boron showed greater response as compared to their lower levels (Table 2). Sharma *et al.* (2004) and Vijayapriya *et al.* (2005) too reported improved nodulation due to sulphur application. The positive effect of boron on root nodulation was reported by Rahman *et al.* (1999).

All the yield attributes and yield were significantly affected by the levels of sulphur and boron (Table 3). The response was restricted upto 30 kg S and 1.0 kg B. The response to applied sulphur and boron may be explained by the fact that both sulphur and boron are actively involved in many of the metabolic activities of the plants (Ram, *et al.*, 2014). The sulphur is a constituent of many amino acids and results in increased protein content, thus it helps in improving seed quality, in the presence of ample quantity of sulphur, the plant tends to put up more yield attributes. Further, once the availability of sulphur reaches a certain point, response will not increase beyond that point. Thus 30 kg S/ha was observed to be a point of optima for soybean in this experiment. These observations are in agreement with the findings of Parkasha *et al.* (2010). Likewise the boron is an important nutrient involved in the physiological processes of reproductive organs like stigma receptivity, pollen viability etc. which are very vital for the successful flowering, pollination and fertilization. Thus the increased availability through boron application increased most of the yield attributing characters (Ross *et al.,* 2006). Further the interaction effect between sulphur and boron recorded significant impact on all the yield attributes except seed index. Here the application of 30 kg S and 1.0 kg B/ hashowedthe highest values of these attributes at par with other combinations of higher levels of both the nutrients indicating that this was the optimum combination. The synergistic effect between sulphur and boron may be the reason for enhancing yield attributes by the combined application of these nutrients.It may be concluded that there is a need for application of sulphur and boron for better growth, nodulation and yield of soybean. And a combination of 30 kg S and 1.0 kg B/ha could be sufficient for realizing higher yield from the *kharif*soybean in the agro-climatic conditions of the Northern Plain Zone of the country.

ACKNOWLEDGEMENT

The authors are thankful to Indian Agricultural Research Institute, New Delhi for providing necessary facilities and financial support to carry out the research.

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