Growth and yield of soybean (*Glycine max* L.) as influenced by the application of sulphur and molybdenum

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Abstract: An experiment was conducted at Bangladesh Agricultural University Farm, Mymensingh to study the growth and yield of soybean cv. Shohag in relation to different levels of added sulphur (0, 6, 12 and 18 kg S ha^{-1}) and molybdenum (0, 1, 2 and 3 kg Mo ha^{-1}). The results indicated that single and combined effect of different levels of sulphur and molybdenum had significant effect on growth and yield of soybean. Biological yield attributes viz., leaf area, leaf chlorophyll and total sugar content of soybean leaf were also significantly affected by the application of different levels of sulphur and molybdenum. The highest number of effective pod $plant^{-1}$(40.42), pod length (3.85 cm), grain and stover yield (1825 and 2883 kg ha^{-1} respectively) and harvest index (39.60%) were found by the application of 12 kg S ha^{-1}. The maximum number of effective pod $plant^{-1}$ (39.67), grain and stover yield (1773 and 2767 kg ha^{-1} respectively) and harvest index (39.05%) were obtained by the application of 2 kg Mo ha^{-1} and the lowest from the control. However, it was evident from the present study that different growth parameters and yield of soybean were also influenced by sulphur and molybdenum interactions.

Key words: Soybean, growth, yield, sulphur and molybdenum.

Introduction

Soybean (*Glycine max* L.) is an important legume crop. This crop is extensively cultivated in many countries of the world including Bangladesh because it has exceptionally high protein content (around 60%), cholesterol free oil and it has versatile uses as pulses, soya flour and soya milk. But several survey reports revealed that its cultivation is greatly hampered due to nutritional deficiency. In addition to N, P and K deficiencies, some other nutrients such as S, Zn, B and Mo deficiencies are being observed in many parts of the country (Jahiruddin *et al.,* 1995). Among these, sulphur induces chlorophyll concentration in leaf, grain yield and protein content in soybean (Chatterjee *et al.,* 1992 and Sharma *et al*., 2002). It influenced leaf area (Ganeshamurthy and Reddy, 2000) and reducing, non-reducing and total sugar content of soybean leaf (Kumar *et al.,* 1981). However, it plays a significant role in chlorophyll content, seed formation, oil and protein contents of soybean. Recently, the use of trace elements including Mo in various crops are well established in Bangladesh which is also required for different yield attributing characters and nitrogen metabolism of soybean. It is needed by nodule bacteria in the process of nitrogen fixation from the atmosphere and its deficiency symptoms appear pale green color in developing leaves resulted in decreased growth, yield and quality of soybean (Boswell, 2000). There is a lack of sufficient information on the effect of S and Mo for successful cultivation of soybean under Bangladesh condition. Keeping these points

in view, the present study was conducted to investigate the effect of sulphur and molybdenum on growth, yield and yield attributes of soybean.

Materials and Methods

The study was conducted at the Farm of Bangladesh Agricultural University, Mymensingh during December, 2002 to April, 2003. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications comprised of four levels of sulphur viz., 0, 6, 12 and 18 kg S ha^{-1} from gypsum and four levels of molybdenum viz., 0, 1, 2 and 3 kg Mo ha^{-1} from ammonium molybdate. The test crop soybean (*Glycine max* L.) cv. *Shohag* was also fertilized with TSP and MOP at the rates of 160 kg P_2O_5 and 110 kg K_2O ha^{-1}, respectively during final land preparation. The seeds of soybean were treated with biofertilizer (*Rhizobium japonicum*) before sowing at the rate of 30 g inoculum kg^{-1} seeds. Recommended cultural practices were done for the normal growth and development of plants. Data on leaf area at three different growth stages, leaf chlorophyll and total sugar content were determined by Delta-T-programme, Yoshida method (Yoshida *et al.,* 1976) and phenol-H_2SO_4 method (Dubois *et al.,* 1951), respectively. At the same time, data on different growth parameters such as branch $plant^{-1}$, pod length, effective pod $plant^{-1}$, seed $plant^{-1}$, 100-seed weight, grain and stover yield and harvest index were recorded followed by standard methods and the mean values were analyzed for statistical interpretation.

Results and Discussion

Results obtained from the study showed that sulphur and molybdenum alone or combined had significant positive effect on leaf area of soybean at three growth stages viz., 45, 60 and 75 days after sowing (DAS). The highest leaf areas were found by the application of 12 kg S and 3 kg Mo ha^{-1} and the lowest was in control at three growth stages (Table 1). The results were in concurrence with the findings of Hemantaranjan and Trivedi (1997), Ganeshamurthy and Reddy (2000) and Boswell (2000). They also reported that sulphur and molybdenum application increased leaf area at all the stages that might due to the cumulative favourable effect of sulphur and molybdenum on soybean plant.

Data presented in Table 1 showed that the conents of chlorophyll in leaf were significantly influenced by the application of sulphur and molybdenum. The highest chlorophyll ‘a’ (2.18 and 2.06 mg g^{-1}) were obtained by the treatments of 18 kg S and 1 kg Mo ha^{-1}, respectively whereas the maximum amount of chlorophyll ‘b’ (0.586 and 0.614 mg g^{-1}) were recorded with 12 kg S and 2 kg Mo ha^{-1}, respectively. From the results, it is apparent that the application of sulphur and molybdenum increased leaf chlorophyll content up to certain limit and then decreased with increasing levels of sulphur and molybdenum with one exception. Millar (1955) and Tabatabai (1986) observed that sulphur deficiency caused yellowish of the leaves due to diminished levels

of chlorophyll. Similar results were also reported by Reid and York (1958), Braud (1970) and Smith and Connell (2001). Dwivedi *et al. (*1997) showed that 80 kg P_2O_5 and 1 kg Mo ha^{-1} gave the highest chlorophyll contents during the flowering and pod filling stages. However, results in Table 2 revealed that interaction effect of sulphur and molybdenum on chlorophyll 'a' content was significant but chlorophyll 'b' content was insignificant.

The total sugar content in soybean leaf was significantly influenced by the application of different levels of sulphur and molybdenum (Table 1). The highest amounts of total sugar (4.92 and 4.79 mg g^{-1}) were obtained from the treatments of 12 kg S and 2 kg Mo ha^{-1}, respectively. Badruddin (1999) reported that sulphur deficiency resulted in decreased the accumulation of total sugar in chickpea leaf. Kumar *et al*. (1981) studied the effect of sulphur, phosphate and molybdenum on sugar content and reported that these nutrients increased reducing, non-reducing and total sugar contents of soybean leaf. Among the treatment combinations of sulphur and molybdenum, the combination of $S_{12}Mo_2$ gave the highest (4.93 mg g^{-1}) amount of total sugar and the lowest (2.49 mg g^{-1}) was obtained from the control (Table 2).

Response of soybean to sulphur levels showed that branch $plant^{-1}$, effective pod $plant^{-1}$, pod length, seed $plant^{-1}$, 100-seed weight, grain and stover yield and harvest index were significantly influenced by different levels of sulphur (Table 3). The maximum number of branches $plant^{-1}$ (4.81), number of seeds $plant^{-1}$ (92.2) and 100-seed weight (13.35 g) were recorded from the treatment 18 kg S ha^{-1} and the lowest from the control. Similar results were observed by Rathore and Manohar (1989) and Dubey *et al*. (1997) on the number of branches $plant^{-1}$ of mustard and linseed, respectively. The results on seed $plant^{-1}$ and 100-seed weight corroborated the findings of Ghosh *et al.* (1997) and Sharma and Singh (1997), respectively. The highest number of effective pod (40.42), pod length (3.85 cm), grain and stover yield (1825 and 2883 kg ha^{-1} respectively) and harvest index (39.60 %) were found by the application of 12 kg S ha^{-1} (Table 3). Similar observations were also been reported by Rao and Gangasaran (1991), Hemantaranjan and Trivedi (1997), Chaubey *et al.* (2000) and Babhulker *et al.* (2000).

Different levels of molybdenum significantly influenced pod length, seeds $plant^{-1}$, 100-seed weight and grain and stover yield but branch $plant^{-1}$, effective pod $plant^{-1}$ and harvest index were insignificant (Table 3). The highest number of effective pod $plant^{-1}$ (39.67), grain and stover yields (1773 and 2767 kg ha^{-1} respectively) and harvest index (39.05%) were obtained by the application of 2 kg Mo ha^{-1} and the lowest from the control. On the other hand, the maximum number of branch $plant^{-1}$ (3.94) and pod length (3.90 cm) were produced by the application of 1 kg Mo ha^{-1}. Hugar and Kurdikeri (2002) noted that molybdenum application increased the number of effective pod $plant^{-1}$ and number of seeds $plant^{-1}$. Lee *et al.* (2000) reported that application of molybdenum resulted higher pod length. Similar findings on grain and stover yields

were also observed by Sharma and Minhas (1986) and Dwivedi *et al.* (1990).

The interaction effect of sulphur and molybdenum failed to show any significant effects on branch plant^{-1}, effective pod plant^{-1}, pod length and harvest index but showed significant influence on number of seeds plant^{-1}, 100-seed weight and grain and stover yield of soybean (Table 4). Among the interactions of sulphur and molybdenum, the combination of $S_{12}Mo_2$ gave the highest number of effective pod plant^{-1} (44.0), 100-seed weight (14.23 g) and grain and stover yield (2022 and 2903 kg ha^{-1}, respectively). From the present study, it was evident that different growth parameters and yield of soybean were indeed influenced by sulphur and molybdenum interaction.

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Table 1: Effect of sulphur and molybdenum on leaf area at different growth stages, leaf chlorophyll and total sugar content of soybean leaf cv. *Shohag*

Treatments	Leaf area (cm^2 $plant^{-1}$)			Chlorophyll content at 85 DAS (mg g^{-1})		Total sugar content at 90 DAS (mg g^{-1})
	45 DAS	60 DAS	75 DAS	Chlorophyll 'a'	Chlorophyll 'b'	
S_0	63.58b	105.34d	167.74c	1.71c	0.435c	3.32c
S_6	70.77c	163.11c	213.68b	1.98b	0.579ab	3.82b
S_{12}	84.15a	192.65a	226.72a	2.14ab	0.586a	4.93a
S_{18}	77.27b	184.74b	217.99b	2.18a	0.543b	4.36ab
CV (%)	3.15	3.43	3.13	6.60	8.44	7.16
Level of significance	**	**	**	**	**	**
Mo_0	68.78c	151.52c	198.37c	1.89b	0.430c	3.48c
Mo_1	70.87b	159.89b	204.94b	2.07a	0.546b	4.71b
Mo_2	72.82a	166.02a	210.93a	2.01ab	0.614a	4.79a
Mo_3	73.29a	168.43a	211.90a	1.95b	0.553b	3.86bc
CV (%)	3.15	3.43	3.13	6.68	8.44	7.16
Level of significance	**	**	*	*	**	**

* = Significant at 5% level
** = Significant at 1% level

Table 2: Interaction effect of sulphur and molybdenum on leaf area at different growth stages, leaf chlorophyll and total sugar content of soybean leaf cv. *Shohag*

Treatments	Leaf area (cm^2 $plant^{-1}$)			Chlorophyll content at 85 DAS (mg g^{-1})		Total sugar content at 90 DAS (mg g^{-1})
	45 DAS	60 DAS	75 DAS	Chlorophyll 'a'	Chlorophyll 'b'	
S_0Mo_0	48.99i	79.46k	150.45f	1.33e	0.328	2.49g
S_0Mo_1	50.91i	100.28j	163.51e	1.56d	0.493	3.37fg
S_0Mo_2	56.19h	113.90i	173.41de	1.71cd	0.504	3.51efg
S_0Mo_3	58.25h	127.74h	183.60d	2.24a	0.514	3.55efg
S_6Mo_0	64.35g	146.22g	203.54c	1.85d	0.485	3.69def
S_6Mo_1	70.96e	160.71f	214.60bc	2.25a	0.630	3.75def
S_6Mo_2	72.96ef	168.59ef	217.51b	2.29a	0.651	3.87cdef
S_6Mo_3	75.50de	176.94de	219.07b	1.95bc	0.551	3.97cde
$S_{12}Mo_0$	80.26c	187.05abcd	221.45b	2.15ab	0.558	4.30bc
$S_{12}Mo_1$	84.72ab	195.96a	225.63b	2.30a	0.435	4.67ab
$S_{12}Mo_2$	86.34a	197.22a	238.50a	2.25a	0.660	4.93a
$S_{12}Mo_3$	85.29ab	190.39abc	221.34b	1.58c	0.620	4.90ab
$S_{18}Mo_0$	81.52bc	193.34ab	218.04b	2.25a	0.450	3.09gd
$S_{18}Mo_1$	77.60cd	182.62cd	216.02b	2.15ab	0.565	3.07gh
$S_{18}Mo_2$	75.81de	184.37bcd	214.30bc	1.76cd	0.625	3.47gh
$S_{18}Mo_3$	74.15def	178.65d	223.60b	1.75cd	0.525	3.83cdef
CV (%)	3.15	3.43	3.13	6.68	8.44	7.16
Level of significance	**	**	**	**	NS	**

** = Significant at 1% level; NS= Not significant

Table 3: Effect of sulphur and molybdenumon growth, yield and yield attributes of soybean cv. *Shohag*

Treatments	Branch plant^{-1} (No.)	Pod length (cm)	Effective pod plant^{-1} (No.)	Seeds plant^{-1} (No.)	100 seed weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Shell yield (kg ha^{-1})	Harvest index (%)
S_0	3.73c	3.66c	35.75c	86.5c	9.81c	1581d	2512c	279.8c	37.32b
S_6	3.89c	3.78a	40.00a	89.9b	11.40b	1629c	2733b	359.2b	37.34b
S_{12}	4.25b	3.85a	40.42a	91.6a	13.12a	1825a	2883a	419.1a	39.60a
S_{18}	4.81a	3.77b	38.50b	92.2a	13.35a	1726b	2724b	353.7b	38.78a
CV %	8.7	6.08	10.51	3.3	5.15	56.00	45.5	5.53	2.84
Level of significance	**	*	*	*	**	**	**	**	**
Mo_0	3.66	3.65b	38.33	82.7c	10.92b	1575c	2581c	335.8c	37.78
Mo_1	3.94	3.90a	39.58	87.0b	11.47a	1625b	2634b	336.6c	38.15
Mo_2	3.89	3.85a	39.67	93.7a	11.49a	1773a	2767a	383.8a	39.05
Mo_3	3.73	3.88a	39.08	94.1a	12.24a	1630b	2633b	355.6b	38.23
CV %	8.70	6.08	10.51	3.3	5.15	56.0	45.5	5.53	2.84
Level of significance	NS	*	NS	*	*	**	**	**	NS

* = Significant at 5% level; ** = Significant at 1% level; NS= Not significant

Table 4: Interaction effect of sulphur and molybdenum on growth, yield and yield attributes of soybean cv. *Shoahg*

Treatments	Branch plant^{-1} (No.)	Pod length (cm)	Effective pod plant^{-1} (No.)	Seed plant^{-1} (No.)	100 seed weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Shell yield (kg ha^{-1})	Harvest index (%)
S_0Mo_0	3.00	3.50	35.00	79.3g	8.94g	1560e	2527e	258.2g	38.19
S_0Mo_1	3.30	3.69	36.33	83.0cf	9.02g	1694de	2534e	343.6ef	44.06
S_0Mo_2	3.40	3.71	36.00	85.9d	11.95cd	1778cd	2556de	258.2g	41.02
S_0Mo_3	3.40	3.66	36.67	83.3c	9.34g	1699de	2655d	259.2g	39.02
S_6Mo_0	3.56	3.70	37.67	81.2f	10.76ef	1784cd	2714c	381.6cd	39.66
S_6Mo_1	4.20	3.59	38.33	84.5de	10.90def	1790cd	2739c	364.7de	39.52
S_6Mo_2	4.20	3.81	39.33	87.3cd	11.79cde	1874c	2696cd	369.6de	41.00
S_6Mo_3	3.60	3.84	40.67	89.5bc	12.41bc	1879c	2720c	383.9c	40.85
$S_{12}Mo_0$	4.10	3.64	40.00	86.1cd	12.15c	1956b	2756bc	419.5ab	41.51
$S_{12}Mo_1$	4.33	3.98	43.00	88.1c	13.28ab	1967b	2825b	457.1a	41.04
$S_{12}Mo_2$	4.36	3.97	44.00	91.4a	14.23a	2022a	2903a	447.6ab	41.05
$S_{12}Mo_3$	4.50	3.87	42.67	90.1b	12.57c	1996ab	2818b	382.5cd	41.46
$S_{18}Mo_0$	4.00	3.91	40.67	91.0b	10.74ef	1889bc	2810b	346.8ef	40.20
$S_{18}Mo_1$	3.93	3.69	39.67	91.2b	10.46f	1876c	2714c	399.9bc	40.87
$S_{18}Mo_2$	3.60	3.96	35.67	92.5a	10.99def	1963b	2734c	347.3def	41.79
$S_{18}Mo_3$	3.73	3.94	38.67	91.3a	10.88def	1875c	2688cd	320.8f	41.09
CV %	8.70	6.08	10.51	3.3	5.15	56.00	45.5	5.35	2.84
Level of significance	NS	NS	NS	*	**	**	**	**	NS

* = Significant at 5% level; ** = Significant at 1% level; NS= Not significant