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Effect of sulphur on yield, nutrient concentration and sulphur use efficiency of mulberry

P. C. BOSE, R. KAR AND S. K. MAJUMDER

Soil Science and Chemistry Section
CSR & TI, Berhampore – 742101, West Bengal

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Mulberry (*Morus alba* L.), a perennial deep rooted foliage plant, is cultivated in approximately 1.85 lakh ha area in India as sole feed for mulberry silkworm (*Bombyx mori* L.) to produce cocoons or silk. Once planted, mulberry continues to give economic yield for ten years and more, the most important component in the sericulture economy. Mulberry acquires energy and chemical elements from the external environments for growth, development and productivity. Silkworms get their nutrition from the nutrients acquired by mulberry plants from soil. Though the effect of phosphorus and potassium on growth and development of mulberry was studied earlier in detail (Bose *et al.*, 2009 a, b) but inspite of deficiency of sulphur in 41 percent soils of India (Bose and Kar, 2007), it has not yet been included as a standard practice in the fertilization programme for mulberry. Leaf yield in mulberry is adversely affected if the sulphur removed from soil is not replenished (Bose *et al.*, 1992). The decrease in leaf yield since the last few years is observed due to sulphur deficiency from intensive sericulture, by the cultivation of high yielding mulberry varieties and use of sulphur free high analysis inorganic fertilizers. The present research programme was, therefore, undertaken to study the effect of sulphur, particularly in deficient soil, on yield, quality, percent yield response, sulphur use efficiency and apparent sulphur utilization of mulberry.

The field experiment with mulberry, (cv. S_{1635}) was conducted at Central Sericultural Research and Training Institute, Berhampore, West Bengal, India under irrigated condition on a sandy clay loam soil having pH of 8.27, EC of 0.15 dS m^{-1}, organic carbon content 5.13 g kg^{-1}, available nitrogen 177 kg ha^{-1}, available phosphorus 35 kg ha^{-1}, available potassium 352 kg ha^{-1} and available sulphur 19 kg ha^{-1}. The experiment was laid out a Randomizee Complete Block design with three replications. Mulberry planting was done with a 60 cm x 60 cm spacing. The treatments included three levels of S (20, 30 and 40 kg ha^{-1} $year^{-1}$ in five equal splits) through two sources (elemental sulphur and ammonium sulphate). All the treatments including the control received recommended doses of N, P_2O_5 and K_2O @ 336:180:112 kg ha^{-1} $year^{-1}$, applied in five equal splits along with 20 mt FYM ha^{-1} $year^{-1}$. Five harvests were taken in a year and the plantation was pruned at a height of 15 cm every time. Mulberry leaf and shoot yields were recorded. Standard methods were followed for the estimation of nitrogen, phosphorus, potassium and sulphur contents of plant samples (Piper, 1966). Percent yield response, sulphur use efficiency, apparent sulphur utilization and relative yield of mulberry were computed as follows.

Percent yield response = {(treatment yield – control yield)/ control yield} x 100

Sulphur use efficiency = (treatment yield – control yield)/ sulphur applied

Apparent sulphur utilization = {(treatment sulphur uptake - control sulphur uptake)/ sulphur applied} x 100

Relative yield = (control yield/ treatment yield) x 100

Application of 20 to 40 kg sulphur ha^{-1} $year^{-1}$ through either of the two sources resulted in increase in leaf, shoot and biomass yield as compared to control. The highest yields of these parameters were associated with application of 40 kg ammonium sulphate.

The increase in yield of mulberry may be attributed to the involvement of sulphur in the formation of chlorophyll, activation of enzymes, protein synthesis, meristemaric activity etc (Jat *et al.*, 2008; Tandon, 1995). Moreover, the improved nutritional environment as a result of increased sulphur supply might have favourably influenced the carbohydrate metabolism. The increase in leaf yield was due to increase in the photosynthetic activities resulting in the accumulation of higher amount of carbohydrates in the vegetative parts of the plant ultimately increasing the leaf and shoot yield. The results are in agreement with the findings of Bansal *et al.* (2000).

Application of S through both the sources exerted significant positive influence on the nitrogen, phosphorus, potassium and sulphur content of mulberry leaf and shoot (Table 2, 3).

Short communication

Email : csrtiber@rediffmail.com

The increase in N, P, K and S content of leaves and shoots might have been due to the influence of sulphur on physical, chemical and biological properties of soil resulting in the change like significant drop in soil pH from 8.27 to 7.42 at 40 kg sulphur ha^{-1} $year^{-1}$ as ammonium sulphate. Due to drop in pH, there was an increased availability of native nutrients (Swarup, 1981).

The N:S and P:S ratios in mulberry leaf varied from 29.06 to 31.70 and 3.25 to 3.43, respectively and while the N:S and P:S ratios in mulberry shoot varied from 18.23 to 20.22 and 3.68 to 3.87, respectively under graded doses of S. A synergistic interaction coupled with a higher or preferential N and P uptake may be responsible for a gradual increase in these ratios (Tables 2, 3). The K:S ratio in mulberry leaf varied from 15.94 to 16.80 and while the ratio in shoot varied from 21.30 to 23.79 at various doses of K.

Sulphur application showed synergistic effect on N content in rice and on N, P and K contents in wheat (Anonymous, 1997). Results further indicated the existence of synergistic effect of S on N and K in maize and chickpea crops (Anonymous, 1997 and Singh *et al.*, 2008). These results corroborate the present findings.

Various sulphur use efficiency parameters, *viz.* apparent utilization (recovery), agronomic efficiency, percent yield response and relative yield are presented in table 4 and 5. Application of S as ammonium sulphate has improved all the above parameters. The maximum improvement of apparent utilization, agronomic efficiency and relative yield of sulphur was observed with the application of 20 kg S ha^{-1} $year^{-1}$ whereas 40 kg S ha^{-1} $year^{-1}$ has been found to increase the percent yield response of mulberry to the maximum extent.

Table 1: Effect of sulphur on the yield of mulberry

Levels of sulphur (kg ha^{-1} $year^{-1}$)	Leaf yield (t ha^{-1} $year^{-1}$)	Shoot yield (t ha^{-1} $year^{-1}$)	Biomass yield (t ha^{-1} $year^{-1}$)
0	32.36	22.66	55.02
20 (ES)	34.30	24.25	58.55
30 (ES)	35.14	25.19	60.33
40(ES)	35.94	25.95	61.89
20 (AS)	34.71	24.74	59.45
30(AS)	35.73	25.46	61.19
40(AS)	36.34	26.70	63.04
LSD(0.05)	**0.67**	**0.52**	**1.33**

ES = Elemental sulphur AS = Ammonium sulphate

Table 2: Effect of sulphur on nutrient content and their ratios in leaf

Levels of sulphur (kg ha^{-1} $year^{-1}$)	Nutrient concentration (%)				Nutrient ratios		
	N	P	K	S	N:S	P:S	K:S
0	3.22	0.36	1.82	0.1108	29.06	3.25	16.42
20 (ES)	3.35	0.38	1.90	0.1131	29.62	3.36	16.80
30 (ES)	3.56	0.38	1.92	0.1164	30.58	3.26	16.49
40(ES)	3.58	0.40	1.92	0.1166	30.70	3.43	16.46
20 (AS)	3.37	0.39	1.83	0.1148	29.35	3.40	15.94
30(AS)	3.70	0.39	1.87	0.1167	31.70	3.34	16.02
40(AS)	3.71	0.40	1.92	0.1182	31.39	3.38	16.24
LSD(0.05)	**0.09**	**0.01**	**0.05**	**0.0028**	--	--	--

Table 3: Effect of sulphur on nutrient content and their ratios in shoot

Levels of sulphur (kg ha^{-1} $year^{-1}$)	Nutrient concentration (%)				Nutrient ratios		
	N	P	K	S	N:S	P:S	K:S
0	0.93	0.19	1.19	0.0506	18.38	3.75	23.52
20 (ES)	0.93	0.19	1.21	0.0510	18.23	3.72	23.72
30 (ES)	0.95	0.20	1.23	0.0519	18.30	3.85	23.70
40(ES)	1.04	0.21	1.28	0.0568	18.30	3.70	22.53
20 (AS)	0.95	0.20	1.23	0.0517	18.37	3.87	23.79
30(AS)	1.10	0.20	1.27	0.0544	20.22	3.68	23.34
40(AS)	1.16	0.23	1.28	0.0601	19.30	3.83	21.30
LSD(0.05)	**0.05**	**0.01**	**0.04**	**0.0018**	---	---	---

Table 4: Effect of sulphur on apparent recovery and agronomic efficiency of mulberry

Levels of sulphur (kg ha^{-1} year^{-1})	Apparent sulphur utilization (%)			Agronomic efficiency (kg kg^{-1} S)		
	Leaf	Shoot	Biomass	Leaf	Shoot	Biomass
0	--	--	--	--	--	--
20 (ES)	5.00	1.05	6.05	97.00	79.50	176.50
30 (ES)	4.10	1.00	5.10	92.67	84.33	177.00
40(ES)	3.07	0.95	4.02	89.50	82.25	171.75
20 (AS)	5.90	1.20	7.10	117.50	104.00	221.50
30(AS)	5.70	1.80	7.50	112.33	93.33	205.66
40(AS)	4.40	1.97	6.37	99.50	101.00	200.50

Table 5: Effect of sulphur on percent yield response and relative yield of mulberry

Levels of sulphur (kg ha^{-1} year^{-1})	Percent yield response			Relative yield (%)		
	Leaf	Shoot	Biomass	Leaf	Shoot	Biomass
0	--	--	--	--	--	--
20 (ES)	5.99	7.02	6.41	94.34	93.44	93.97
30 (ES)	8.59	11.16	9.65	92.09	89.96	91.20
40(ES)	11.06	14.52	12.48	90.04	87.32	88.90
20 (AS)	7.26	9.18	8.05	93.23	91.59	92.55
30(AS)	10.41	12.36	11.21	90.57	89.00	89.92
40(AS)	12.30	17.83	14.58	89.05	84.87	87.28

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