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Effect of long term application of nitrogen and sulphur nutrition on nitrogen assimilation in Soybean

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Abstract
Nitrogen and sulphur are assimilated primarily into protein and they occur in a molar ratio of about 20:1 in most plants. A product of nitrogen metabolism is considered to be a limiting factor for sulphate assimilation. Studies on the interaction of N and S release can yield useful information especially in oil seed crops. The ratio of total N to total S in the plant indicates the relative requirement of these nutrients. The central role of N and S in protein synthesis makes it necessary to visualize relation between N- and S-metabolism. The most important constraints to crop growth are those caused by the shortage of plant nutrients. Sulphur (S) requirement of plants has become increasingly importance in India as well as world agriculture. However, to achieve high yields and rates of S fertilizer should be recommended on the basis of available soil S and crop requirement.

Keywords: N and S metabolism, Protein and Oil content, N and S Interaction

Introduction
With the improvement of crop productivity through the adoption of high-yielding varieties and multiple cropping systems, fertilizer use has become more and more important to increase crops yield and quality. S is an essential plant nutrient for crop production. For oil crop producers, S fertilizer is especially important because oil crops require more S than cereal grains. For example, the amount of S required to produce one ton of seed is about 3-4 kg S for cereals (range 1-6); 8 kg S for legume crops (range 5-13); and 12 kg S for oil crops (range 5-20). In general, oil crops require about the same amount of S as, or more than, phosphorus for high yield and product quality. In intensive crop rotations including oil crops, S uptake can be very high, especially when the crop residue is removed from the field along with the product. This leads to considerable S depletion in soil if the corresponding amount of S is not applied through fertilizer. S is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. The importance of S in agriculture is being increasingly emphasized and its role in crop production is well recognized (Jamal *et al.*, 2005, 2006a; 2006b; 2006c; 2009; 2010; Scherer, 2009) [1, 2, 3, 4, 5, 6, 10, 11]. S is best known for its role in the formation of amino acids methionine (21% S) and cysteine (27% S); synthesis of proteins and chlorophyll; oil content of the seeds and nutritive quality of forages (Tandon, 1986; Jamal *et al.*, 2005, 2006a; 2009) [7, 1, 2, 5]. Although S is one of the essential nutrients for plant growth with crop requirement similar to phosphorus, this element received little attention for many years, because fertilizers and atmospheric inputs supplied the soil with adequate amounts of S. Now, areas of S deficiency are becoming widespread throughout the world due to the use of high-analysis low S fertilizers, low S returns with farmyard manure, high yielding varieties and intensive agriculture, declining use of S containing fungicides and reduced atmospheric input caused by stricter emission regulation. An insufficient S supply can affect yield and quality of the crops, caused by the S requirement for protein and enzyme synthesis as well it is a constituent of the amino acids, methionine and cysteine. To overcome the problems associated with S deficiency a number of S-containing fertilizers as well as other S containing by-products from industrial processes are available. The information on impact of S-fertilization and S in general has been reviewed and presented under the following heads: The function of S, Soil organic S, Soil inorganic S, S deficiency in soil, Sulphur and nitrogen interaction in soil, Sulphur and nitrogen interaction in plant, Sulphur and nitrogen interaction in relation to yield and quality of crop, Sulphur and nitrogen interaction in relation to uptake and assimilation of sulphur and nitrogen, N:S ratio in relation to sulphur and nitrogen interaction.

Material and Methods

The study was conducted in the All India Coordinated Research Project on Long Term Fertilizer Experiment [LTFE], Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. The experimental sites (23°10″ N latitude and 79°57″ E longitude) have a semi arid and sub-tropical climate with a characteristic feature of dry summer and cold winter. In winter season i.e. from November to February the temperature ranges from 8.9°C to 34.5°C and the relative humidity varies from 70% to 90%. Dry and warm weather usually persists during the month of March to June. The temperature may rise as high as 46^0C during these summer months. Monsoon season extends from mid June to mid September. The temperature during this period varies between 22°C and 38°C and the relative humidity ranges from 70 to 80%. The total annual rainfall varies from 1200 to 1500 mm. The soil of the experimental sites falls under Vertisol and belongs to Kheri-series of fine montmorillonite, Hyperthermic family of Typic Haplusterts popularly known as "medium black soil". At the inception of this experiment in 1972, pooled soil sample were drawn from the surface layers (0-20 cm) of the experimental field has pH (7.6), electrical conductivity (0.18), organic carbon (0.57%), available N (193.0 kg ha-1) available P (7.60 kg ha-1) and available K (370 kg ha-1) and available sulphur (17.47 kg ha-1). The treatments consist of T1-50% NPK, T2-100% NPK, T3-150% NPK, T4-100% NP, T5-100% N, T6-100% NPK + FYM, T7-100% NPK-S and T8-Control, and replicate with four times in randomized block design.

Experimental details

Design used	:	Randomized block design
Replication	:	04
Treatments	:	8
Plot size	:	17x10.8 m (183.6 m^2)
Space between replications	:	2m
Space between plots	:	1 m
Experimental area	:	146X58 m
Cropping sequence	:	Soybean-wheat

RDF soybean 20:80:20 kg ha^{-1} NPK

RDF Wheat 120:80:40 kg ha^{-1} NPK

Nutrient sources

i.	Nitrogen	Urea (46% N)
ii.	Phosphorus	Single superphosphate (16% P_2O_5) while, Di-ammonium – phosphate (46% P_2O_5) in T_7
iii.	Potassium	Muriate of potash (60% K_2O)

Table 1: Physico-chemical properties of soil (0-20 cm depth) at the start of the Long-Term Fertilizer Experiment (1972)

S. No.	Soil Properties	Unit	Value
1.	Mechanical composition		
	i. Sand	%	25.27
	ii. Silt	%	17.91
	iii. Clay	%	56.82
2	Textural class	-	Clay
3.	Bulk density	Mg m^{-3}	1.3
4.	Particle density	Mg m^{-3}	2.5
5.	Cation exchange capacity	C mol $(P^+)kg^{-1}$	49.0
6.	pH (1:2.5)	--	7.6
7.	Electrical conductivity (1:2.5)	dSm^{-1}	0.18
8.	Organic carbon	g kg^{-1}	5.70
9.	Calcium carbonate	%	4.60
10.	Available nitrogen	kg ha^{-1}	193.0
11.	Available phosphorus	kg ha^{-1}	7.60
12.	Available potassium	kg ha^{-1}	370.0
13.	Available sulphur	kg ha^{-1}	17.47
14.	Available zinc	mg kg^{-1}	0.33

Source: Annual report (2014) of AICRP on Long-Term Fertilizer Experiment, JNKVV, Jabalpur.

Result and Discussions

Effect of continuous addition of fertilizers and manure on Sulphur and nitrogen interaction in soil

Available N content in surface soil (0-20 cm) was 193.00 kg ha^{-1} when the experiment was started. The available N content values in soil as influenced by the continuous addition of fertilizers and manure are presented in Table 2. The result revealed that the available N content in soil increased successively and significantly from 217 to 275 kg ha^{-1} and 291 kg ha^{-1} as the doses of fertilizer increased from 50%, 100% and 150% NPK treatment respectively. The highest value of available N (310 kg ha^{-1}) was recorded in 100% NPK+FYM treatment. While, the lowest value of available N was observed in control (182 kg ha^{-1}). The available content of N in soil decreased with increasing depth irrespective of treatments and fertilizer application in soil.

The initial value of available sulphur content was 17.47 kg ha^{-1} when the experiment was started. Perusal of the data showed (Table 2) that the content of available sulphur was successively and significantly increased with the increasing in fertilizer doses from 50% NPK (24.17 kg ha^{-1}) to 100% NPK (34.98 kg ha^{-1}) and 150% NPK (39.30 kg ha^{-1}). Higher amount of available S found in T6 treatment (100% NPK + FYM (42.66 kg ha^{-1}). The content of available sulphur was found significantly higher in 100 % NPK (34.98 kg ha^{-1}) as comparatively to 100% NPK-S (15.94 kg ha^{-1}) whereas the content of available sulphur was found to be higher in 100% NP (30.82 kg ha^{-1}) as compared to 50% NPK (24.17 kg ha^{-1}). However, the highest and lowest content of available S was observed in 100% NPK + FYM (42.66 kg ha^{-1}) and control (13.95 kg ha^{-1}) respectively.

The maximum N:S ratio was observed with control and with application of N alone followed by 100% NPK without S and 50% NPK addition. However, due to addition of P in fertilizer schedule a significantly decline in proportion of N:S from 23.22 to 18.5 was marked with 100% NP. Further there was no significant variation was observed with addition of K (100% NPK). As regard to the successive addition of fertilizer from 50% NPK to 100% NPK to 150% NPK resulted in proportionate significant decline in the values of N:S from 22.2 to 18.6 and 15.1 respectively. A integrated application of organic manure noticed a significant reduction in the values of N: S ratio (14.7:1) over balanced application of fertilizer (18.6:1) i.e. 100% NPK.

An intensive agriculture with use of improved cultivars and high analysis fertilization offers conditions of nutrients exhaustion resulting in nutrient imbalance in soils. Fazili *et al.*, (2008) reported that lack of S limits the efficiency of added N, therefore, S addition becomes necessary to achieve maximum efficiency of applied nitrogenous fertilizer.

Sulphur and nitrogen interaction in relation to uptake and assimilation of sulphur and nitrogen

This regard lowest uptake of nutrient was found with control and N alone application. However, supplement of P with N (100% NP) was resulted in significantly higher nutrient uptake over 100% N alone while balance application of NPK had resulted in significantly higher amounts of nutrient uptake as compared to imbalanced application (Table 3). With respect to application of suboptimal, optimal and super optimal NPK out turn it has proportionate higher uptake of nutrient. There by higher uptake was found in super optimal application of fertilizer. On the other hand omission of S in fertilizer schedule (100%NPK-S) declined the nutrients uptake over balanced NPK with sulphur. The highest nutrient uptake was associated when optimal fertilizers applied along with organic manure (NPK + FYM). The data indicated that increasing level of fertilizer application successively increased the nutrient content in the crop. The lowest nutrient content of soybean was found in control. Similarly, it was also found that application of 100% N fertilizer resulted in moderately extension of yield and deliberately augmented the nutrient content when P fertilizer was accommodate in fertilizer schedule. While, there was a further enhancement noted when K nutrient introduce over imbalanced NP application i.e. 100% NPK (Table 3).

Nitrogen increased utilization of fertilizer-S in plants (Dhankar *et al.*, 1995) observed that large doses of N created a deficiency of S. Fazli *et al.*, (2008) [10] found that uptake of N was considerably reduced under S deficiency. However, the effect of N rate on S uptake varied with S application rate. But nitrogen content increased significantly with both S and N application, such interaction was also observed in other plants. A number of studies indicated synergistic effect of combined application of S and N on the uptake of these nutrients by maize, rapeseed (Fazli *et al.*, 2008) [10]. However, N application increased the grain S concentration at high but not at low S and increased grain N concentration in all S treatments.

Effect of long term fertilizers and FYM application on yield of soybean

The perusal of the data (Fig. 1) indicated that the lowest grain yield (513 kg ha^{-1}) was recorded in control. While, it was found to be increased (925 kg ha^{-1}) in treatment receiving sub optimal fertilizer dose (50% NPK), which was significantly higher than that obtained with application of 100% N alone (675 kg ha^{-1}). These results indicated that even if 50% of recommended optimal dose applied it was found to be much beneficial in comparison to the application of imbalanced nutrient application. Application of recommended optimal dose (100% NPK) resulted in productivity of grain yield for 1010 kg ha^{-1} but exclusion of sulphur (i.e. 100% NPK-S) dose had resulted in comparatively lower grain yield (988 kg ha^{-1}). Similar results have also been observed by Hati *et al*. (2007) and Kundu *et al*. (2007) [12]. On the other hand, the grain yield obtained in 100% NPK + FYM treatment (1300 kg ha^{-1}) was significantly higher than 150% NPK treatment (1225 kg ha^{-1}). The data clearly indicated that under intensive cultivation addition of integrated application of fertilizer with FYM was found to be beneficial for maintaining the fertility of the soil as well as subsequently improving the productivity potential of soybean-wheat cropping system (Sonune *et al*., 2003) [14]. Similarly, it was also found that 100% N treatment resulted in lower yield (675 kg ha-1) and progressively increased to 925 kg ha^{-1} when P fertilizer (100% NP) was included in fertilizer schedule. These results established the importance of sulphur application and found to be a major fertility constraint in controlling productivity of soybean grown especially in black soil (Dwivedi and Dixit, 2002 and Dwivedi *et al*., 2007) [15, 13, 16].

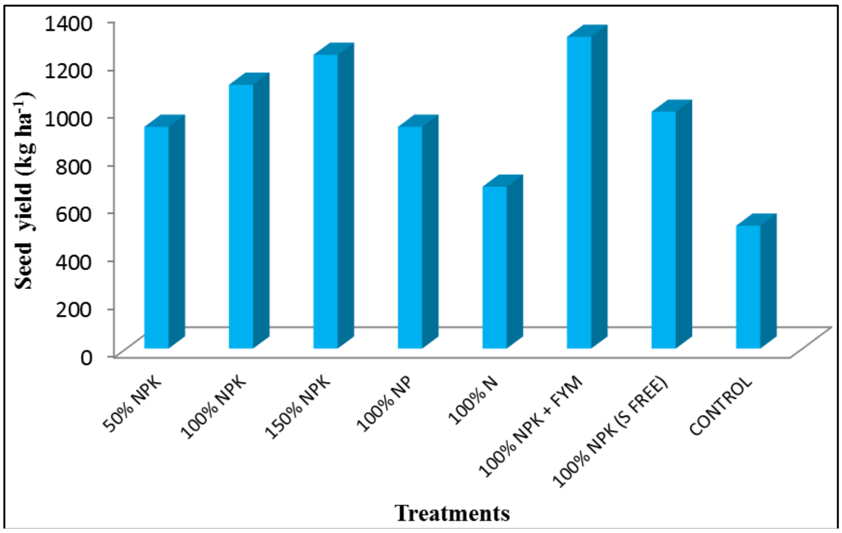

Fig 1: Soybean yield at different treatments

Table 2: Effect of continuous addition of fertilizers and manure on distribution of available nutrients.

Treatments	Available nutrients status [kg ha^{-1}]							
	N		P_2O_5		K_2O		S	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
50% NPK	217.00	182.00	22.61	20.16	243	234	24.17	22.34
100% NPK	275.00	238.00	33.18	28.95	275	253	34.98	32.64
50% NPK	291.00	260.00	40.55	39.15	296	275	39.30	37.21
100% NP	240.00	215.00	30.75	28.88	225	180	30.82	27.40
100% N	198.00	180.00	11.26	10.80	207	172	15.08	14.63
100% NPK+FYM	310.00	280.00	42.88	40.81	328	297	42.66	38.47
100% NPK (S FREE)	248.00	217.00	30.15	27.86	255	245	15.94	14.63
CONTROL	182.00	165.00	10.01	9.80	208	165	13.95	12.72
SEm±	12.18	12.90	2.20	2.05	11.14	11.51	0.81	0.97
CD (P=0.05)	35.35	37.44	6.40	5.94	32.34	33.39	2.39	2.85

Table 3: Effect of continuous application of fertilizers and manure on N, P and K nutrients uptake by soybean

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})			Sulphur (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
50% NPK	26.54	27.17	53.70	1.64	2.08	3.71	17.77	28.85	46.62	1.47	1.86	3.33
100%NPK	44.13	45.67	89.80	2.48	3.51	5.99	26.20	46.22	72.42	2.12	3.24	5.35
150%NPK	74.04	67.34	141.37	4.11	5.73	9.84	44.05	68.61	112.66	3.61	4.92	8.53
100%NP	38.34	38.25	76.59	2.13	2.75	4.88	15.74	33.30	49.03	1.62	2.43	4.06
100%N	18.69	23.68	42.38	0.86	1.68	2.54	12.00	23.46	35.46	0.67	1.32	1.99
100%NPK+ FYM	76.81	84.09	160.90	4.91	7.19	12.09	49.97	85.30	135.27	4.25	6.39	10.64
100%NPK-S	42.73	52.22	94.95	3.19	4.08	7.27	31.13	52.02	83.15	1.74	2.79	4.53
Control	17.35	17.96	35.31	0.42	0.84	1.26	10.08	17.85	27.94	0.45	0.84	1.29
SEm±	4.712	7.466	8.872	0.246	0.587	0.598	3.353	7.470	8.003	0.301	0.473	0.512
CD (5%)	13.675	21.666	25.747	0.715	1.705	1.734	9.729	21.690	23.223	0.872	1.373	1.487

Conclusion

Sulphur is an important nutrient for plant growth and development. Sulphur interactions with nitrogen nutrients are directly related to the alteration of physiological and biochemical responses of crops, and thus required to be studied in depth. This would help to understand nutritional behaviour of sulphur in relation to nitrogen nutrients and provide guidelines for inventing balanced fertilizer recommendations in order to optimise yield and quality of crops.

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