INFLUENCE OF SOIL FERTILITY ON THE PROTEIN AND SULPHUR CONTENTS ON GRAIN LEGUMES

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It is generally believed that seeds within a particular cultivar are relatively uniform in composition. This generalization is an oversimplification which should be applied with caution. Many factors influence the composition of seeds - environmental factors, including soil fertility, have important roles to play. This report involving several investigators deals briefly with recent research on the influence of soils and plant nutrition on the nitrogen and sulfur nutrition of grain legumes.

Nitrogen and sulfur nutrition of plants via the soil is extremely complex, when the plant is a nodulated legume complexity is multiplied. Thus, nitrogen fertilization of legumes has direct effects on the crop and indirect effects as a result of modifications in the rate of nitrogen fixation by nodulating organisms.

Both uninoculated and inoculated soybeans have responded to nitrogen fertilizer at IITA because the soil is nitrogen deficient and because symbiotic nitrogen fixation does not proceed fast enough and early enough to prevent serious N deficiency during early growth. In one experiment yields of inoculated soybeans were increased from about 1100 kg/ha to 2000 kg/ha as a result of applying 120 kg N/ha (Table 1). Much of the response came from the first 30 kg N.

Increased yields were associated with depressed protein percentage of the grain for the first (30 kg) increment of N applied. This is probably an example of the "dilution effect" associated with increased dry matter production since the same effect was noted on uninoculated soybean also. Protein yield in the grain of inoculated soybean increased exponentially with each increment of nitrogen fertilizer applied (30-120 kg N/ha). The pattern for uninoculated soybean was different in this respect: the first increment of nitrogen resulted in no yield increase and decreased protein yield in the grain. Yields, protein percentage and thus protein yields were depressed, relative to inoculated soybeans, at all levels of nitrogen applied when soybeans were uninoculated. These observations demonstrate that the first increment of applied nutrient (nitrogen in this case) may not be the most efficient, especially if the base level is extremely low.

Mineral nutrient deficiencies and excesses can result in depressed protein percentage in soybean vegetative parts and in soybean grain. In an investigation of the nature of variability of growth of soybean within a minimum tillage plot belonging to Dr. Ratan Lal at IITA, we observed that low yields and protein percentage of soybean grain were associated with manganese in excess of about 325 ppm in the upper fully expanded leaves and potassium less than about 1.5%. Manganese accumulation was inversely related to soil pH over the range 5.1 to 7.0. Acetylene reduction by nodules, which gives an estimate of nitrogen fixation, were made by Dr. A. Ayanaba. There was close agreement

Table 1. Effect of Inoculation and Nitrogen application on protein content and protein yield of soybean (cultivar TK-5)

N added kg/ha	Seed yield kg/ha		Seed protein content %		Protein yield kg/ha	
	Uninoculated	Inoculated	Uninoculated	Inoculated	Uninoculated	Inoculated
0	1108	1141	31.1	36.0	345	411
30	1141	1699	29.1	34.2	332	581
60	1639	1799	30.3	36.9	497	664
120	1758	2007	36.6	38.1	643	765

between the rate of acetylene reduction, plant green color, nitrogen content of the plant and final protein yield of the grain. The summary Table 2 illustrates the kind of results obtained.

Table 2. Relation between soil pH, N fixation and protein yield of grain.

Soil pH (.01M$CaCl_2$)	Plant Mn (ppm)	Color	N fixation M/plant	Protein content/yield in grain	
				%	(kg/ha)
4.8	400	Yellow	4	29	290
6.4	270	Dark Green	40	32	680

Protein percentage of grain among 26 samples representing the spectrum of leaf color from most chlorotic to darkest green varied from 26.7 to 34.4 (29%) while leaf nitrogen percentage varied from 2.61 to 4.82 (85%) and nitrogen percentage in the whole plant from 1.10 to 2.77 (152%).

Phosphate fertilizer trials with soybean demonstrate that the protein content of grain can be materially increased by phosphate application to Egbeda soil which was very phosphate deficient ($<$6 ppm Bray No. 1 extractable P). Grain yield was increased by phosphate fertilization from 1300 kg/ha to 2500 kg/ha and protein yield from 470 to almost 1000 kg/ha (Table 3).

Table 3. Effect of residual phosphorus on protein yield of soybean cultivar Bossier.

Initial P added kg/ha	Seed yield kg/ha	Seed protein content %	Protein yield kg/ha
0	1355	32.7	479
26	1839	37.5	630
52	2199	40.5	814
78	2248	41.0	842
104	2563	42.5	995

Possibilities for increasing the protein percentage of cowpea grain are less favourable than for soybean, apparently. For example, increasing rates of phosphate which gave a near linear increase in seed yield from 1200 to 1800 kg/ha resulted in a slight decrease in protein percentage in cowpeas. Phosphorus fertilization did produce a big increase in nodule weight per plant and a tendency toward increased nitrogen percentage of leaves, however (Table 4).

Nitrogen fertilization at IITA has less effect on seed yields of cowpea than on soybean and may actually have a detrimental effect on protein percentage of cowpea seeds.

Table 4. Effect of P application on nodulation and leaf protein content, cowpea cultivar TVu 1190.

P-rate kg/ha	Nodule wt Mg/plant	N-content (%)	Protein Content (%)
0	28.6	4.42	27.6
12	58.4	4.50	28.6
24	110.1	4.26	26.6
36	201.0	4.64	29.0
48	154.6	4.77	29.8

The combined effect of nitrogen and phosphorus (with sulfur as an accessory nutrient carried by both the nitrogen and phosphour fertilizers) was studied by Dr. D. Nangju. The soil was sandy textured. The area is derived savannah north of Oyo, Nigeria. There was considerable yield response to added N and P but relatively little change in seed protein content (Table 5).

Both nitrogen and phosphous fertilizers increased the ratio of sulfur to nitrogen in the seed. This ratio is believed to give a rough indication of protein quality.

Table 5. Effect of N and P on seed yield and protein quality of cowpea cultivar TVu 1190.

N-P-rate kg/ha	Seed yield kg/ha	Seed protein (%)	S/N ratio in seed
0 - 0	942 a 1465 b	23.1	0.057
30 - 0	1465 b	24.1	0.072
0 - 30	1558 b	22.2	0.069
30 - 30	1706 b	22.1	0.081

The sulfur content of cowpea grain is greatly influenced by the concentrations of sulfur in growth media. Three varieties of cowpea were grown in pots with soil solutions regulated at 7 different concentrations from near zero to 45 ppm. The sulfur content of the seed tended to remain low and constant when concentration was $<$ 0.2 to 0.6 ppm S in the soil solution, a concentration range where there was a direct response of grain yield to increasing soil sulfur. As the soil solution sulfur concentration was increased further, seed sulfur content increased in the variety Sitao Pole. The sulfur contents of two other varieties, 201-1D and 76-2E, also rose with higher soil sulfur but tended to level off between 5 and 15 ppm. Near maximum yields for all cultivars were obtained when seed sulfur was about 0.26%. This corresponded to sulfur levels in the soil solution of about 2 to 6 ppm. The range of sulfur in the grain for all levels of applied sulfur in the three cultivars was about 0.11 to 0.36%. In general, nitrogen percentage in the grain decreased with increasing yields associated with higher levels of soil sulfur in the deficiency range.

Some data have been obtained on the partition of plant sulfur between grain and vegetative parts. For adequately fertilized cowpea about 60% of the sulfur is translocated to the grain. Assuming a good yield (3.6 kg/ha/day) of cowpea grain the sulfur requirement is about 0.07 kg/ha/day. The sulfur requirement for good yields of soybean are 3 to 4 times greater. Since sulfur in the rainfall of central and northern Nigeria is about .006 kg/ha/day and sulfur reserves in the soil are low there seems little possibility for sustained high yields of sulfur-rich grain unless there are inputs of sulfur ranging from about 10 kg/ha/yr upward depending upon the legume crop grown.