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EFFECTS OF FOLIAR APPLICATION OF NITROGEN AND MOLYBDENUM ON THE UPTAKE OF NITROGEN, SEED YIELD AND ITS QUALITY OF SOYBEANS (*Glycine max* (L.) Merr.)

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Abstract

Effects of foliar nutrition of soybeans (cv.PB-I) with nitrogen and molybdenum on the seed yield and its quality are reported. Nitrogen uptake was positively affected by the foliar application of nitrogen. Foliar applcation of 1% ammonium nitrate solution (30kgN/ha) during the early pod-fill period has significantly increased the seed yield and the % protein in seeds. This effect was further enhanced by incorporation of 0.05% ammonium molybdate in the spray solution. Application of nitrogen: 3.0kgN/ha at two leaves ($V_2$2), 15kgN/ha at early flowering (R1-R2) and 30kgN/ha at early pod-fill (R4-R5) periods had a better effect on the seed yield and the % protein in seeds. The highest seed yield (1727 kg/ha), protein yield (703.4 kg/ha) and fats (351.6 kg/ha) were recorded in the fertilizer treatment where nitrogen was applied together with molybdenum at all three stages of growth.

Key words: Foliar nutrition, Nitrogen, Molybdenum, Leaf nitrogen, Seed yield, Protein and Fat content

1. Introduction

Nitrogen requirement of soybeans is one of the highest of agronomic crops (Sinclair and de Wit, 1975). However, nitrogen fertilization of this crop is not a common practice as combined nitrogen tends to depress the extent of symbiotic nitrogen-fixation by root nodules (Harper, 1974; Johnson et al, 1975; Weber, 1966). Until the nodules become active in nitrogen fixation, there is a great demand for nitrogen, without which the soybean plant shows symptoms of nitrogen deficiency. The use of nitrogen upto 20 kg per hectare for soybeans as a "starter doze" has been suggested by many researchers (Hashimoto, 1971; Singh and Saxena, 1972; Chesney, 1973), which may not meet the full demand for nitrogen at early stages of vegetative growth of the crop.

Supply of nitrogen through uptake from soil and N_2-fixation usually do not meet the demand for nitrogen of the developing seeds during period of pod-fill and nitrogen is translocated to the seeds from leaves and other vegetative parts. This decrease in nitrogen level and the breakdown of proteins cause a decrease in physiological activity and ultimately leaf senecence, thus restricting the period of pod-fill (Sinclair and de Wit, 1975). The restriction of the pod-fill stage can limit the soybean yields and the additional supply of nitrogen at this stage could correct this. During the period of pod-fill nodules stop fixing nitrogen and roots become inactive in the uptake of nutrients (Hanway, 1975). Belikow (Belikov, 1960) using labled $^{14}CO_2$, demonstrated that during the pod-fill stage of soybeans most of the photosynthates of a particular leaf are translocated to the pod situated at the base of the same leaf. Belikov (Belikov, 1967) observed an increase of soybean yields due to application of 3% urea solution at the early pod-fill stage. Research by Garcia and Hanway (Garcia & Hanway, 1976) demonstrated that in certain experiments soybean yields were significantly increased by foliar fertilization with N,P,K and S during the period of pod-fill. They have also found that the optimum rate of nutrients for foliar application during pod-fill period was $N_{80}+P_8+K_{24}+S_4$ kg/ha. However, very limited data regarding foliar nutrition of legume crops have been reported. Besides, previous work on foliar nutrition has mainly confined to application of fertilizers during the pod-fill stage.

The studies herein were conducted to determine the effects of foliar application of nitrogen and molybdenum at different stages of plant growth on the uptake of nitrogen, seed yield and its quality of soybeans.

2. Materials and Methods

A field experiment with nine fertilizer treatments as described in Table 1, was conducted at the University of Sri Jayewardenepura on a Yellow podsolic soil with sandy clay-loam texture (pH = 5.1; Total nitrogen: 0.19%; Available phosphorus (0.1N H_2SO_4 extractable): 10mgP_2O^5/100g soil). A randomized, complete block design was employed with four replications. Plot size was 3.0x6M. Soybean variety PB-I (matures in 85 days) was planted with spacing 40x5cm. Seeds were inoculated with *Rhizobium japonicum* commercial preparation, "Nitrogen S" before planting.

Table 1. Rates and times of foliar application of fertilizers for soybeans

No	*Fertilizer Treatment*	*Rate of Foliar Application, N kg/ha*			*Total Nitrogen kg/ha*
		Stages of Growth			
		V2	*R1-R2*	*R4-R5*	
1	P_{80} K_{100} (Control I)	—	—	—	—
2	P_{80} K_{100} N_{20} (Control I)	—	—	—	—
3	CII +NFI	3.0	—	—	3.0
4	CII +NF2	—	15.0	—	15.0
5	CII +NF3	3.0	—	15.0+15.0	30.0
6	CII +(NF1 +NF2)	3.0	15.0	—	18.0
7	CII +(NF1 +NF2 +NF3)	3.0	15.0	150.+15.0	48.0
8	CII +(NF3) +MoF	—	—	15.0+15.0	30.0
9	CII+(NF1+NF2+NF3)+MoF	3.0	15.0	15.0+15.0	48.0

NF1 — 0.5% NH_4NO_3; NF_2 & NF_3—1% NH_4NO_3 solution. All solutions for sprays contained 0.1% Tween 80; (MoF) was applied as 0.05% Ammonium molybdate in NH_4NO_3 solution.

V2 — Completely unrolled leaf at the unifolliolate node.
R1 — One flower at any node.
R2 — Flower at node immediately below the uppermost node with completely unrolled leaf.
R4 — Pod 2 cm. long at one of the four uppermost nodes with a completely unrolled leaf.
R5 — Beans begin to develop at one of the four uppermost nodes with a completely unrolled leaf.

All treatments in the experiment were supplied with a basal application of N_{20} $P_{80}K_{100}$ kg/ha, except for the Control-I which was given only $P_{80}K_{100}$ Kg/ha. Urea, Triple superphosphate and Muriate of potash were used for basal application. Fertilizer was brodcast and forked in. Foliar sprays with fertilizers (ammonium nitrate and ammonium molybdate) were conducted at different stages of growth (Fehr et al.,1971) as described in Table 1. The spray solution also contained 0.1% Tween 80 as a surfactant which has been previously used by other researchers (Vasilas et al.,1980). Foliar applications were made in the evening with a hand sprayer. The plots were watered with a garden flower can.

For chemical analysis plant samples were taken from each plot after five days of final spray of fertilizers applied at each stage of growth. All samples were dried to a constant weight at 70°C and ground. Total nitrogen of plant samples was determined by micro-Kjeldahl procedure and the samples were digested with concentrated sulphuric acid and perchloric acid as the catalyst in ratio 10 : 1 (Ranaweera, 1975)

Plants were harvested by cutting at ground level and seeds were separated by threashing. Moisture content of seeds was determined and yields were adjusted to 13.5% moisture. Percentage of crude protein in seeds were determined by the nitrogen content (N%x 6.25) in seeds. Fat content of seeds was determined by defatting the ground seed sample (1gm) with petroleum ether, by refluxing in a soxhlet apparatus for 18 hours (Petereburski, 1968).

Data were analysed by ANOVA method at 5% level of significance using MINITAB statistical package.

3. Results

Uptake of Nitrogen:

Foliar application of nitrogen and molybdenum had a significant effect on the nitrogen uptake by the soyabean plant (Table 2 and 3). Application of NFI (3.0kgN/ha) at "two leaves" stage (V2), significantly increased the nitrogen content in the plant by 0.52%. Average recovery of foliarly applied nitrogen at this stage was found to be 27.6%. No significant effect of molybdenum on the nitrogen content was observed at V2 stage.

Nitrogen uptake was not significantly affected by the application of nitrogen (NF2) at the rate of 15kgN/ha, during early flowering (R1-R2) period. However, a combined effect of NF1 and NF2 has been observed. Application of (NF1+NF2) has increased the leaf nitrogen from 2.57% (in control II) to 3.47%. Recovery of nitrogen due to fertilizer treatment, (NF1+NF2) was found to be 72% whilst it is only 44.5% due to the treatment NF2. Application of molybdenum together with nitrogen (NF1+NF2) significantly increased the nitrogen content in leaves from 2.98% to 3.41% and in stems from 0.63% to 0.84%.

Foliar application of nitrogen (NF3) at the rate of 30kgN/ha, during the period of pod-fill (R4-R5) has increased the nitrogen content in pods from 3.18% in the control (II) to 3.91%. Application of foliar nitrogen (NF1+NF2+NF3) at all three stages of growth has increased the nitrogen content in pods by 0.85% and incorporation of molybdenum (0.05%) into this treatment further enhanced the uptake upto 1.34%. Total uptake of nitrogen was increased from 57.67 Kg/ha in control (II) to 69.6 kg/ha and 75.97 kg/ha due to NF3 and (NF1+NF2+NF3) respectively. Recovery of foliarly applied nitrogen during the period of pod-fill was more marked (61%) in the treatment (NF1+NF2+NF3) than that in NF3 (40%). A higher recovery percentage of 70.4% was obtained when molybdenum was applied together with (NF1+NF2+NF3).

Table 2. Effects of foliar application of nitrogen and molybdenum on the nitrogen content (%) in soybean plant at different stages of growth.

	Fertilizer Treatment	*Stages of Growth*						
		V2	*R1 - R2*		*R4 - R5*			*Harvest*
		Whole plant	*Leaves*	*Stems*	*Leaves*	*Stems*	*Pods*	*Seeds*
1	P_{80} K_{100} (Control I)	2.91	1.81	0.55	1.64	0.56	3.01	5.09
2	P_{80} K_{100} N_{20} (Control II)	3.33	2.57	0.58	2.24	0.58	3.18	5.40
3	C I + NF1	3.98	2.68	0.57	2.32	0.75	3.87	5.44
4	CII + NF2	3.68	2.92	0.57	2.45	0.63	3.69	5.69
5	CII + NF3	3.68	2.65	0.67	2.43	0.98	3.91	5.91
6	CII + (NF1 + NF2)	4.03	2.98	0.62	2.35	0.78	3.64	5.64
7	CII + (NF1 + NF2 + NF3)	4.26	3.56	0.65	2.30	0.74	4.03	6.02
8	CII + (NF3) + MoF	3,50	2.28	0.63	2.25	0.90	3.93	5.93
9	CII + (NF1+NF2+NF3)+MoF	4.32	3.41	0.84	2.57	1.02	4.52	6.52
	LSD at 5%	0.37	0.51	0.16	N S	0.26	0.49	0.43

Table 3. Effects of foliar application of nitrogen and molybdenum, on the total uptake of nitrogen, and the recovery percentage.

Fertilizer Treatments	*Stages of Growth*											
	V2			*R1-R2*			*R4 - R5*					
	Foliar Nitrogen Doze kg/ha	*Total Uptake Nkg/ha*	*Recovery %*	*Foliar Nitrogen Doze kg/ha*	*Total Uptake Nkg/ha*	*Recovery %*	*Foliar Nitrogen Doze kg/ha*	*Total Uptake, N kg/ha*				*Recovery %*
								Pods	*Leaves*	*Stems*	*Whole Plant*	
1 $P_{80}K_{100}$ (Control I)	—	2.60	—	—	16.32	—	—	26.27	5.58	1.07	32.92	—
2 $P_{80}K_{100}N_{20}$ (Control II)	—	4.12	—	—	26.26	—	—	42.70	13.05	1.92	57.67	—
3 CII+NF1	3.0	4.98	28.7	—	31.97	—	—	44.95	14.33	2.50	61.78	—
4 CII+NF2	—	4.56	—	15.0	32.92	44.5	—	46.87	11.98	1.80	60.65	—
5 CII+NF3	—	4.15	—	—	28.33	—	30.0	54.68	12.37	2.55	69.60	40.0
6 CII+(NF1+NF2)	3.0	4.97	28.3	15.0	36.87	70.8	—	45.73	15.78	2.79	64.30	—
7 CII+(NF1+NF2+NF3)	3.0	4.89	25.7	15.0	39.05	72.0	30.0	52.09	21.29	2.59	75.97	61.0
8 CII+NF3)+MoF	—	4.56	—	—	24.43	—	30.0	53.15	14.49	3.00	70.64	43.2
9 CII+(NF1+NF2+NF3)+MoF	3.0	5.03	30.3	15.0	38.08	78.9	30.0	53.63	22.05	3.10	78.78	70.36

Seed Yield and its components:

Table 4. Effects of foliar application of nitrogen and molybdenum on the seed yield, % protein and % fat in seeds of soyabeans.

	Fertilizer Treatment	*Seed Yield, kg/ha*	*Protein %*	*Fats %*	*Yield, kg/ha*	
					Protein	*Fats*
1	P_{80} K_{100} (Control I)	838	31.81	22.55	266.8	189.0
2	P_{80} K_{100} N_{20} (Control I)	1188	33.75	23.08	400.6	274.2
3	CII + NF1	1200	34.00	22.09	408.0	265.0
4	CII + NF2	1228	35.57	23.38	436.8	287.0
5	CII + NF3	1445	36.94	21.04	534.0	304.0
6	CII + (NF1 + NF2)	1419	35.25	20 67	500.5	293.0
7	CII + (NF1 + NF2 + NF3)	1629	37.63	21.42	613.3	349.0
8	CII + (NF3) + MoF	1537	37.06	21.17	569.6	325.4
9	CII + (NF1 + NF2 + NF3) + MoF	1727	40.75	20.36	703.4	351.6
	LSD at 5%	181	2.68	1.11	—	—

Foliar application of nitrogen had a significant effect on the seed yield (Table 4). Application of NF3 significantly increased the seed yield from 1118 kg/ha in control (II) to 1445 kg/ha. Application of nitrogen at all three stages of growth (NF1+NF2+NF3) had a better effect increasing it to 1629 kg/ha The highest seed yield of 1727kg ha was obtained from the treatment (NF1+NF2+NF3)+MoF, where molybdenum was applied in combination with nitrogen.

Application of nitrogen foliarly at pod-fill period (NF3) significantly increased the protein content in seeds from 33.75% in control (II) to 36.94% (Table 4). Application of nitrogen at all three stages of growth (NF1+NF2+NF3) gave a better effect increasing the protein content to 37.63%. Application of molybdenum together with nitrogen in this treatment has further increased the protein content to 40.75%. The highest yield of proteins (703.4 kg/ha) and fats (351.6 kg/ha) was recorded in the fertilizer treatment (NF1+NF2+NF3)+MoF.

4. Discussion

Results obtained in our study has indicated a positive effect of foliar application of nitrogen and molybdenum on the uptake of nitrogen and its meatabolism in soybeans. Recovery percentages from single applications of

nitrogen conducted at "two leaves" (V2), early flowering (R1-R2) and early pod-fill (R4-R5) periods were 28%, 44.5% and 40.8% respectively. Previous studies on foliar application of nitrogen for soybeans were mainly confined to the pod-fill period of the plant and a recovery of 51% has been observed from its application during this period by soybean cultivar "Williams" (Vasilas et al., 1980). Better recovery of 71% and 61% were obtained in the treatments, (NF1+NF2) and (NF1+NF2N+F3) respectively. The total uptake of nitrogen due to application of nitrogen at all three stages of growth (75.97kg/ha) is more when compared to the treatment with a single fertilizer treatment given only at R4-R4 period (69.6 kg/ha). This positive effect of increased uptake of nitrogen, probably would have been due to the absorption of more nitrogen from soil as result of efficient functioning of root system and higher rate of nitrogen fixation by root nodules. However, no significant effect of foliar nitrogen has been observed either on the nodule number or nodule weight (Results are not presented).

A significant effect of molybdenum on the uptake of nitrogen was observed when it was combined with foliar treatments with nitrogen. Role of molybdenum in reduction of nitrate in plants (Steinberg, 1937; Nicholas, 1957) and in fixation of atmospheric nitrogen by root nodules of soybeans (Van Niel, 1935; Peive, 1971) has been reported. Molybdenum is an essential component of nitrate reductase (Notton and Hewitt, 1971; Aparicio et al., 1971) and nitrogenase enzymes (Bergersen, 1970).

Results obtained from our experiment demonstrate conclusively that seed yield of soybeans can be significantly increased by foliar application of nitrogen during all three stages of growth (V2, R1-R2 and R4-R5) rather than applying it only during early pod-fill stage R4-R5).

Protein content of seeds was significantly increased both by foliar applications of nitrogen NF3 and (NF1+NF2+NF3). Application of molybdenum in combination with nitrogen (NF1+NF2+NF3) has further significantly increased the crude protein content. This may probably have been due to better and efficient utilization of nitrogen by the plant. The treatment (NF1+NF2+NF3) +MoF has produced the highest yield of crude protein (703.4 kg/ha) and fat (351.6 kg/ha) and this seems to be the best fertilizer treatment in the experiment.

From the results obtained in our experiment it can be concluded that foliar application of nitrogen in combination with molybdenum (0.05%) at the rate of 3.0 kgN/ha at "two leaves" stage (V2) until the nitrogen fixation by nodules sets in, 15kg N/ha at early flowering (R1-R2) and 30kg N/ha at early pod-fill (R4-R5) periods during which the soybean plant is in big demand for nitrogen, can produce high seed yield with high protein and fat content.

5. References

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