Effects of Soluble Nitrogenous Components On the Growth of Soybean Plants

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Soybean plants have been considered as one of the most difficult crops in cultivation management, since the soybean yield does not increase readily by mere improvement of fertilizer application.

They accumulate much more nitrogen in the seed as compared with the grain crops so that they are in need of a large amount of nitrogen throughout the whole growth period, especially at the pod filling stage.

However, when a large amount of nitrogen is applied to soybean plants for the purpose of increasing the nitrogen uptake, the weight of the vegetative portions and the number of flowers increase remarkably but the bean yield hardly increases because the falling of flowers and young pods also increase.

Their falling may be caused by sterilization, mechanical damage and insufficient or unbalanced supplies of metabolites to them.

Generally, soybean plants continue to grow vigorously after the blossoming stage; therefore, growing vegetative portion may compete with the pods for some metabolites. This tendency is more remarkable in cool regions, such as Hokkaido, than in warm districts.[4] The author has been studying on the metabolities, for which the pods are in competition with the growing vegetative portions.

Causes of the falling of young pods

The pods which will fall, cease to grow and then change from green to yellow-green color. In order to know which of the metabolites is insufficient for the normal growth of the pods, several components in green and yellow-green pods were determined.[2]

As shown in Table 1, in regard to total-N, α-amino-N, nitrate-N and allantoin-N concentration, the difference between both kinds of pods is not remarkable. But the total sugar contents in the yellow green pods and in the seeds which are enveloped in them are very small as compared with the green ones.

The total sugar contents in the stems grown

Table 1. Concentration of nitrogenous components and total sugar in pods of soybean plants

(% based on dry weight)

Kind of pod	amount of nitrogen application	Pod					Seed		
		Total —N	α-Amino —N	Allantion —N	Nitrate —N	Totol sugar	Total —N	α-Amino —N	Total sugar
	kg/a								
Yellow-green pod	0	2.83	0.162	0.825	0.043	1.28	6.79	0.031	0.28
	0.4	2.96	0.182	0.735	0.060	2.19	6.57	0.045	0.49
Green pod	0	2.68	0.143	0.668	0.013	10.56	6.12	0.293	6.23
	0.4	2.75	0.152	0.521	0.020	8.23	6.01	0.265	4.95

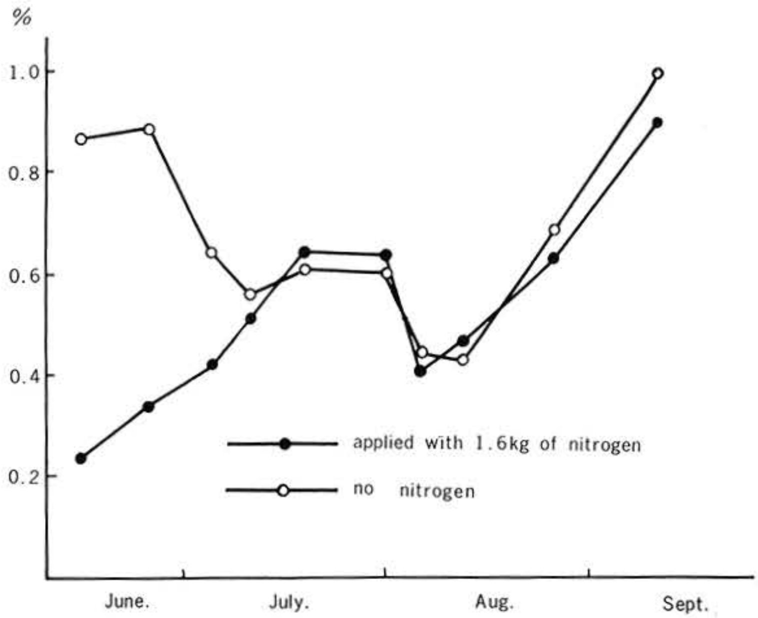

Fig. 1. Total sugar concentration in stems of soybean plants grown in the field. (% based on fresh weight)

in the field were determined at successive stages of growth. From the results shown in Fig. 1, one should note that sugar contents increase until the blossoming stage and then decrease during the early pod setting stage when soybean plants are rapidly growing vegetatively, and the falling of pods occurs frequently. After cessation of rapid growth, sugar content in the stems increases gradually and the falling of pods decreases rapidly. Therefore, we concluded that the insufficient supply of sugar to the pods may be related to the falling of the pods, and that any nitrogenous components do not seem to be responsible for it.

In order to increase the bean yield and to decrease the falling of pods, the vegetative growth must be controlled or repressed during the early pod setting stage. It is also important to promote the vegetative growth before the blossoming stage in cool regions.

Relationship between the growth and the nitrogenous components

It is generally recognized that two thirds of nitrogen uptake by soybean plants may be supplied from the root nodule and the remainder is absorbed from the soil. In the case of researching on the effects of nitrogenous components, we should consider the difference between the soil and the nodules as sources of nitrogen.

Therefore, the nodulating-type soybean plant, A62-1, and the non-nodulating type, A62-2, were cultivated in solutions containing various amounts of nitrogen, and determined the weights and the nitrogen concentration in the stems and leaves. From the results it is recognized that the dry weights and the nitrogen concentrations increase with increasing of nitrogen in culture solution.

One should note that the difference in nitrogen concentration between both types of soybean plants is remarkable, while the difference in the dry weights can be neglected, when the culture solution has the same nitrogen concentration. It is also found in field grown soybean plants that the growth rate of non-nodulating type is greater than that of the nodulating type containing the same nitrogen concentration as the non-nodulating type.

Table 2. Effect of N-concentration in culture solution on the vegetative growth and N-concentration in leaves and stems of soybean plants

N-concentration in solution	Dry weight g/plant (Leaves+Stems)		Total Nitrogen Concentration dry matter (% based on dry weight)			
			Leaves		Stems	
	Strain A62-1	A62-2	A62-1	A62-2	A62-1	A62-2
0 ppm	6.13	—	4.28	—	2.63	—
20	6.37	6.64	4.63	2.64	2.67	0.92
50	7.56	8.34	4.71	3.59	2.58	1.33
100	8.26	8.52	5.28	5.26	3.16	2.73

From the facts described above, we conclude that the root nodule not only supplies fixed nitrogen to the host plants but also may control the vegetative growth of the host, and that the vegetative growth rate may not primarily depend on total nitrogen concentration in the vegetative portions, but depend on the concentration of soluble nitrogenous components, for instance, amino acid, allantoin, and nitrate. Therefore they were determined at successive stages of growth.

As shown in Fig. 2, the nitrogen application results in a decreasing of allantoin-N concentration and an increasing of α-amino-N concentration in the nodulating type plants, A62-1. The allantoin increases rapidly after the blossoming stage. The allantoin in non-nodulating type plants, A-62-2, is so little as to be neglected, but α-amino-N is almost the same in concentration as A62-1 when it is applied with the same amount of nitrogen. These facts prove that the amino acid concentration is controlled by nitrogen application and that the allantoin by the degree of nodulation.

Subsequently, the field experiment was car-

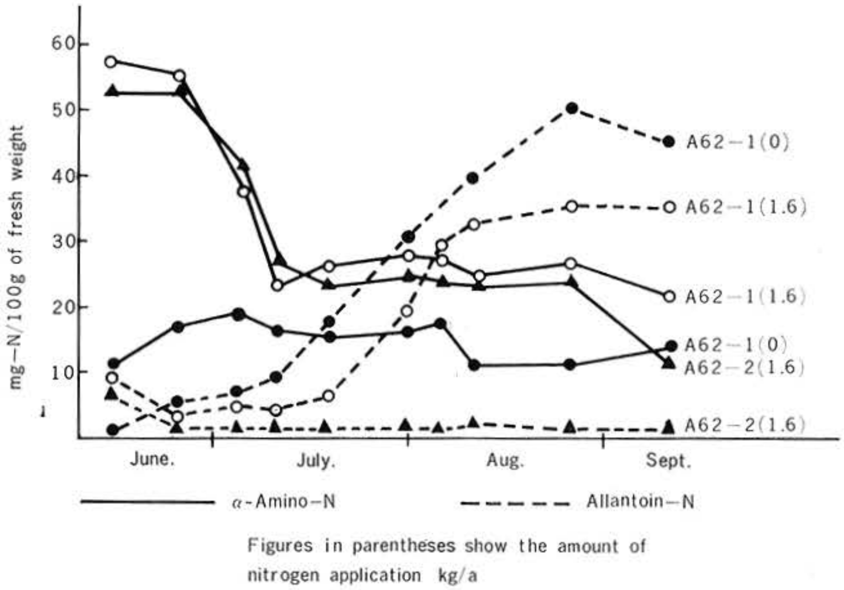

Fig. 2. α-Amino- and allantoin-nitrogen concentration in stems of soybean plant grown in the field.

ried out to elucidate the effect of soluble nitrogenous components on the vegetative growth of soybean plants, the correlation coefficient between the relative growth rate (RGR) and the concentration of α-amino-, allantoin and NO_3-N were calculated.[1),2)]

As shown in Table 3, the factors which correlated possitively with RGR were α-amino- and the NO_3-N concentration. It is natural that α-amino-N concentration correlates closely with RGR because amino acids in vegetative portions seem to be used directly as block material for protein synthesis. Therefore, the promotion of vegetative growth by nitrogen application is considered to be attributable to the increase of the amino acid concentration.

Table 3. Correlation coefficient between RGR and concentration of nitrogenous components

Period \ Component \ Portion	Neaves			Stems		
	Nitrate —N	α-Amino —N	Allantoin —N	Nitrate —N	α-Amino —N	Allantoin —N
July 1 ~July 10	0.24	0.39	−0.33	0.59	0.70	−0.11
July 10~July 23	0.56	0.73	−0.21	0.66	0.83	−0.17
July 23~Aug. 6	0.32	0.43	−0.10	0.13	0.46	−0.69

$RGR=\frac{\log_e(\omega_1/\omega_2)}{t_1-t_2}$, where ω_1 or ω_2 : fresh weight of vegetative portions at time t_1 or t_2

On the contrary, the allantoin concentration correlates negatively with RGR. It is well known that a very small amount of allantoin is contained in many plant species and that a large amount of it is accumulated in some plant species, such as maple and comfrey.[5)] The allantoin contents in maple and comfrey are involved in an annual rhythm.

In spring, allantoin ascends from the roots and arrives in the leaves where it is decomposed. In autumn, the reciprocal process takes place. Therefore, in these plants, allantoin plays an important role in storage and the translocation of nitrogen. If allantoin played the same role in soybean plants as in maple, etc. and were consumed for protein synthesis in the vegetative portions, the allantoin concentration might be expected to correlate positively with RGR. As indicated in Table 3, the author can not reach a conclusion that the allantoin is consumed for protein synthesis in leaves and stems.

We consider that most of the allantoin in soybean plants may be translocated into the pods and plays an important role in seed protein synthesis because it is accumulated very abundantly in the pods as shown in Table 1.

From another experiment, it is suggested[3)] that only a few kinds of amino acids, for instance, Arginine and Canavanine, are rapidly translocated from the pods into the embryos via the seed coats, but other amino acids hardly translocate. These results are considered to be the reason why allantoin is an important substance among various nitrogenous components moving into the embryos via the seed coats.

The physiological roles of allantoin in the vegetative portions are the storage of nitrogen which is needed for seed protein synthesis and the repression of excessive growth, since the allantoin synthesis results in the decreasing of amino acid concentration.

As described above, the vegetative growth rate may depend on the composition of nitrogenous components. However, their composition can't be controlled arbitrarilly yet. We can easily increase the amino acid concentration by nitrogen application, but we have never been able to decrease it after the pod setting stage for the purpose of the repression of vegetative growth. The sole way of increasing allantoin concentration is to promote nodulation, and any other effective ways have never been found. The studies on the mechanism of its accumulation are now in progress, and will be published in near future.

References

1) Ishizuka, J. *et al.*: Physiological studies on the nutrition of the soybean plants (Part 3). The relation between contents of nitrogenous components in stems and vegetative growth. *J. Sci. Soil Manure, Japan* **41**, 78–81 (1970). [In Japanese.]

2) Ishizuka, J.: Nitrogen metabolism of leguminous crops. *Agr. and Hort.* **45**, 1053–1957 (1970). [In Japanese.]

3) Ishizuka, J.: Nitrogen metabolism of leguminous crops. *Abust. Ann. Meeting, Soc. Sci. Soil Manure, Japan,* **16**, 154 (1970). [In Japanese, Summary of oral presentation].

4) Kato, I.: Series of Crops Science, Chapter 4, Beans. 1st ed., 22–25, Yôkendo, Tokyo, 22–25 1962). [In Japanese.]

5) Reinboth H. *et al.*: Urea and ureides and guanidines in plants. *Ann. Rev. Plant Phsyol.* **13**, 129–150 (1962). [In Japanese.]