ACTA AGROBOTANICA
vol. 40, z. 1-2 — 1987
67-72

Effects of mineral nutrition on $^{35}SO_2$ uptake by bean (*Phaseolus vulgaris* L.)

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(Received: March 21, 1986)

Abstract

Experiments with bean have shown, that the concentration of all of the mineral components in the nutrient solution exerts a significant influence on $^{35}SO_2$ uptake by leaves. The greatest amount of $^{35}SO_2$ was taken up by bean leaves grown either in a high supply of nutrients or in their deficiency. The bean leaves which were grown in favourable nutritional conditions took up less $^{35}SO_2$ from the air.

INTRODUCTION

Many previous studies have been performed mainly to investigate the influence of mineral nutrition on the sensitivity of plants to SO_2. The determination of the amount of SO_2 absorbed from the atmosphere has been one of the objectives of these studies (Cowling and Koziol, 1982; Guderian, 1971; Klein et al., 1974; Klein and Jäger, 1976; Leone and Brennan, 1972; Zahn, 1963). Among the main elements of mineral nutrition, special attention has been paid to sulphur and nitrogen. Zahn (1963) has proved that nitrogen fertilization has no influence on the amount of SO_2 in plants. However, Guderian (1971) has found that the effect of nitrogen on the absorption of SO_2 by plants depends on the type of soil and on the plant species. Calcium causes a decrease in SO_2 uptake, whereas phosphorus causes an increase in the sulphur content. During experiments with tobacco and tomatoes, nitrogen deficency resulted in a decrease in the SO_2 uptake by plants (Leone and Brennan, 1972). Different results for pea, obtained by Klein et al. (1974), were explained by the differences in the time at which the plant material was sampled. According to Klein and Jäger (1976) and Kaczor (1986), the rate of SO_2 uptake depends on the form of nitrogen nutrition and on the potassium supply.

Furrer (1965) has shown the relationship between the amount of soil sulphur and SO_2 uptake for low concentrations of SO_2 in the atmosphere. As the sulphur concentration in the nutrient solution increases, the SO_2 uptake is reduced. This relation has not been confirmed for high SO_2 concentrations (Faller, 1972).

Mineral fertilization of conifers resulted in a decrease of the sulphur content in the needles (Materna and Kohout, 1967; Olszowski and Warteresiewicz, 1974; Stefan, 1972). This influence was observed in pines for two years (Olszowski and Warteresiewicz, 1974; 1976).

Due to the differences of opinions, was have undertaken experiments on the effects of the concentration of all of the mineral components in the nutrient solution on the $^{35}SO_2$ uptake by bean leaves.

MATERIAL AND METHODS

The experiments with bean (*Phaseolus vulgaris* L.) were conducted in solution-culture. Knop's nutrient solution and A-Z Hoagland and Snydler micronutrient solution were used. The concentration of the particular nutrient was calculated in relation to the standard Knop nutrient solution, which was labeled nutrient solution 1K. Nutrient concentrations 1/8K, 1/4K, 1/2K, 3/4K, 1K, and 2K were used in the experiments.

The bean was germinated in perlite and than each plant was placed in a 0.5 l glass vessel. The nutrient solutions were aerated every day.

After 30 days the plants were fumigated with $^{35}SO_2$ in a 0.3 m^3 plexiglass chamber. The average concentration of SO_2 was 0.3 ppm, and the dose of radioactivity 18.5 MBq.

The time of fumigation was 30 min. Three plants were fumigated for each experimental series. During the experiment the chamber was lighted with halogen lamps (105 $W \cdot m^{-2}$).

Six discs from the second and third pair of leaves were taken for radioactivity measurements by means of a Geiger counter. The amount of $^{35}SO_2$ taken up was expressed in $imp \cdot min^{-1} \cdot cm^{-2}$.

The data presented are the average for 3 samples from each nutrient solution. Total sulphur content in non-fumigated plants was determined by the turbidimetric method after combustion in a calorimeter bomb (Warteresiewicz, 1979). The weight of plants and the area of leaves were also determined. Variance analysis and Student's t test were used for data evaluation.

RESULTS AND DISCUSSION

The bean plants were fumigated with $^{35}SO_2$ in the early stage of growth. At that time distinct differences in the size of leaves and the yield of plants occurred and it was obvious that the slowest growth of plants was in the series with the highest and the lowest concentrations of nutrient solution. The total sulphur content in the leaves and stems of non-fumigated plants lay in a narrow range and did not depend on the nutrient concentration (Table 1).

Table 1

Sulphur content in leaves and stems of non-fumigated bean plants

Concentration of Knop's nutrient solution	Sulphur content (percent of dry weight)	
	leaves	stems
1/8 K	0.31	0.31
1/4 K	0.34	0.33
1/2 K	0.33	0.31
3/4 K	0.35	0.32
1 K	0.36	0.34
2 K	0.35	0.39

Analysis of the results shows distinct differences in the intensity of $^{35}SO_2$ uptake from the atmosphere by bean leaves. The amount of absorbed $^{35}SO_2$ was dependent on the nutrient concentration. The most intensive $^{35}SO_2$ uptake was observed in the plants grown in 1/8K and 2K nutrient solutions, which is confirmed by the results of the statistical analysis.

The plants cultivated in the 1/2K, 3/4K, 1K series absorbed smaller amounts of $^{35}SO_2$, with no significant differences among these series (Fig. 1). This refers to the second as well the third pair of leaves.

The dependence of SO_2 uptake from air on mineral nutrition has also been mentionend by Cowling and Koziol (1982) in their discussion on the sensitivity of plants to SO_2. Up to now, the problem has been investigated mainly for single components of the mineral nutrients, therefore it is difficult to perform a strict comparison of our results with data obtained by other researchers, although some analogies can be found.

Our experiments have shown that plants with nutrition deficiency take up $^{35}SO_2$ more intensively: 1/8K nutrient solution can serve as an example. A similar relation for nitrogen and sulphur was found by Klein et al. (1974) and for sulphur by Furrer (1965). However, Zahn (1963) and Guderian (1971) obtained different results. Numer-

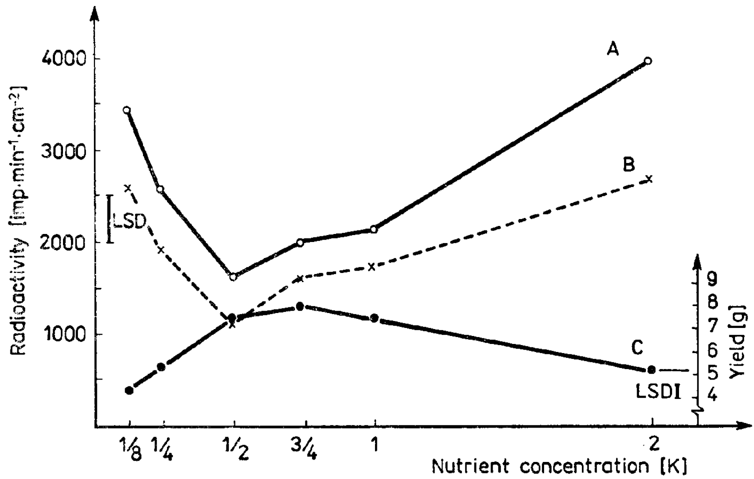

Fig. 1. Influence of nutrient solution concentration on $^{35}SO_2$ uptake by bean leaves (younger and older) and on yield of aerial parts of plants. A — radioactivity of younger bean leaves, B — radioactivity of older bean leaves, C — yield — fresh weight of parts of one plant. (Bars represente LSD P = 0.05)

ous reasons, like different experimental conditions and differences in plant species could contribute to this lack of agreement.

In the case of beans, either the excess or the deficiency of mineral nutrition results in the increase of the $^{35}SO_2$ uptake compared to the plants grown, under favourable conditions (Fig. 1).

We found a relation between the yield of aerial parts of plants and the $^{35}SO_2$ uptake by bean leaves and also between the size of leaves and the amount of $^{35}SO_2$ (Fig. 1). This was confirmed by statistical calculations, since a negative correlation between leaf size and $^{35}SO_2$ uptake (the correlation coefficient was $r = -0.88$) and between plant yield and $^{35}SO_2$ uptake ($r = -0.90$) was found. Thus, weaker and worse developed plants take up more SO_2 from the atmosphere, which leads to the conclusion that the physiological status of the plant influences the SO_2 uptake rate. Some relevance to studies by Whitmore and Freer-Smith (1982) could be noticed, since they have shown that *Phleum pratense* was more sensitive to SO_2 when growth was slow, and it was suggested that exposures during winter may be particularly phytotoxic. However, it is not clear to what extent one can compare the stress caused by unfavourable nutritional conditions with the stress caused by other factors, for example climatic conditions, which can also contribute to the increase in sensitivity of plants to air pollutants.

The analysis of $^{35}SO_2$ uptake for older and younger fully expanded leaves (secondary and third leaf) indicated that the younger ones take up more $^{35}SO_2$ (significant difference was stated at $P = 0.05$). Similar results were obtained for other plant species (Guderian, 1970) and (Warteresiewicz, 1979). This is consistent with the hypothesis that SO_2 uptake is more significant for leaves with intensive gas exchange (Guderian, 1970).

The data presented indicate the importance of nutrient supply for uptake of SO_2 by plants. It is unknown, however, how other plant species will behave under the same conditions.

CONCLUSIONS

1. Experiments have shown that the concentration of mineral nutrients exerts a significant influence on $^{35}SO_2$ uptake by leaves.
2. The greatest amount of $^{35}SO_2$ was taken up by bean leaves grown either in a high supply of nutrients (nutrient solution concentration 2 K) or in their deficiency (nutrient solution concentration 1/8K).
3. The bean leaves which were grown in favourable nutrient conditions (nutrient solution concentrations: 1/2K, 3/4K, 1K) absorbed less $^{35}SO_2$ from air.
4. The younger leaves took up more $^{35}SO_2$ then the older ones.

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POBIERANIE $^{35}SO_2$ Z POWIETRZA PRZEZ FASOLĘ (*PHASEOLUS VULGARIS* L.) PRZY RÓŻNYM POZIOMIE ŻYWIENIA MINERALNEGO

Streszczenie

Badano wpływ koncentracji składników mineralnych w pożywce na intensywność pobierania $^{35}SO_2$ z powietrza przez liście fasoli. Stosowano pożywkę Knopa o różnej koncentracji. Liście fasoli, która rosła w korzystnych warunkach żywienia (koncentracja pożywki — 1/2 K, 3/4 K, 1 K) pobierały mniejszą ilość $^{35}SO_2$ z powietrza. Natomiast w warunkach niedoboru składników pokarmowych (koncentracja pożywki 1/8 K), jak też przy nadmiernym stężeniu składników pokarmowych w pożywce (koncentracja 2 K) rośliny pobierały więcej $^{35}SO_2$ na jednostkę powierzchni. Stwierdzono większą intensywność pobierania $^{35}SO_2$ przez w pełni rozwinięte liście młodsze niż przez liście starsze.

Przedstawione w pracy wyniki pozwalają wnioskować, że zaopatrzenie roślin w składniki pokarmowe ma wpływ na pobieranie $^{35}SO_2$ z powietrza przez liście fasoli.