Effect of Sulfur Dioxide on Nutrition Uptake by Plants

Zang-kual U

亞黃酸 가스가 植物의 養分吸收에 미치는 影響

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Summary

Barley and maize plants were fumigated in acryl chambers with different concentrations of SO_2 gas in order to induce acute effects on the nutrients uptake. The treated SO_2 concentration ranged from control(without SO_2) to relatively high dosages(medium : 86mg/m^3 and high : 172 mg/m^3) to magnify the fumigation effects for a short time. The upper parts of plants and shoots, were fumigated in the chamber, were separately dipped in the culture solutions labelled with $^{35}SO_4$ and $^{32}PO_4$.

Nutrients uptake by roots of barley, known susceptable to SO_2 gas, was not much influenced by SO_2 fumigation for both $^{35}SO_4$ and $^{32}PO_4$. The translocation of $^{35}SO_4$ from roots to shoots in barley plants quite decreased with SO_2 treatment but $^{32}PO_4$ movement was little influenced. Apparently, contrasting with reports in the literature, maize seemed to be rather sensitive to SO_2 treatment in aspects of ion uptake phenomenon at short term and acute dosages. SO_2 fumigation reduced $^{35}SO_4$ uptake by maize roots remarkably, and depressed the translocation of $^{35}SO_4$ to shoots in both medium and high concentration treatments. In comparison with $^{35}SO_4$, maize plants received less effects of SO_2 treatment on $^{32}PO_4$ uptake and translocation.

Under the experimental conditions used it was found that maize was, with regard to nutrients uptake, more susceptable to SO_2 fumigation than barley. The uptake and translocation of $^{35}SO_4$ showed much more severe influence by SO_2 fumigation than those of $^{32}PO_4$. The relationship between SO_2 sensitivity of plants and uptake of essential elements should be investigated further.

Introduction

Since 1970 it has been surveyed that SO_2 gas has taken part in most of air pollutants in Korea. It is estimated that annual loss of several hundred million dollars in the United States come from air pollution injury to crop plants with approximately one third of this total loss attributable to SO_2 injury.

Jeung(1972) reported that injury of SO_2 gas on growth and the yield of paddy rice depended on SO_2 concentration of atmosphere and growth stage of rice plants. Also Brisley(1950) and Han(1973) pointed out that the crop yield losses were proportional to the concentration of inflicting sulfur dioxide gas. The plants can be grouped by the senitivity to SO_2 gas(日本化學會編, 1975) : barley belong to the most susceptable group while maize to the most resistance one. Although the various responses of plants(Jerome, 1978) to SO_2 gas have been well documented, the mechanism is still one of the attractive topics for the investigators. This study was conducted to know the characteristics of sulfur dioxide sensitivity with regard to nutrition uptake by plants using ^{32}P and ^{35}S labelled culture solutions and SO_2 fumigation chamber.

Materials and Methods

Plants cultivation

Two crops, barley and maize, were used to compare their characteristics of nutrient. uptake as influenced by sulfur dioxide fumigation After germinated in the cheese-cloth seedling bed, plants were supported by the plastic vessels with small holes at the bottom side, cultivated at half concentration of Hoagland's solution under the infra red and fluorescent lamps for two weeks, and served for the experiment.

Preparation and measurement of sulfur dioxide gas

As shown in Fig. 1, the gas generation system consisted of a reaction bottle, a moisture absorption bottle, a SO_2 gas containing bottle, and the aspirating line with a vacuum gauge. All the system was evacuated by aspirating just before gas generation. After closing stopcock 1, excess amount of concentrated H_2SO_4 was added from buret to the reaction bottle containing Na_2SO_3. To get quick and enough reaction it was necessary to heat the reaction bottle in the water bath. Shaking and heating was continued untill gas bubbling in the moisture absorption bottle stopped and the reactants became a clear liquid; so particle of Na_2SO_3 presented in the solid form. The concentration of SO_2 gas produced by the above procedure, depending on the amounts of Na_2SO_3 used, was controlled to be about 829 g/m³. 100 ml of this gas was transfered to a dilution vessel with 1.6 l capacity and diluted to 52 g/m³. Finally 100 ml of this diluted gas can make 86 mg/m³ of SO_2 concentration in the acryl fumigation chamber with 60 l volme.

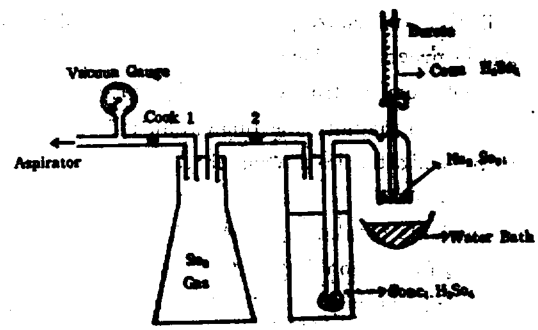

Figure 1. Diagram of SO_2 gas generation system

The measurement of SO_2 concentration was carried out by Kisida method using glass tube detectors containing some color developing reagents. The length of color developing produced by passing through of sample gas was read on the measuring scales graded on the tube detector surface in percentage or ppm.

SO_2 fumigation and radioisotopes treatment

Dimension of the fumigation chamber was 30cm x 40cm x 50cm, the volume being 60 l. As shown in Fig. 2, the chamber was made up by six pieces of acryl plate and a small fan driven by D.C. motor for air circulation. Among six acryl plates five were sealed tightly to make a bottomless box which could be combined to or removed from the bottom plate on which several holes supported plants. Cum paste prepared from the commercial chewing gum, was used to fix the plants in the holes and in addition could provide air tight condition. After planting, the chamber immediately received sulfur dioxide gas by means of injection. SO_2 concentrations of the chamber were adjusted initially 86mg/m^3 for medium dosage and 172 mg/m^3 for high dosage. But SO_2 concentration decreased gradually as time elapsed. About twenty miuntes after the initial adjustment of SO_2 concentration, it was observed that 86mg/m^3 reduced to 70mg/m^3 and 172mg/m^3 decreased to 143mg/m^3. One more injection of So_2 gas was carried out to readjust the change of gas concentration. After one hours fumigation the bottom plates were separated from the covering box and placed on the vessel containg the $^{32}PO_4$ or $^{35}SO_4$ labelled eulture solution. The plants were allowed to absorb the tagged nutrients under the light condition at 18°C for one hour.

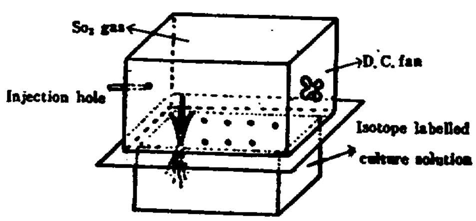

Figure 2. SO_2 fumigation

In brief, treatments were two crops, two ions of $^{32}PO_4$ and $^{35}SO_4$, and three SO_2 concentrations of control, medium and high, having five replications.

Radioactivity counting

Sample preparation for radioactivity measurement was followed according to the laboratory training manual(IAEA, 1964). Radioactivities of the samples were measured on the planchets for ten minutes by Berthold Model BF-1017 GM counter. The dry weight of the samples was taken and counting results were expressed per unit of dry metter.

Results and discussion

As reported in the many literatures the acute effects of SO_2 gas on the plants occur in the range of 2 - 3 ppm or less dosage(Jerome, 1978). But it is rather tedius and difficult to keep the fumigation chamber contineously as low as few ppm because such a tiny amount of SO_2 gas can likely be involved in the plants and environments, especially if the fumigation chamber is not so big comparing to the plants population under the examination. This fact was revealed from the preliminary experiment in which a trial had been done to get 5 ppm of SO_2 in the fumigation chamber but the SO_2 concentration in the chamber was reduced to nearly zero about 20 minutes after SO_2 gas injection. This means that continual SO_2 gas flow through the chamber is needed to maintain as low as 5ppm and also some considerable facilities are required to get stable gas flow-conditions(Kühn and Faller, 1970). Since the aim of this experiment is to investigate the characteristic differences between susceptable plants and resistant one in aspects of nutrition uptake, comparatively high dosages such as 87mg/m^3 and 172mg/m^3 were introduced to induce an acute injury to the plants for a short time. Although the plants seemed to show somewhat wilting symptoms on foliage, visual differences were just a little at the end of fumigation.

The experimental results are concentrated in Table 1 and Table 2. As shown in Table 1, sulfate uptake by barley roots was much higher than by maize regardless of SO_2 fumigation treatments. It can be explained that barley roots are morphologically more favorable for ion uptake than maize: larger numbers of fine root hairs causing bigger surface area per unit dry weight. Another interpretation might be done that maize, tolerable to SO_2 gas, could utilize SO_2 gas and consequently depressed the sulfate absorption from the culture solution. With regard to this point Fried(1948) suggested that SO_2 in air could be utilized as a nutrition source of sulfur by plants. Faller(1972) also reported that the tobacco plants absorbed more sulfur from the air than from the optimal sulfate nutrient solution.

Table 1. $^{35}SO_4$ uptake and translocation of the plants as influenced by SO_2 fumigation.

SO_2 treatments	control		medium		high	
	cpm/g	transl. ratio	cpm/g	transl. ratio	cpm/g	transl. ratio
Barley shoot	3413		1288		722	
root	37510		36810		36100	
shoot/root		0.091		0.035		0.020
Maize shoot	4031		783		329	
root	26177		17797		14325	
shoot/root		0.154		0.044		0.023

Table 2. $^{32}PO_4$ uptake and translocation of the plants as influenced by SO_2 fumigation.

SO_2 treatments	control		medium		high	
	cpm/g	transl. ratio	cpm/g	transl. ratio	cpm/g	transl. ratio
Barley shoot	2237		2095		724	
root	131596		130943		120586	
shoot/root		0.017		0.016		0.006
Maize shoot	2561		1176			
root	63480		51373			
shoot/root		0.040		0.023		

It was notable that the amount of sulfate absorbed by the barley roots was hardly influenced by the SO_2 fumigation while sulfur uptake by maize was decreased very much. One common thing for both plants was that translocation from roots to shoots, given in the ratio the activity of shoots to that of roots, was cosiderably influenced by SO_2 treatment. On the other hand, Furrer(1967) investigated that the uptake of atmospheric sulfur by plants was lower with higher sulfur concentration of the nutrient solution. Faller(1971) reported that foliar assimilation of SO_2 affected the uptake of N, P, K, and other nutrients.

Table 2 shows phosphate uptake by barley and maize at different dosages of SO_2, in which a tendency similar to sulfate uptake can be observed. . Generally barley plants took up larger amount of phosphate through the roots than maize but translocated it much less than maize. SO_4 fumigation hardly influenced phosphate uptake and translocation of barley roots at the medium dosage but reduced translocation at the high level.

Comparing phosphate to sulfate, both barley and maize absorbed phosphate preferably by roots and translocated it to shoots rather slowly but sulfate translocation by the plants was four to five times quicker than phosphate. This result indicates that maize is more sensitive to acute effects of SO_2 gas than barley. Considering that barley is well known as one of the most susceptable plants to SO_2 gas, further investigation about nutrition uptake of essential elements should be performed to understand the relationship between SO_2 gas sensitivity of plants and effects on nutrients uptake or translocation.

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論文抄錄

보리와 옥수수의 유식물을 아크릴상자내에서 아황산가스로 처리하고 이에 따른 ^{32}P 및 ^{35}S로 표지된 인산이온 및 황산이온의 흡수가 어떻게 다른가 살펴보았다. 접촉가스의 농도는 단시간내에 급성효과를 유발시키기 위하여 비교적 높게(중농도 : 86mg/m³, 고농도 : 172mg/m³) 처리했고 상자밑면의 구멍에 심어놓은 식물체는 줄기와 잎부분만 상자내에서 가스와 접촉시키고 뿌리는 상자밑에 놓여 있는 영양액에 담가져 있도록 하였다. 이때 가스가 상자외부로 유출됨을 막기 위해서 식물체와 구멍간의 틈을 검으로 밀폐했다.

아황산가스에 아주 민감한 것으로 알려져 있는 보리의 뿌리에 의한 인산이온과 황산이온의 흡수는 가스처리에 의해서 큰 영향을 받지 않는 것으로 관찰되었다. 한편 황산이온의 줄기나 잎부위로의 이행은 아황산가스 영향으로 줄어들지만 인산이온은 별다른 감소를 보이지 않았다.

아황산가스에 대한 저항성이 크다고 알려진 옥수수의 경우 이온흡수 및 이행이라는 측면에서는 예상과 달리 아황산가스에 대해서 매우 예민한 것으로 나타났다. 즉 아황산가스 처리는 옥수수뿌리에 의한 황산이온 흡수를 많이 저하시켰고 상체부위로의 이행도 처리농도에서 모두 상당히 감소되었다. 인산이온도 비슷한 경향이나 황산이온 보다는 훨씬 적게 영향받았다.

결국 본실험의 조건하에서 관찰된 결과로는 아황산가스에 의한 이온흡수의 급성영향은 옥수수가 보리보다 훨씬 민감하게 받았으며 인산이온 보다는 황산이온이 더 예민한 반응을 보였다. 앞으로 식물체에 대한 아황산 가스의 감수성과 필수원소의 흡수와의 관계가 더 구체적으로 구명되어야 할 것으로 생각된다.