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Oxygen Transport to Flooded Roots for Respiration via Aerenchyma in Soybean (*Glycine max*)

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ABSTRACT

In soybean plants, secondary aerenchyma derived from a phellogen is formed in flooded stem, root and nodule. It is suggested that the aerenchyma is an oxygen pathway and aerial oxygen is transported to roots and nodules, so we investigated that oxygen from stem to root via aerenchyma was used for roots respiration using stable isotope ^{18}O as a tracer. Stem with or without aerenchyma just above water level was exposed by the $^{18}O_2$ gas for 3 h, and then the water was extracted from sampled root. Water samples were analyzed for oxygen isotope ratios on an isotope ratio mass spectrometer. In control plants, after the basal region of the no aerenchymatous stem was applied by $^{18}O_2$ gas, $\delta^{18}O$‰ of extracted water indicated little increase. In contrast, when the basal region of the aerenchymatous stem was exposed to $^{18}O_2$ gas, $\delta^{18}O$‰ significantly increased. Therefore, aerenchyma transports oxygen for respiration and its formation is morphological adaptation to flooding in soybean plants.
KEYWORDS: Aerenchyma, Flooding stress, Oxygen transport, Root respiration, Soybean

1. INTRODUCTION

Internal oxygen movement from shoot to root via aerenchyma is demonstrated in some different ways. According to Dacey and Klug (1982), when leaves of the yellow waterlily (*Nuphar luteum*) are exposed to stable isotope $^{18}O_2$ gas as a tracer, the $^{18}O_2$ supply from leaf to flooded rhizome via aerenchyma is confirmed, and most of the oxygen in the aerenchyma of rhizome originates in the atmosphere. In soybean plants, white and spongy porous tissue (secondary aerenchyma) derived from a phellogen is formed in flooded stem, root and nodule. It is suggested that the aerenchyma of soybean plants is an oxygen pathway and aerial oxygen is transported to roots and nodules. Here, we investigated that oxygen from stem to root via aerenchyma was used for roots respiration using stable isotope $^{18}O_2$ gas as a tracer.

2. MATERIALS AND METHODS

2.1. Plant material and growth conditions

The seeds of soybean cv. Asoaogari were sown in low-humic andosols in a plastic pot. When primary leaves had fully expanded, some plants were grown under continuously flooded conditions. The remaining plants were used as non-flooded controls. Approximately 5-6 weeks after flooding, the plants developing secondary aerenchyma at flooded stems, roots and nodules, were used for the experiment.

2.2. ^{18}O tracing via aerenchyma

In aerobic respiration with ^{18}O in plants, carbohydrate is degraded as follows:

$$C_6H_{12}O_6 + 6^{18}O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2{}^{18}O$$

So, ^{18}O of water produced by respiration in root tissues was traced.

$^{18}O_2$ was applied to the basal stem without aerenchyma in control plants and with aerenchyma in flooded plants. Plants were harvested at 3 h after exposure to $^{18}O_2$, and then the sampled roots were subjected to a cryogenic vacuum distillation apparatus to extract water from the tissues for several hours. The extracted water samples were analyzed for oxygen isotope ratios on an isotope ratio mass spectrometer with an automated CO_2-O_2 equilibration unit. All oxygen isotope ratios are expressed as $\delta^{18}O$ values relative to V-SMOW in ‰.

3. RESULTS AND DISCUSSION

In control plants, after the basal region of the non-aerenchymatous stem was applied by $^{18}O_2$ gas for 3 h, $\delta^{18}O$ of extracted water from root tissues indicated little increase (Fig. 1. Control). Similarly, no significant $^{18}O_2$ enrichment of extracted water of a continuously flooded 5-6 week plant 3 h after its basal stem without aerenchyma had been exposed to $^{18}O_2$, was observed (Fig. 1. Flooding Ae-Close). In contrast, when the basal region of the flooded stem with lenticels was exposed to $^{18}O_2$ gas for 3 h, $\delta^{18}O$ significantly increased by 32.9‰ (Fig. 1. Flooding Ae-Open). In addition, the changes of $\delta^{18}O$ from 0 to 3 h showed that the values increased in course of time, and the $^{18}O_2$ enrichment was detected after only 0.5 h of $^{18}O_2$ gas applying (Fig. 2.). The results of this study show that hypertrophic lenticels of the lower stem just above the water surface are the first entry points of oxygen and facilitate oxygen entry into the aerenchyma, and then the aerenchyma enhances oxygen movement to flooded tissues in soybean plants.

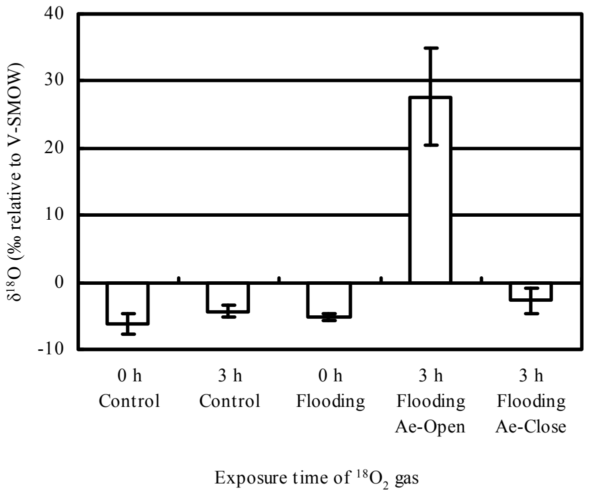

Figure 1. The $\delta^{18}O$‰ of water extracted from soybean root tissues after 3 h of exposure of basal stem with or without aerenchyma to $^{18}O_2$ in each treatment. (n=5, ± SD)

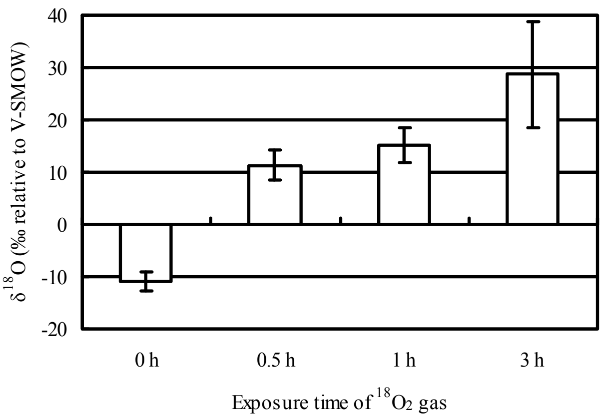

Figure 2. The $\delta^{18}O$‰ enrichment of water extracted from flooded soybean root tissues during 3 h of exposure of basal stem aerenchyma to $^{18}O_2$. (n=3, ± SD)

REFERENCES

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