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Leakage of Gases from Inoculated and Sterile Grass Roots*

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Abstract

Gas concentrations in the ectorhizosphere were linear to the volumes of root aerenchymas, which rice and Kallar grass develop in order to facilitate root aeration under waterlogged conditions. The root porosities varied with plant age and species. Additionally the established gas concentrations in the rhizosphere turned out to be dependent on the kind of gas used, the grass species and water levels above the shoot base. Inoculation of one month-old plants with *Azospirillum brasilense* Cd increased the oxygen concentrations in the rhizosphere by factor 3.1 for rice and 4.6 for Kallar grass, due to reduced diffusive resistance of the root cell wall.

Introduction

Flooding of soils causes development of cortical air space (aerenchyma) as found in rice and Kallar grass, which enriches the rhizosphere with oxygen and decreases the respiratory demand of the subapical parts of the root (Armstrong 1979). Colonization of grass roots with associative microaerobic diazotrophic bacteria like *Azospirillum brasilense* Cd, which are able to promote plant growth (Morgenstern and Okon 1987) and to exhibit positive aerotaxis (Barak 1982), also depends on the oxygen concentration in the rhizosphere. To elucidate the determinants of gas leakage from colonized as well as sterile roots of rice and Kallar grass, the impact of root aerenchyma sizes on gas concentrations in the ectorhizosphere and inoculative effects on cell wall permeability were studied. Wheat, a non-aerenchymatic plant, was used as a negative control. In addition, gas concentrations in the aerenchyma were determined.

Materials and Methods

The cultivation of bacteria (*Azospirillum brasilense* Cd) and plants (*Oryza sativa*,

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Leptochloa fusca, Triticum aestivum), composition of the test vessel, experimental set-up and performance of measurements were as outlined by Ueckert et al. (1990). The test vessel allowed separation of shoots and roots. Gases injected to the top part were measured in the bottom of the vessel, the gas space of which is only partially filled with nutrient solution, by gaschromatography and emissionspectrometry (for $^{15}N_2$). Aerenchyma sizes and porosities were determined by a pycnometer method (Jensen 1967). Every single plant was tested with 4 types of gases over a total time of 102 hrs. The experiments were carried out in at least 10 replicates for each grass species and age.

Results and Discussion

The experiments revealed a linear correlation between aerenchyma sizes and gas concentrations in the ectorhizosphere. This fact is expressed in the introduced quotient Q_r (Table 1), which stands for the established gas concentration in % per μl of root aerenchyma volume after 24 h of incubation. Obviously root inoculation with *A. brasilense* Cd during plant cultivation increased the diffusion rate, caused by reduced resistance of the cell wall, since all conditions were kept constant and the permeability of the shoot aerenchyma is high (Armstrong et al., 1976). This effect is probably due to phytohormone-like substances exuded by *A. brasilense* Cd, which is known to release IAA (Morgenstern et al., 1987).

Table 1. Q_r-values (% h^{-1} μl^{-1}) for sterile and *A. brasilense* inoculated 1 month-old plants.

		O_2	$^{15}N_2$	C_2H_2	C_2H_4
Kallar grass	−B	0.005	0.011	0.007	0.005
Kallar grass	+B	0.023	0.026	0.018	0.014
Rice	−B	0.015	0.010	0.009	0.006
Rice	+B	0.046	0.062	0.017	0.013
Wheat	−B	0.004	0.006	0.005	0.005

The root porosity, expressed as aerenchyma/root-volume in % (Table 2), determines root aeration and withit flooding tolerance of plants, which was high for rice and even higher for Kallar grass (a salt-tolerant plant from Pakistan), but much lower for wheat which does not grow under waterlogged conditions. The high Q_r-values of wheat comparable to that of Kallar grass results from similar cell wall permeability, regardless the root porosity.

Further evidence for significant diffusional resistance of the root cell wall display the data of internal gas concentrations (Table 3).

After 6 hours of incubation, gas concentrations in the aerenchyma approximated those provided initially for shoots. On the contrary, data of the ectorhizosphere were

Table 2. Root porosities [%] of sterile grasses.

	1	3	Age [months]
Kallar grass	22.1	28.6	
Rice	23.2	25.5	
Wheat	0.5	—	

Table 3. C_2H_2-concentrations (%) in the aerenchyma of 3 months old sterile plants at different incubation times.

	0	2	4	6	Time [hr]
Kallar grass	0	1.53	5.73	9.33	
Rice	0	0.73	5.30	10.00	

Table 4. O_2-concentrations (%) in the ectorhizosphere of flooded plants after 24 hrs of incubation. Shoot size was ca. 41 cm.

	0	1	3	Waterlayer [cm]
Kallar grass	2.56	1.07	0.96	
Rice	1.71	0.53	0.19	

10 times lower at a given time of incubation (Ueckert et al., 1990).

A different experiment clarified the involvement of the shoot in root aeration (Table 4). When water-immersed parts of the shoots were increased, the diffusion rate slowed progressively. This was especially true for rice; and the shoot region just above ground, in particular, exhibited reduced resistance to gas diffusion.

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