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Weathering of Micas in the Rhizospheres of Maize, Pine and Beech Seedlings influenced by Mycorrhizal and Bacterial Inoculation*

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Abstract

Different experimental devices have been used to study the influence of mycorrhizal fungi (*Glomus mosseae*, *Laccaria laccata*) and phosphate-dissolving bacteria (*Enterobacter agglomerans*, *Agrobacterium* sp., *Agrobacterium radiobacter*) in plant rhizospheres (maize, pine and beech seedlings) on the weathering of silicate minerals (biotite, phlogopite).

Used as only source of potassium for maize growth, biotite released K, Mg and Fe after 9 weeks in maize rhizosphere. Endomycorrhizal inoculation of maize roots increased this mobilization in the adopted experimental conditions. Pine and beech roots induced the release of K, Fe and Mg from phlogopite after 2 years. But the transformation of the mineral was more important in pine rhizosphere (formation of vermiculite). This result can explain, at least for a part, the more important weathering observed in natural conditions in pine forest soils. *Laccaria laccata* and both *Agrobacterium* increased this mineral weathering.

Introduction

The ability of root systems and of microorganisms to weather minerals has been shown in different works (e.g. review of Robert and Berthelin, 1986, Berthelin, 1988, and recently, Hinsinger et al., in press), but their relative importance and their interactions have not been so well studied (Leyval, 1988). Results from different experiments, in growth chamber or in greenhouse, are presented to point out some effects of bacteria and mycorrhiza on the weathering of micas in maize, pine and beech rhizopheres.

Material and Methods

Maize (*Zea mays*) was grown for nine weeks in a phytotronic chamber (Laheurte

*Reviewed

and Berthelin, 1988) and inoculated or not by an endomycorrhizal fungus (*Glomus mosseae*) and/or a phosphate-dissolving bacterium (*Enterobacter agglomerans*). Pine (*Pinus sylvestris* L.) and beech (*Fagus sylvatica* L.) seedlings, inoculated or not with an ectomycorrhizal fungus (*Laccaria laccata*) and/or a phosphate dissolving bacterium (*Agrobacterium* sp., *Agrobacterium radiobacter*) were grown in a greenhouse for 2 years (Leyval, 1989; Leyval and Berthelin, 1989). All plants were cultivated in cylindric tubes, filled with acid-washed sand, and were fed automatically. Silicated minerals (biotite, phlogopite) were used as only sources of K, Fe and Mg for plant growth. At the end of the experiments, dry weight of plants and their mineral content (K, Fe, Mg) were determined. Transformation of minerals were observed using chemical and mineralogical analyses (described in Bonneau and Souchier, 1979). Mineral element mobilization from phlogopite and biotite were evaluated by adding the amounts uptaken by plants and released in the nutrient solutions. These procedures have been described by Leyval (1988), Laheurte and Berthelin (1988) and Leyval and Berthelin (1989).

Results

Endomycorrhizal inoculation of maize increased K and Fe mobilization in comparison to non inoculated plants (Table 1), but *Enterobacter agglomerans* had no significant effect (Laheurte, 1985).

Table 1. Mobilisation of mineral elements from phlogopite by beech and pine (two-year growth) and from biotite by maize (9 weeks growth) (mg/plant). mgX mobilized = (mgX uptaken/plant) + (mgX in solution)-(mgX initial in the medium and in the seeds). Two treatments with the same letter in the same column are not significantly different (0.05 > P).

	Beech (phlogopite)			Pine (phlogopite)			Maize (biotite)		
	Mg	Fe	Al	Mg	Fe	Al	Mg	Fe	K
Root treatment									
non inoculated	1.8a	0.8a	7.5a	8.6a	8.3a	17.1a	2.6a	4.6a	3.0a
+ bacteria	4.7b	3.0b	11.9b	10.3b	6.8a	18.4b	1.0a	4.6a	3.2a
+ mycorrhiza	4.9b	4.1b	11.3b	7.6a	9.6b	14.1c	2.7a	5.5b	4.1b
+ bact + mycor	2.1a	1.4a	9.1a	9.7a	11.1b	15.1c	2.4a	4.6a	3.3a

The inoculation with the phosphate-dissolving bacteria or with *Laccaria laccata* promoted the release of Mg, Fe and Al from phlogopite in beech rhizosphere (Table 1). In pine rhizosphere, *Agrobacterium radiobacter* increased the release of Mg and Al from phlogopite and *Laccaria Laccata* the release of Fe (Table 1). These microbial inoculations also modified the cation exchange capacity of the phlogopite, that was already significantly increased (0.01 > P) in the rhizosphere of non inoculated plants in comparison to the controls without plants (Table 2). The inoculation with both microorganisms slightly increased Mg, Fe and Al mobilization in beech rhizosphere and Mg and Fe mobilization in pine rhizosphere comparatively to non inoculated plants, but not significantly except for Fe in pine rhizosphere. Synergistic effects were not really observed in the results, except for the cation exchange capacity in pine rhizosphere (Table 2).

Table 2. Modification of the cation exchange capacity of phlogopite (me/100 g) in pine and beech rhizospheres inoculated or not with bacteria and/or a mycorrhizal fungus.

	non inoculated	+bacteria	+mycorrhiza	+bacteria +mycorrhiza
Control	5			
in pine rhizosphere	12	17	16	25
in beech rhizosphere	19	11	10	8

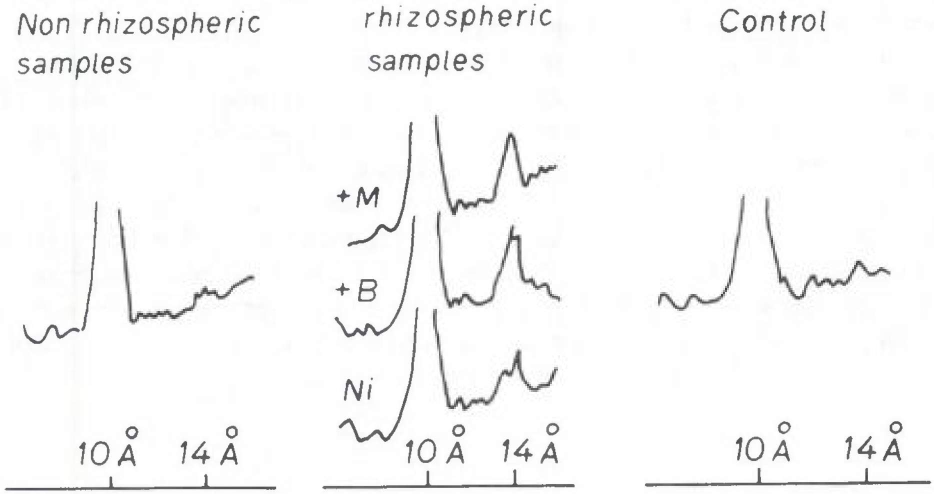

Figure 1. X-Ray diffraction diagrams showing the transformation of phlogopite (10Å peak) into vermiculite (14Å peak) in the pine rhizosphere. (+B or +M = inoculated with bacteria or mycorrhiza: Ni = non inoculated).

X-Ray diffraction diagrams on phlogopite particles collected in the rhizosphere and out of the rhizosphere (Fig. 1) showed a transformation of phlogopite (10Å peak) into vermiculite (14Å peak) in pine rhizosphere, but neither in beech rhizosphere nor in non rhizospheric fractions of both plants.

Discussion and Conclusion

Used as only source of potassium for maize growth, biotite released, under the effect of axenic roots, relatively large amounts of K, Mg and Fe after 9 weeks growth. In these experimental conditions, endomycorrhizal inoculation of maize roots increased this mobilization. Such results are in agreement with those of Mojallali and Weed (1978) who have observed the transformation of phlogopite into clay in the rhizosphere of endomycorrhizal soybeans. Pine and beech roots promoted the release of Fe, Mg and Al from phlogopite determined after two-year growth. But the transformation of the mineral was more important in pine rhizosphere, where a peak of the clay vermiculite appeared on the X-Ray diffraction diagrams. This more important weathering of the mica phlogopite in the rhizosphere of pine than in the beech one could be explained by the greater amount of organic acids released by pine roots (Laheurte et al., this issue). Hinsinger et al., (in press) have observed a fast weathering of phlogopite into vermiculite in the rhizosphere of rye-grass (*Lolium multiflorum*) but did not distinguish the possible role of plant species and rhizospheric microorganisms. *Agrobacterium radiobacter* and *Agrobacterium* sp. increased the release of Mg and Al from phlogopite, as they increased the amount of organic acids collected in the rhizosphere of pine and beech (Laheurte et al., this issue).

In these experiments, the mycorrhizal effect and in particular the effect of *Laccaria laccata* on the mobilisation of mineral elements and mica weathering could not be explained by the production of an increased amount of organic acids (Laheurte et al., this issue). An indirect effect seems to be involved and might be due to an effect on plant growth that increased the sink effect of the plant and/or also to an increase of the volume of soil exploration by the mycorrhizal roots, as observed by Leyval (1988), and consequently of the surface of exchange between the roots and the minerals.

The stronger weathering of phlogopite in pine than in beech rhizosphere can also certainly be related to the stronger mineral weathering observed in soil under pine forest that is known as an efficient soil acidifying vegetation.

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