How rhizosphere may affect nutrient uptake under drying soil condition?

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چکیده

در این مطالعه تاثیر موسیلاژ، ترکیبی ژل مانند که توسط نوک ریشه در خاک ترشح می شود، بر روی پخشیدگی عناصر غذایی در خاک مورد بررسی قرار گرفت. فرضیه اولیه این مطالعه این بود که حضور موسیلاژ در اطراف ریشه گیاه این محیط را مرطوب تر نگاه داشته و همچنین مانند پلی پیوستگی فاز محلول خاک را در شرایط خشک حفظ نموده و در نتیجه انتقال مواد غذایی از خاک به ریشه گیاه را تسهیل می بخشد. نتایج نشان داد که حضور موسیلاژ در خاک ریزوسفری سبب افزایش ضریب پخشیدگی خاک در شرایط پتانسیل آبی یکسان در مقایسه با نمونه خاک غیر ریزوسفری می گردد. سپس تاثیر موسیلاژ بر روی غلظت عناصر غذایی در اطراف ریشه گیاه مابین دو دوره آبیاری با استفاده از مدلسازی حرکت املاح با روش عددی مورد بررسی قرار گرفت. نتایج نشان داد که در شرایط مرطوب حضور موسیلاژ سبب افزایش غلظت عناصر غذایی در مجاورت ریشه گیاه و تسهیل انتقالشان به گیاه گردید. بطور شگفت انگیزی در شرایط خشک خاک حضور موسیلاژ در ریزوسفر از تجمع ناگهانی عناصر غذایی و در نتیجه اعمال تنش خشکی جلوگیری نمود.

چکیده:جذب عناصر غذایی، موسیلاژ، ریزوسفر، تنش شوری

Introduction

To be taken up by the roots, the nutrients in the soil solution should be transported in soil towards the roots. The main mechanisms of nutrient transport in soils are mass flow and diffusion which both are strongly affected by soil water content. As soil dries these two mechanisms reduced by several orders of magnitude in different soils. Increasing evidences have been suggesting that plants actively modify their surrounding soil so called the rhizosphere to improve their access to water and nutrients. Although the rhizosphere effects on nutrient mobility have been focused of several studies from biological and chemical point of view, its effect on diffusion properties of nutrient has not been yet explored. In this study, the effect of mucilage a gel like components released by roots on the diffusive transport of nutrient in soil was investigated. Mucilage is capable of holding large volume of water. We hypothesized that mucilage by keeping soil near the roots wetter and acting as a hydraulic bridge between soil particles avoids a big drop in diffusion coefficient of nutrients as soil dries helping plant to better access nutrient at dry condition.

Materials and Methods

An autoradiography technique was used to study diffusion of radionuclides of 33P and 137Cs in the rhizospheric soil. As an analogy of rhizospheric soil, a quartz sand was mixed by mucilage extracted from chia seeds. The soil was packed into contraries with size of 5×2×1 cm which was portioned in two parts. The first half of the containers was filled with soil mixed with mucilage and equilibrated at different water potential with nutrient solution (containing 33P and 137Cs). The other half was filled with soil mixed with mucilage and equilibrated at the same water potential with water. Same setup was prepared for soil without mucilage. The radionuclides diffused from one half of the soil container into the other half by diffusion. Repeated Phosphor-Imaging (autoradiography) was used to visualize solute transport and obtain the profiles of radionuclide concentration with time. A diffusion equation with adsorption term was used to describe the transport of nutrients. After being numerically solved in Matlab, diffusion coefficient was adjusted to best reproduce the measured profile of concentrations.

Results and Discussion

As expected diffusion of these two ions strongly depended on soil water potential (soil water content). The higher was the soil water potential the greater was the diffusion coefficient. Comparing diffusion coefficients obtained from rhizospheric soil and bulk soil showed that at the same water potential the diffusion coefficients were greater in presence of mucilage. These differences were more pronounced at low water potential occurring at dry condition. Indeed, mucilage by bridging water between soil particles preserved the continuity of liquid phase in drying soil.

In a simple scenario the effect of mucilage on concentration of nutrient during a drying and rewetting cycles was evaluated. To this end, the transport of nutrient around a single transpiring root (40 days old maize plant) was numerically simulated by solving a diffusion-convection equation in Matlab. The results showed that at an early stage of a drying cycle the presence of mucilage could favor higher concentration of nutrients at the root surface. This will help plants to better access and extract nutrients from soil. As soil dries, diffusive transport of nutrients will be limited at soil and concentration of nutrients dragged by mass flow towards the root tend to increase at the root surface. Fast accumulation nutrient at the root surface could induce a salinity stress to plants. Interestingly presence of mucilage at in the rhizospheric soil delayed an expected buildup of concentration at the root surface. We conclude that presence of mucilage in the rhizosphere of plant plays an important role in sustaining the transport of nutrient into the roots particularly at drying condition.

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Abstract

In this study, the effect of mucilage a gel like components released by roots on the diffusive transport of nutrient in soil was investigated. It was hypothesized that mucilage by keeping soil near the roots wetter and acting as a hydraulic bridge between soil particles could avoid a big drop in diffusion coefficient of nutrients as soil dries and help plants to better access nutrients at dry condition. Comparing the diffusion coefficients obtained from rhizospheric soil (soil treated with mucilage) and bulk soil showed that at the same water potential the diffusion coefficients were greater in the rhizospheric soil. Thereafter, the effect of mucilage on concentration of nutrients during a drying and rewetting cycles was evaluated. To this end, transport of nutrients in soil was numerically simulated by solving a diffusion-convection equation. The results showed that at the early stage of a drying cycle the presence of mucilage in the rhizosphere could favor a higher concentration of nutrients at the root surface. Interestingly at the late stage of a drying cycle presence of mucilage delayed an expected buildup of concentration at the root surface by avoiding a big drop in diffusion coefficient of nutrients.

Keywords: Nutrient uptake, Mucilage, Rhizosphere, Salinity stress.