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Profondeur d'extraction racinaire et signature isotopique de l'eau prélevée par les racines des couverts végétaux

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Résumé

Nous cherchons à identifier la profondeur à laquelle l'eau est extraite par les racines dans les sols. En effet, à l'état isotopique stationnaire dans le réservoir d'eau foliaire, la transpiration introduit dans l'atmosphère une vapeur dont la signature isotopique est identique à celle de l'eau racinaire. Dans les modèles isotopiques de circulation générale atmosphérique, il est classiquement admis que la signature de la transpiration appartient à la droite des eaux météoriques. Ceci suppose que l'eau prélevée par les racines ait échappé à l'évaporation du sol et soit donc issue des couches profondes du sol. Lors d'une expérimentation réalisée sur des plants de maïs (Nemours, Seine-et-Marne), cette profondeur d'extraction a été déterminée à partir de la comparaison entre la signature de l'eau mesurée au niveau du premier entre-nœud des tiges des végétaux et le profil isotopique de l'eau dans le sol. Lorsque le flux de transpiration atteint une valeur maximale, la plante prélève de l'eau issue des précipitations, qui conserve son caractère non évaporatoire après s'être rapidement infiltrée dans les couches profondes du sol. Lors de cette expérience, ceci ne concerne que 55 % de la vapeur d'eau émise par le couvert végétal, le restant présentant un caractère évaporatoire plus ou moins marqué en fonction des conditions environnementales. Cette expérience invalide, en régions tempérées, l'hypothèse retenue dans les modèles isotopiques de circulation générale atmosphérique. En effet, seule la moitié de la quantité de vapeur d'eau émise par la plante au cours de la journée présente une signature identique à celle de l'eau des précipitations prélevées dans les couches profondes du sol. ***Pour citer cet article : Z. Boujamlaoui et al., C. R. Geoscience 337 (2005).***

Abstract

Depth of extraction roots and water isotopic signature uptake by plant roots. We seek to identify the depth to which water is extracted by the roots in the soil. Indeed, in an isotopic steady-state condition of leaf water, transpiration introduces into the atmosphere a vapour whose isotopic signature is identical to that of root water. In the isotopic models of atmospheric general

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circulation, it is classically allowed that the signature of transpiration belongs to the meteoric water line. This supposes that the water taken by the roots has escaped with the evaporation of the soil and comes thus from the deep layers of the soil. At the time of experimentation carried out on maize plants (Nemours, Seine-et-Marne, France), this extraction depth was inferred from the comparison between the signature of the water measured on the level of the first internode of the stems of the plants and the isotopic profile of water in the soil. When the flow of transpiration reaches a maximum value, the plant uptakes water resulting from precipitations and which preserves its non-evaporating character after having quickly infiltrated in the deep layers of the soil. This relates to only 55% of the flux transpired by the canopy, the remainder presenting an evaporating character more or less marked according to ambient conditions. This experiment invalidates the classical hypothesis used in isotopic models of general atmospheric circulation in temperate regions. In fact, only half the amount of water vapour transpired by the canopy during the day presents a signature similar to that of the rainwater sampled in deep soil layers. ***To cite this article: Z. Boujamlaoui et al., C. R. Geoscience 337 (2005).***

Mots-clés : Eau ; Oxygène 18 ; Deutérium ; Extraction racinaire ; Maïs ; Premier entre-nœud ; Régions tempérées ; Composition isotopique de la vapeur d'eau atmosphérique

Keywords: Water; Oxygen-18; Water extraction by roots; Maize; First internode; Temperate regions; Isotopic composition of atmospheric vapour

Abridged English version

The objective of this study is to test the hypothesis of the specificity of the vapour isotopic signature transpired by plant canopy. Isotopic models of atmospheric general circulation assume that when the leaf water content reaches an isotopic steady state, the heavy isotope content of transpiration vapour is identical to that of the precipitation water absorbed by plant roots in deep soil layers. This concerns rainwater that would have escaped by soil evaporation due to fast infiltration in the deep soil layers. Nevertheless, as the roots developed in surface soil layers have access to water subjected to evaporation, it requires the precise determination of the soil depth which is affected by root water uptake. The isotopic methodology (^{18}O, ^{2}H) can allow this determination by comparing isotopic signatures of the soil water profile to that of the water extracted at the level of the first internodes of the plant stem. This comparison can be carried out with the caveat that (*i*) no isotopic fractionation occurs during root water uptake, (*ii*) there is a vertical isotopic gradient of water in the soil profile, (*iii*) the roots are distributed according to soil depth, and (*iv*) there is a moisture gradient in the soil. To test in temperate regions the hypothesis used in the isotopic models of atmospheric general circulation, an experiment was carried out on a research plot cultivated in maize (Nemours, Seine et Marne, France). During a 24-h period, the flow of evapotranspiration and the isotopic composition of the soil water and of that of the plants (leaves, stems taken at the level of the first internodes) were measured. After sampling, soil and plant water samples were vacuum extracted. The ^{18}O signature of extracted water samples was classically analysed with an isotopic mass spectrometer equipped with multiple collectors after equilibration between water and carbon dioxide. The deuterium content was analysed after extracting the hydrogen of the water by reduction on uranium metal. The root density and soil water content were also measured at the time of sampling. Contrary to what is usually reported in the literature, the water isotopic composition of the first stem internodes of the maize plant evolves through time. During the daily cycle, this composition decreases appreciably between 03 h 00 and 15 h 00, then increases afterwards to reach the initial isotopic content observed during the previous night. Three hypotheses can be invoked to justify the temporal isotopic evolution of the water of the first internodes. The first hypothesis calls upon the double circulation in the stem saps, the ascending xylem sap having an isotopic signature close to that of soil water, while the descending phloem sap is comparatively more enriched in the heavy isotope. However, heavy isotope content of first internode water reached a minimal value when the heavy isotope content of leaf water was highest. The increase in the heavy isotope concentration of the phloem sap should consequently cause that of the stem water, which is not observed here and thus calls for the rejection of