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Evaluation of the interaction between plant roots and preferential flow paths

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Introduction

Preferential flow causing environmental issues by carrying contaminants to the groundwater resources level, occurs throughout the world. Soil water flow and solute transportation via preferential flow paths with little resistance could bypass soil matrix quickly. It is necessary to characterize preferential flow phenomenon because of its understanding of ecological functions of soil, including the degradation of topsoil, the low activity of soil microorganisms, the loss of soil nutrients, and the serious source of pollution of groundwater resources (Brevik et al., 2015; Singh et al., 2015). Studies on the interaction between plant roots and soil water flow in response to preferential flow is promising increasingly. However, it is complicated to evaluate soil hydrology when plant roots are associated with the mechanisms of soil water flow and solute transportation, especially preferential flow (Ola et al., 2015). Root channels formed by living/decayed plant roots and root–soil interfaces affect soil hydrology (Tracy et al., 2011). For example, Jørgensen et al. (2002) stated that soil water flow was more obvious in soil profiles with plant roots than in soil profiles without plant roots. The present study was conducted to investigate the interaction between plant roots and soil water flow in response to preferential flow in stony soils.

Materials and methods

Field experiments: field dye tracing experiments centered on experimental plants (S. japonica Linn, P. orientalis (L.) Franco, and Q. dentata Thunb) were conducted to characterize the root length density, preferential flow paths (stained areas), and soil matrix (unstained areas). Brilliant Blue FCF (C.I. Food Blue 2) as dye solution (50 L) was applied to the experimental plots. Laboratory analyses: undisturbed soil columns (7-cm diameter, 10 cm high) obtained from soil depths of 0–20, 20–40, and 40–60 cm, respectively, were conducted with breakthrough curves experiments under different conditions maintaining (1) a constant hydraulic head of 1·0 cm of water with various solution concentrations of 0·5, 1·0, and 1·5 g L-1, and (2) a constant solution concentration of 1·0 g L-1 with various hydraulic heads of 0·5, 1·0, and 1·5 cm of water, and those columns were conducted under saturated and unsaturated soil conditions, respectively. The effluent samples were measured with an ultraviolet spectrometer subsystem to determine the relative concentration. The plant root–water interaction (PRWI) was recognized as an indicator of the influences of plant roots on soil water flow.

Results

Our study showed that (1) fine plant roots in preferential flow paths decreased with soil depth and was mostly recorded in the upper soil layers to a depth of 20 cm for all experimental plots. The root length density of preferential flow paths made up at least 50% of the total root length density at each soil depth; (2) preferential flow effects were most apparent on soil water flow at the 0–20-cm soil depth compared with the other depths (20–40 and 40–60 cm); (3) positive correlations between fine plant roots and the plant root–water interaction (PRWI) were observed.

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