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Soil internal forces contribute more than raindrop impact force to rainfall splash erosion

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Abstract: Soil internal forces, including electrostatic, hydration and van der Waals forces, play a critical role in aggregate stability, erosion and other related processes in soil-water system. However, to what extent do soil internal forces influence splash erosion during rainfall remains unclear. Here, we used the cation-saturated soil samples to quantitatively distinguish the effects of soil internal forces from the effect of raindrop impact force (external force) on splash erosion. The electrolyte solutions were employed as rainfall materials to imitate the combination effects of soil internal and external forces, while alcohol was used to simulate the solo effect of soil external force. The results demonstrated that soil internal forces could reach as high as hundreds of thousands of atmospheres, which were much larger than raindrop impact force. Soil splash erosion rate increased with increasing kinetic energy of rainfall in the presence of both electrolyte solutions and alcohol; however, it was also greatly influenced by soil internal forces. Soil splash erosion rate increased first (from 1 to 10^{-2} mol L^{-1}), then leveled off (from 10^{-2} to 10^{-4} mol L^{-1}) as electrolyte concentrations of bulk solutions decreased, which was in agreement with the theoretical analyses of soil internal forces. The contribution rates of soil internal forces on splash erosion at low electrolyte concentrations ($< 10^{-2}$ mol L^{-1}) were more than 70% as rainfall kinetic energy changed from 10 to 40 J m^{-2} min^{-1}; while it was about 3%–25% at the electrolyte concentration of 1 mol L^{-1}. Even when the electrolyte concentration of soil bulk solution reached to 10^{-1} mol L^{-1}, the contribution rate of soil internal forces on splash erosion was more than 50%. Therefore, generally speaking, soil internal forces contribute more than raindrop impact force to rainfall splash erosion under natural field conditions. Our results provide new understanding of the mechanisms of soil splash erosion and open the possibility of splash erosion regulation through the combined controlling of soil internal and external forces.

Keywords: electrostatic force; hydration force; raindrop impact force; splash erosion;