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Soil water repellency as a result of irrigation with treated sewage effluent

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In many semi-arid and arid regions such as Israel, water demand exceeds the reliable supply of surface water and renewable groundwater due to rapid growth in agricultural, municipal and industrial use. The growing competition for scarce water resources has led to a great increase in exploitation of low quality waters such as treated sewage effluent for agricultural production. Recently, we found that prolonged application of treated sewage effluents on certain soils has led to development of water repellency at the soil surface. The development of repellency under these conditions has not yet been described in the scientific literature, and is quite unexpected. This is because suspended and dissolved organic matter in treated sewage effluents is generally surface active, and, from literature reports, could be anticipated to ameliorate repellency rather than to cause it. Considering that soil water repellency adversely affects infiltration, evaporation, spatial and temporal water distribution in the soil profile, and soil erosion, all of which have significant negative repercussions for plant growth, we were motivated to examine in more detail the development of repellency under irrigation with treated effluents. The purpose of the current study was to document the development of water repellency under effluent irrigation, examine its transient nature as a function of season, and delineate the effect of repellency on soil water content in the soil profile and laterally across a transect. The results presented herein form the basis for ongoing studies designed to evaluate in detail the mechanisms that control development of water repellent soils under effluent irrigation.

The experimental site is part of a commercial citrus fruit orchard developed on a sandy soil in the central Israel Coastal Plain. Irrigation was once weekly by a single mini-sprinkler per tree, at an average of about 35-40 mm per irrigation event in June through October, and smaller amounts from April to June and after October, for a total of about 400-500 mm irrigation water over the entire irrigation season. The irrigation season was followed by a rainy season from about November to March, with a total average rainfall of about 500-550 mm. Water repellency of the soil surface layer (0-5 cm) and its spatial variability was studied by intensive soil sampling at the end of the summer (October 2002) and at the end of winter (March, 2003) along a transect between two mini-sprinklers located near adjacent trees along a row. Twenty 0-5 cm samples along the 2.5 m transect were subdivided into 1 cm horizontal slices for a total of 100 samples. Water drop penetration time (WDPT) at original field moisture content, water content and organic matter content were determined for all samples. Additional transects between trees were sampled to 50 cm depth (average 19 profiles per transect, 6 depth intervals per profile), for examining water and organic matter content as a function of depth and season.

In the intensively sampled, 0-5 cm, summer and winter transects, it was found that all the soils were entirely water repellent (WDPT $>$ 5 s) at the end of both seasons, with much greater hydrophobicity at the end of the summer season as compared with the winter season. For both seasons, degree of water repellency decreased sharply with depth within the 0-5 cm soil layer. At the end of the summer irrigation season, 100% of the 0-1 cm samples of undisturbed soil exhibited extremely high repellency (WDPT $>$ 3600 s), compared with 60% of the 4-5 cm layer samples. At the end of the winter season, 40% of the 0-1 cm samples of undisturbed soil exhibited extremely high repellency, while about 50% of the 4-5 cm layer samples fell into the slightly (5-60 s) to strongly (60 – 600 s) water repellent categories. The difference in repellency between summer and winter seasons demonstrates that the repellency developed under effluent irrigation is transient, and is directly related to the quality of the applied water. Both undisturbed and disturbed samples were found to be repellent, but the degree of hydrophobicity was significantly greater for undisturbed samples, such that the method of soil collection can have a direct effect on correct diagnosis of the repellency phenomenon. The importance of water quality for repellency devlopment was confirmed by laboratory studies of flow, infitration, and water redistribution of effluent water-, fresh water-, and non-irrigated soils obtained from the same orchard. Water infiltration was much faster in fresh-water irrigated soils than in effluent-irrigated soils.

The transects to 0-50 cm depth indicated that repellency development affected water distribution in the soil profile. The transect obtained at the end of the effluent-irrigation season revealed that irrigation water infiltrated in a non-uniform way with distinct fingers of 10-15 cm width. The spatial nonuniformity in water content corresponded to the nonuniformity measured in organic matter content. However, the vertical fingers in water content did not correspond to distance from the mini-sprinklers. The transect obtained at the end of the winter rainy season revealed that rainfall water infiltrated in a spatially nonuniform pattern as well, but different in shape from the pattern at the end of the previous summer. The fingers developed during the winter were more regular and essentially disappeared at a depth of about 45 cm, where the wetting front became almost spatially uniform. The spatial distribution of organic matter at the end of the winter season was more uniform than at the end of the previous summer, and was distributed over a larger depth below the soil surface.