

Enhancing the available water content in unsaturated soil zone using hydrogel, to improve plant growth indices

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Abstract

The effects of hydrogels on the soil water retention characteristic curve (WRC) and on the growth indices of *Ligustrum ovalifolium* (an ornamental plant dominating in the landscape of central Iran) were studied. Various amounts of hydrogels (Suprab A200) were added to soil samples having different percentage of water proportional to potential evapotranspiration data. A factorial experiment was used for statistical analysis of data. The results of the soil water retention model showed that, hydrogel caused the residual water content and saturated water content to increase. Available water content increases to a maximum of about 2.3 times the control. Application of hydrogels can result in significant reduction in the required irrigation frequency particularly for coarse-textured soils. This is an important issue in arid and semi-arid regions of the world for enhancing the water management of coarse-textured soils.

Key words: Soil water retention, *Ligustrum ovalifolium*, super absorb, arid zones, water scarcity.

1. Introduction

Ecohydrology is a new concept which suggests that the sustainable development of water resources depends on the ability to maintain the ecosystem processes that have been established by evolution. These ecosystem processes regulate water and nutrient circulation and energy flow at the basin scale in two ways: biota is regulated by floodplain hydrology and hydrology is regulated by biota (Zalewski 2000). Vegetation cover on the floodplain can be an efficient ecohydrological tool for the regulation of floodplains hydraulics, river hydrology and optimization of nutrient retention

(Wagner-Lotkowska *et al.* 2004). Floodplain vegetation influences water flow, matter sedimentation and also biomass production. A fundamental concept in ecohydrology is that plant physiology is directly linked to water availability. Where there is ample water, as in rainforests, plant growth is more dependent on nutrient availability. However, in semi-arid areas like most of Middle East and African countries, vegetation type and distribution relate directly to the amount of water that plants can extract from the soil. When insufficient soil water is available, a water-stressed condition occurs. Plant under water stress decreases both their transpiration and photosynthesis through a number of responses, including closing their stomata. This

decrease in the canopy water flux and carbon dioxide flux can have an impact on surrounding climate and weather. Soil water content is a general term describing the amount of water present in the vadose zone, or unsaturated portion of soil below ground. Since plants depend on this water to carry out critical biological processes, soil water content is integral to the study of ecohydrology. Any attempt to improve water retention capacity of soil may assist in creating optimum water conditions for plant growth.

The uses of alternative water holding amendments and irrigation methods will become more important over time, especially in regions of reduced water availability such as most Middle East and African countries. Hydrogels are superabsorbents that absorb and store water hundreds of times their own weight, i.e. 400-1500 g water per dry gram of hydrogel (Johnson 1984a; Bowman, Evans 1999). Their performance is determined by the chemical properties of the hydrogel, such as molecular weight, formation conditions of the hydrogel, as well as the chemical composition of the soil solution or irrigation water. Water held in the expanded hydrogel is intended as a soil reservoir for maximizing the efficiency of plant water uptake. Commonly used hydrogels can be generally divided into three classes: natural polymers, semi-synthetic and synthetic polymers (Mikkelsen 1994). Synthetic hydrogels usually consist of polyacrylamides (PAM) and polyvinylalcohols. Fully synthetic polymers are chemically cross-linked to prevent them from dissolving in solution (Mikkelsen 1994). The non-cross-linked PAM form is effectively used for soil erosion control, sediment reduction in surface waters and earthen canal bed stabilization (Woodhouse, Johnson 1991).

Hydrogel networks have been reported to improve aeration and drainage of the medium (Bearce, McCollum 1977), improve market life of container grown plant (Eikhof *et al.* 1974; Still 1976; Bearce, McCollum 1977), reduce the moisture stress of plants (Gehring, Lewis 1980) and improve seed coating (Pamuk 2004). Wallace and Wallace (1986) stated that the most favorable results for seed emergence and water infiltration generally came from an anionic polymer and a cationic polymer was less effective.

Hydrogels have been used to establish tree seedlings and transplants in the arid regions of Africa and Australia to increase plant survival (Specht, Harvey-Jones 2000; Save *et al.* 1995; Callaghan *et al.* 1988, 1989). Specht and Harvey-Jones (2000) found that less drought tolerant tree species had a much more favorable response to the application of hydrogels. *Flindersia brayleyana* (Queensland maple) and *Dysoxylum muelleri* (Red bean) had increased overall dry weights when hydrogels were incorporated into the growing substrate, whereas the drought tolerant species of

Flindersia australis (Australian teak) and *Grevillea robusta* (Silky oak) showed no significant increase in overall dry weight. In an experiment, irrigation was stopped for as few as six days, causing all of the control seedlings to die, as compared to the 57% and 71% survival rate of the hydrogel amended soil (Callaghan *et al.* 1989). Drought sensitive plants, such as *Petunia parviflora* (petunia), responded well to the hydrogels in dry conditions and increased flower numbers and dry weights (Boartright *et al.* 1997).

Callaghan *et al.* (1988, 1989) found that hydrogel amendments in sandy soils promoted seedlings survival and growth under arid conditions, while Viero *et al.* (2000) under similar conditions found only an increase in seedling growth when hydrogel was applied in combination with irrigation. Contrasting results may be related to the soil texture, thus hydrogel application in sandy soils promotes an increase in water retention capacity and plant water potential (Huttermann *et al.* 1999, Abedi-Koupai, Sohrab 2004), while in loamy and clay soils the effect may be negligible. The effect of an amendment of sandy soil with highly cross-linked polyacrylamide (Stokosorb K400) on the survival of *Pinus halepensis* (Aleppo pine) seedlings during water stress was investigated by Huttermann *et al.* (1999). Different concentrations of the hydrogel were added to sandy soils at 0.04, 0.08, 0.12, 0.20 and 0.40% weight by weight. The highest addition (0.4%) changed the water retention and its change in water potential with regard to its water content from typical sand to a loam or even silty clay. The survival rates in 0.4% hydrogel were doubled compared to no hydrogel amendments. The hydrogel also allowed for 19 days tolerating drought.

A hydrogel (Stokosorb K 410) effects on growth and ion relationships of salt resistant woody species, *Populus euphratica*, were studied by Chen *et al.* (2003). Addition of 0.6% hydrogel to saline soil has improved seedling growth (2.7 fold higher biomass) during a period of 2 years. Root length and surface area of treated plant had 3.5 fold more than those grown in untreated soil. It was reported that hydrogel treatment enhanced Ca^{+2} uptake and increased capacity of *Populus euphratica* to exclude salt (i.e. reduces contact with Na^{+} and Cl^{-}). Witbooi and Esler (2004) evaluated the effect of different cultivation methods with addition of either organic mulch or a hydrogel (aquasorb), on seedling emergence of seven indigenous plant species in South Africa. Seedling emergence was higher in areas where seed and aquasorb were sown.

The use of increasing levels of the polymer (1, 2 and 4g kg⁻¹) influenced directly *Dendrothema grandiflorum* growth and the absorption of Ca and Mg (Marcato Sita *et al.* 2005). Probably these ions were retained in the polymer frame-

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