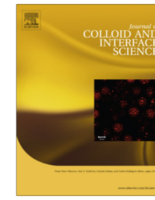
Journal of Colloid and Interface Science xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Journal of Colloid and Interface Science

www.elsevier.com/locate/jcis

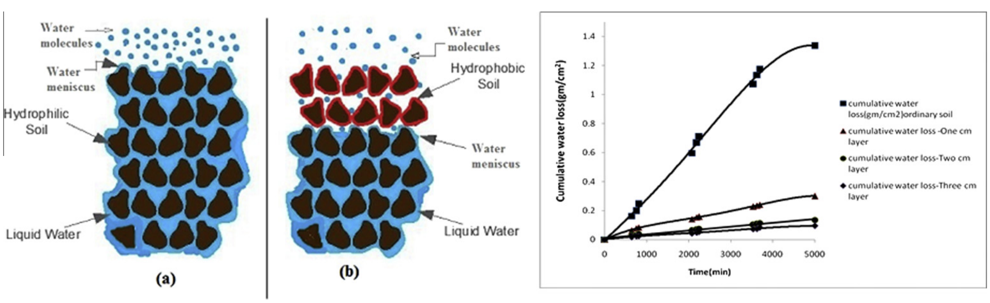


# Effect of top soil wettability on water evaporation and plant growth

Bharat Gupta [a], D.O. Shah [a,b,c,d,*], Brijesh Mishra [a], P.A. Joshi [a,b], Vimal G. Gandhi [a,b], R.S. Fougat [e]

[a] *Chemical Engineering Department, D.D. University, Nadiad 387001, Gujarat, India*
[b] *Shah-Schulman Center of Surface Science and Nanotechnology, D.D. University, Nadiad 387001, Gujarat, India*
[c] *Columbia University, New York, NY, USA*
[d] *Department of Chemical Engineering and Department of Anaesthesiology, University of Florida, Gainesville, FL, USA*
[e] *Department Agricultural Biotechnology, A.A. University, Anand 388110, Gujarat, India*

## GRAPHICAL ABSTRACT




## ARTICLE INFO

*Article history:*
Received 30 November 2014
Accepted 5 February 2015
Available online xxxx

*Keywords:*
Hydrophilic soil
Hydrophobic soil
Chick pea
Growth parameters
Water retention by soil
Diffusion controlled transport of water vapour

## ABSTRACT

In general, agricultural soil surfaces being hydrophilic in nature get easily wetted by water. The water beneath the soil moves through capillary effect and comes to the surface of the soil and thereafter evaporates into the surrounding air due to atmospheric conditions such as sunlight, wind current, temperature and relative humidity. To lower the water loss from soil, an experiment was designed in which a layer of hydrophobic soil was laid on the surface of ordinary hydrophilic soil. This technique strikingly decreased loss of water from the soil. The results indicated that the evaporation rate significantly decreased and 90% of water was retained in the soil in 83 h by the hydrophobic layer of 2 cm thickness. A theoretical calculation based on diffusion of water vapour (gas phase) through hydrophobic capillaries provide a meaningful explanation of experimental results. A greater retention of water in the soil by this approach can promote the growth of plants, which was confirmed by growing chick pea (*Cicer arietinum*) plants and it was found that the length of roots, height of shoot, number of branches, number of leaves, number of secondary roots, biomass etc. were significantly increased upon covering the surface with hydrophobic soil in comparison to uncovered ordinary hydrophilic soil of identical depth. Such approach can also decrease the water consumption by the plants particularly grown indoors in residential premises, green houses and poly-houses etc. and also can be very useful to prevent water loss and enhance growth of vegetation in semi-arid regions.



## 1. Introduction

Fresh water being the major component in agriculture, its judicious use is the need of the time. In farms, evaporation from the soil is the main mechanism by which substantial fraction of water

* Corresponding author at: Shah-Schulman Center of Surface Science and Nanotechnology, D.D. University, Nadiad 387001, Gujarat, India.
*E-mail address:* dineshoshah@yahoo.com (D.O. Shah).

http://dx.doi.org/10.1016/j.jcis.2015.02.018
0021-9797/

is lost from the soil. In general, physically soil–water is stored in three different forms: gravitational water, capillary water and hygroscopic water [1]. Plants take advantage of capillary action to pull capillary water into their root system and push it to the aerial parts of the plant. So, more availability of capillary water to the roots will enhance the growth of roots as well as the plant (as water which gets pulled through gravitational force is not available for root development during initial stages of plant root development) and less availability of capillary water during initial stages of root development results in wilting of plant. Therefore, developing a technology which makes efficient use of water for successful growth of crop plants without sacrificing the yields is a challenge to agricultural scientists and technologists. Thus, it would be more desirable to retain capillary water for longer period of time by tailoring the topography of soil by laying a few centimetre layer of hydrophobic soil on the top surface of ordinary soil. This strategy could help in sustaining moisture above wilting point in ordinary soil for longer period of time and make availability of more capillary water in soil for roots to develop and pull more water into the plant through capillary action.

In nature hydrophobic soil was first detected and described by Schreiner and Shorey [2]. Since then, the existence of hydrophobic soil in nature has been reported by researchers all over the world over last century. This has led to a deeper interest of researchers about its occurrence and formation [3–12], about its chemistry [13–16], about its effect on water movement in soil [9,17–30].

Lemon [24] postulated that a substantial amount of moisture loss from soil occurs by evaporation of moisture from soil through capillary action. To control such evaporation loss from soil, over the years, many efforts have been made through direct (spraying) application of various long chain fatty alcohols on soil [6,31,16,32], waxes [33], plastics [34] etc.

In recent times plastic mulching has been used as an effective method for controlling evaporation of water loss from soil, but it also has certain distinct drawbacks. Plastics mulch have poor degradation characteristics which causes a major disposal issue of plastics after use. Moreover available biodegradable plastics are costly and require suitable conditions for their degradation [35]. Hanada [36] reported that in arid and subtropical areas application of plastic mulch increases the soil temperature which is unsuitable for vegetable production (probability of burning/scorching of young plants due to high temperature) and thus requires an extra protective net for optimization of temperature for vegetable production. The current paper reports only the proof of concept that the layering of hydrophobic soil on top of normal soil can decrease water loss by evaporation as much as 90% (Table 4) and hence it is far more effective method then plastic mulch [35,36]. Thus water saved by reduction in evaporation can enhance the growth of plants.

The main objectives of the research undertaken are (a) to study the impact on water loss by increasing the in thickness of hydrophobic soil and (b) to study growth response of Chick pea (*C. arietinum*) using hydrophobic soil for retention of more water in the ordinary soil.

The following is a brief discussion of our strategy to reduce evaporation of water from soil as described below:

### 1.1. Capillary action in soil

In general, capillary action is related to the surface tension of air/water interface, and wettability or contact angle of capillary surface. The capillary action in soil is similar to the capillary action that happens when a glass capillary is placed in a beaker of water as shown in Fig. 1(a). The water 'climbs' up the glass capillary to a higher level than that outside the capillary. As a result, air water interface form a concave shape interface as shown in Fig. 1(a). When a plexi glass or any other hydrophobic capillary is placed in water, the water is pushed downward. As a result, in this case, the air/water interface form a convex shape inside the hydrophobic capillary as shown in Fig. 1(b). [37]

Fink et al. [33] postulated that wax when applied to soil, melts by absorbing the solar radiation and coats the soil particles or sometimes clog the pores of soil as a result of which soil becomes water repellent and affect the liquid water capillary movement in soil. According to Olsen et al. [31], hexadecanol allows the surface layer to dry and creates a diffusion barrier to water loss by vapour transfer [13,20,23]. Another proposed mechanism stated is that the hexadecanol changes the properties of the soil that influence the capillary rise of water [22,24,15]. Roberts [16] suggested that hexadecanol might form a film on the evaporating water surfaces within a plant or soil similar like a monomolecular film on the open, water surface, and thus reduce evapo-transpiration.

In evaporation process, water in hydrophilic soil moves upward through hydrophilic capillaries as liquid water and reaches to the top of soil through capillary action. Thereafter, evaporates due to temperature or humidity gradient or wind velocity. As shown in Fig. 2(a) soil surface being hydrophilic, the water meniscus is pushed upward by hydrophilic nature of soil particles and thus helps the water to reach to the top surface of the soil. In contrast, the water meniscus is pushed down when a hydrophobic layer is laid over the hydrophilic soil saturated with water as shown in

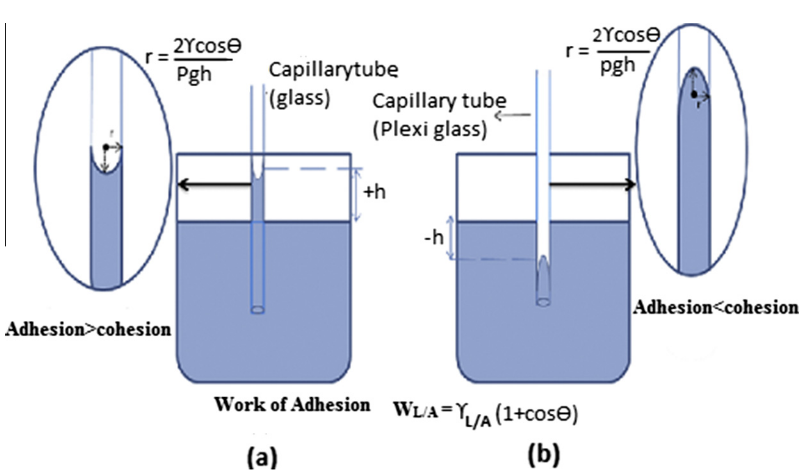



**Fig. 1.** Capillary action and wettability of surface [37].