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Water Repellency in Soils Under Sweet Orange in Marathwada Region

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Abstract: *Present research work entitled "Water repellency in soils under sweet orange in marathwada region" was carried out during 2015-16 at Department of Soil Science and Agricultural Chemistry, VNMKV, Parbhani. It was aimed to study the soil properties in relation to water repellency and to find out relation between soil properties and sweet orange of project consist of a survey of healthy and declined sweet orange orchards was carried out in sweet orange growing soils of Marathwada region of Maharashtra. Soils samples from healthy and unhealthy sweet orange orchards, underneath acacia and lawn were collected from 0-10, 10-20 and 20-30 cm depth. The soil properties like soil texture, hydraulic conductivity, infiltration rate, soil moisture retention, $CaCO_3$ and water drop penetration time were studied. Soil properties were studied under healthy sweet orange trees and declined sweet orange trees. These results revealed that, the soil properties under declined sweet orange trees were degraded. Particularly more reduction in infiltration rate was noted. It was dropped from 17.95 cm hr^{-1} to 9.12 cm hr^{-1}; similarly water drop penetration time was reduced to 0.10 seconds. Hydraulic conductivity was badly affected in soils of declined sweet orange tree orchard; it was reduced from 19.16 to 17.77 cm hr^{-1}. Further soil moisture content at soil moisture constants was higher than the declined orchards soil. (This was mainly because of addition of wax and organic substances which form of wax coat and clod/soil separates). This in turn blocks the macro and micro pores. In respect of soils in sweet orange growing orchard, water repellency was more in declined sweet orange orchards, as compared to normal sweet orange orchard soils. Infiltration rate and hydraulic conductivity was also badly affected in declined orchard soil. Lawn soil had highest water repellent properties followed by acacia tree species soils.*

Keywords: *Water repellency, water drop penetration time, infiltration rate, and hydraulic conductivity.*

INTRODUCTION

Sweet Orange (*Citrus sinensis*) is the most important fruit crop in the world after mango, banana and grapes. In India, Maharashtra is a leading producer of sweet orange and Marathwada region is a leading producer of sweet orange in MS. In India, area under sweet orange is 344.9 million ha and production is 3886.2 million MT with Productivity of 11.6 MT/ha. While, in Maharashtra area under sweet orange cultivation is 95 million ha with production of 712.5 million MT and productivity of 7.5 MT/ha. The low productivity of sweet orange in Maharashtra is due to decline of sweet orange fruit trees from the inception of fruiting age, which is a major constraint in sweet orange production in Marathwada region. Amongst many factors responsible for citrus decline are high calcium carbonate in soil. In addition to this, the citrus decline is getting aggregated to water repellent behaviour of citrus growing soils. In Marathwada region, poor growth of citrus orchards is due presence of high clay, $CaCO_3$ in sub-soil.

A special symposium on water repellent soils was held in 1968 at California (Letey, 1969). In the proceeding it was revealed that water repellent soils are formed in the citrus plantation area is one of the causes of citrus wilt. Water repellent soils exhibit hydrophobic properties when dry, resisting or retarding water infiltration into the soil matrix.

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Infiltration rates may be reduced by an order of magnitude, even in soils which visually appear to wet normally. Repellent soils have been reported in many countries and may occupy large areas, such as sandy soils of South and Western Australia. Jamison (1946) found that "hard to wet" soil was responsible for citrus decline in Florida and recorded the problem of water repellency under citrus trees. who found that some soils in California could not be wetted and thereby were not suitable for agriculture use. Waxy organic substances were responsible for the water repellency. Many workers have reported that water repellence of soils is caused by the organic matter fraction, but the origin of the active components of the total organic matter may differ from soil to soil.

Soils which have hydrophobic properties (also called water repellent soils) can resist or retard surface water infiltration. Soil water repellence can be defined as the phenomenon that a soil does not wet spontaneously when water is applied on the surface. Soil water repellency affects infiltration, evaporation, erosion and the hydrologic balance of soils. Besides the retardation resistance of surface water infiltration, water repellent soils have been associated with preferential flow (Jamison, 1942). Preferential flow paths create spatial variability in soil moisture affecting plant growth (Dekker and Ritsema, 1994). It is important to predict water distribution and flow processes in water repellent soils and to understand how porous media theory developed for hydrophilic soils applies to hydrophobic soils. Water movement in soils is often markedly affected by the development of properties of wetting resistant. This property common with colloidal materials such as clays and soil organic matter and bears an important relationship to the behavior of soils moisture in sandy soil carrying plant residues as compared with subsurface soils low in organic matter content.

The vary nature of organic matter seems to change in soils beneath older citrus trees, especially those affiliated with a peculiar kind of spreading decline and large bodies of dry soils are found beneath citrus trees even at the end of the rainy season. (The ordinary kind of wetting resistant due to drying will return with through drying and these kinds will not). Other factors than desiccations seems to contribute to the development of wettable soil under the citrus trees. Infiltration into a water repellent soil is slower and more variable than into a wettable soil. If the surface of a soil is water repellent, water will not infiltrate into the soil immediately in raining. It will first pond on the soil surface and, if there are any micro topographical or macro topographical contours, then flow to the lower depressions. Instead of flattening out by lateral diffusion the wetting front in a water repellent soil might lead to the formation of ''fingers'' or ''preferential flow paths'' (Ritsema and Dekker, 1994).

In uncultivated, acid, sandy soils receiving no lime or magnesium application, water repellence may be due to other materials that accumulating insoluble soaps. It was suggested that application of sawdust mulch or any organic dressing may induce water repellence in soil. For example, the application of redwood mulch to citrus orchards in the riverside area induced a water repellent condition which hindered the rejuvenation of orchards. Many workers have reported that water repellence of soils is caused by organic matter fraction, but the origin of the active components of total organic matter may differ from soil to soil.

The techniques used to assess the water repellence have varied considerably and this may have contributed to some of the apparent differences in the properties of soils. The suggestion that essential oils from the plant cover were deposited on the soil surface was logical and found some support, especially as the area of leaf- drip was often more water repellent than soil outside the canopies. The importance of the type of plant cover is well recognized, but whether this is a direct or an indirect effect needs clarification.

In Marathwada region, citrus is grown in south-east part along the railway track passing through Nanded, Parbhani, Jalna and Aurangabad. The citrus decline in these districts is induced by many factors; the formation of water repellent soil is one of these factors. Very few workers have focused this aspect; hence, this investigation is an initial step towards opening of new era of water repellence.

MATERIAL AND METHODS

Soil Sampling and Analyses

A survey comprising of healthy and declined sweet orange orchards was carried out in sweet orange growing soils of Marathwada region. Simultaneously, soil sample underneath the healthy and unhealthy (declined) sweet orange trees were collected separately from the depth of 0-10, 10-20 and 20-30 cm and was processed for further analysis.

In situ, infiltration rate and hydraulic conductivity was determined underneath healthy trees and declined trees and similarly soils underneath the Acacia and Lawns were also studied. Five healthy and five unhealthy fruit plants of sweet orange were selected (Avg. Age 15-20 yrs) and the soils of the selected sites were analyzed for various soil properties. Soils underneath the Acacia trees (3 Samples) and the lawns (3 Samples) of depth 0-10, 10-20 and 20-30 cm were also studied against sweet orange growing soils for various properties. The soil samples (depth wise) underneath the sweet orange trees was taken from the sweet orange orchard of department of water management, V.N.M.K.V., Parbhani.

The soil was air-dried, passed through 2-mm sieve, and analyzed for particle size distribution (International Pipette Method, (USDA Triangle Method); soil moisture (Oven Dry Method).

Hydraulic Conductivity

It was determined by constant head method with following procedure.

1. Air dried soil passed through 2 mm sieve is taken for this experiment. Put the filter paper or glass wool at the bottom of the cylinder. Dump the entire soil in one motion into the cylinder that has been fitted with a screen and filter paper.
2. This method of transfer of soil is used to prevent particle size segregation. The cylinder containing the soil is dropped 20 times through a distance of 2.5 cm on to the packing block. Placed a filter on the soil and introduce water into the cylinder with minimum of soil disturbance. The ratio between h/L should be at least 2 to 2.5 *i.e.* approximately half soil and standing water head. Recorded the time of application of water and if possible the time of the initial outflow.
3. Collected the percolated material/solution into a suitable receptible and measured the volume at convenient time intervals. That was run until the volume of water that has passed through the soil corresponds to approximately 12 cm of depth of water on the soil surface.
4. Calculate hydraulic conductivity and plot against accumulated equivalent depth of percolate (generally the readings are continued until an equilibrium value of percolate is reached).

Infiltration Rate

It was determined by using double ring infiltrometer with following procedure.

1. Drive first the central cylinder vertically downwards into the soil (at a suitable spot selected in the field) to a depth of 15-20 cm by hammering on the central guide rod of the circular cap taking care that the soil is disturbed to a bare minimum and the ring is driven in to the soil straight downwards from all sides.
2. Tap soil into the space between the soil column and the cylinder to bring the soil inside the ring to its natural condition as far as practicable.
3. Drive the outer ring into the soil isodimetrically with the central ring.
4. Covered the soil with splash guard and applied 10 to 15 cm water in the central as well as in the space between the central the outer rings.
5. Removed the splash guard and placed the hook gauge or staff gauge in the central ring.
6. Recorded readings of water level against time at suitable intervals in the central ring.
7. Expressed infiltration rate in cm/hr or inches/hr, using values averaged over time intervals.

Calculations

$$di \text{ Infiltration rate} = t = \frac{di}{dt}$$

Where, di = Change in cumulative infiltration, dt = Time interval

Water Drop Penetration Time

Measurement of WDPT was done with following procedure given by J. Letey (1968). The most commonly used method to assess soil water repellency is the ''water drop penetration time'' (WDPT) test. It involves placing droplets of distilled water onto the surface of a soil sample and recording the time for their complete infiltration. This test broadly determines the presence of soil water repellency and how long it persists in the contact area of a water droplet. To distinguish between wettable and water repellent soils, an arbitrary WDPT threshold of 5 has been used widely. Compared to all the other available measurement techniques to assess soil water repellency, the WDPT test is used by scientists and practitioners more than any other because it is inexpensive (only a water dropper and watch are required) and easy to perform in the field and in the laboratory.

Statistical Analysis

The data of various observations were compiled, tabulated and analyzed by adopting CRD (Completely Randomized Design) suggested by Panse and Sukhatme 1985.

Facilities Required and Their Availability

All the laboratory facilities and research needs were available at Department of Soil Science and Agril. Chemistry, V.N.M.K.V., Parbhani.

Place of Research Work

An experiment was conducted at sweet orange orchard of Department of water management, V.N.M.K.V, Parbhani.

RESULTS AND DISCUSSIONS

Soil water repellence can adversely affect general and hydrological soil properties. It reduces infiltration capacity and induces preferential flow, surface runoff as erosion. The research work in this area is mainly centralized in USA and European countries. There are very few references in respect of Indian continent. (Although primarily described from alluvial soil supporting lawn and sweet orange orchards almost no research work was carried out on black soils of Maharashtra and particularly sweet orange growing belts of Marathwada). The review supports that soil water repellence behaviour is one of the cause of citrus decline. Therefore to initiate the research work on this topic a project on "Water repellency in soils under sweet orange cultivation" was planned and executed.

The properties like free calcium carbonate, hydraulic conductivity, infiltration rate and water drop penetration time (WDPT) were determined from healthy and declined sweet orange orchards, underneath the acacia and lawn growing soils at a depth of 0-10, 10-20 and 20-30 cm respectively. The data were collected and analyzed in CRD. The results emerged out are presented in following tables under appropriate sub-heads.

Soil Texture

The soil texture denotes the soil separates contribution in soil. It is the most important unchangeable property of soil. Many soil processes like adsorption-desorption, swelling-shrinkage, water absorption and its retention are governed by content of sand, silt and clay in soil. Soils under sweet orange cultivation were clay in texture, (clay content 58-59 per cent) while soils under acacia and lawn were sandy loam and sand. In healthy and declined sweet orange cultivated soil, coarse sand, fine sand, silt and clay was 15, 12, 13 and 60 and 16, 12, 13 and 59 per cent respectively. While in acacia and lawn soil it was 18, 16, 36 and 30 and 20, 26, 36 and 18 per cent coarse sand, fine sand, silt and clay per cent respectively.

Table 1
Soil Texture of various soils

	Sand (%)			
Treatments	*Coarse sand*	*Fine sand*	*Silt (%)*	*Clay (%)*
SH (1-5)	15	12	13	60
SD (1-5)	16	12	13	59
A (1-3)	18	16	36	30
L (1-3)	20	26	36	18

Infiltration rate

Among the hydrological properties infiltration rate of soil is one of the major properties. There was drastic reduction in infiltration rate under the declined sweet orange orchard trees. The infiltration rate was ranged between 9.12 to 27.72 cm/hr. the infiltration rate was minimum (9.12) in soils of declined sweet orange orchards and maximum (17.95 cm/hr) under healthy sweet orange orchards trees. While soils supporting lawn cultivation showed highest infiltration rate to the tune of 27.72 cm/hr. This was due to coarse texture of lawn soil which contain maximum amount of coarse sand and fine sand (46%).

Table 2
Infiltration rate of various soils

Treatments	*Infiltration rate (cm hr^{-1})*
SH (1-5)	17.95
SD (1-5)	9.12
A (1-3)	11.22
L (1-3)	27.72
SE (±)	0.320
CD @ 5%	0.980
GM	16.50

Hydraulic Conductivity

The data presented in Table 3 on hydraulic conductivity of various soil types, study revealed that the hydraulic conductivity was badly affected under the decline sweet orange trees as compared to healthy sweet orange trees followed by soil under the lawn. Maximum hydraulic conductivity was recorded underneath the acacia tree. The low hydraulic conductivity (17.42 to 18.41) under declined sweet orange tree might be induced by coatings of plant derived waxes covering the soil particles. Further the hydraulic conductivity was decreased with depth of soil.

Water Drop Penetration Time (WDPT)

The depth wise soil samples collected from each treatment were processed and time required for penetration of water drop was measured. The relevant data is presented in table 4. It was very cleared from data that water drop penetration time required was more in case of soils of declined sweet orange trees followed by healthy sweet orange trees. While soils under acacia trees and lawn required less water drop penetration time.

Table 3
Hydraulic conductivity of various soils

	Depth (cm)			
Treatments	*0-10*	*10-20*	*20-30*	*Mean*
SH (1-5)	19.12	19.12	19.25	19.16
SD (1-5)	18.41	17.47	17.42	17.77
A (1-3)	31.95	29.46	27.18	29.53
L (1-3)	21.93	16.32	14.98	17.74
SE (±)	1.80			
CD @ 5%	5.52			
GM	21.05			

Table 4
Water drop penetration time (WDPT) of various soils

	Depth (cm)			
Treatments	*0-10*	*10-20*	*20-30*	*Mean*
SH (1-5)	2.97	2.88	2.82	2.89
SD (1-5)	3.09	2.99	2.89	2.99
A (1-3)	2.94	2.74	2.67	2.78
L (1-3)	2.67	2.47	2.35	2.50
SE (±)	0.101			
CD @ 5%	0.309			
GM	2.79			

The difference in time taken for penetration was attributed to textural class of soils. (Sandy soils separates are more in acacia and lawn soil). However among the sweet orange cultivation the soils were clay in texture and hence water drop penetration time was more as compared to treatment T_3 and T_4. Even though the sweet orange cultivated soils were clay in texture, declined tree soils showed water repellent behaviour, indicating that these soils does not wet spontaneously, where water drop applied. Water repellence occurs at low energy surfaces where the attraction between the molecules of the solid and liquid interface *i.e.* weak (Heslot *et al*. 1990, Roy and McGill 2002). Further more leaf litter of sweet orange trees add wax and hydrophobic compounds which further aggregates the water repellent behaviour of soil.

Soil Moisture Retention

The soil moisture retention curves were plotted from the data collected on water content at different soil moisture constant. The data presented in Table 5 and Figure 1 revealed that, the sweet orange on healthy soils and in declined soils; the soil moisture content was dropped drastically from 0 to 0.1 bars which were further reduced at 0.33 bars. The moisture content was ranging from 90 and 87 per cent at 0 bar, 40 and 35 per cent at 0.1 bar, 33 and 31 per cent at 0.33 bars, 16 and 15 per cent at 15 bar and 11 and 10 per cent at 31 bars. In case of acacia and lawn soils which were sandy loam and sandy in texture showed lowest moisture content at all soil moisture constants.

Table 5
Soil moisture retention under different land use

	Water content (%)				
Treatments	*0 bar*	*0.1 bar*	*0.33 bar*	*15 bar*	*31 bar*
SH (1-5)	90	40	33	16	11
SD (1-5)	87	35	31	15	10
A (1-3)	80	23	18	8	7
L (1-3)	78	21	17	7	6

Calcium Carbonate

The data on calcium carbonate content under various soil and depth are presented in Table 6. The calcium carbonate content being a sensitive soil property found to vary due to variation in locations. High $CaCO_3$ content (8.8%) was noted in soil under lawn followed by soil under acacia, soil under declined sweet orange orchard and soil under minimum in healthy sweet orange. Further the $CaCO_3$ percentage was increased with increase in depth in healthy and decline sweet orange growing soils. However the there was reverse condition in acacia soil and lawn soil. This depth wise uncertain behaviour of $CaCO_3$ might be due to litho sequence. As it was observed that parent material and its management under specific condition is responsible for movement of $CaCO_3$ in soil.

Soil Properties and Sweet Orange Decline

The soil properties were studied in context of sweet orange decline. For this study soil properties from declined sweet orange trees and healthy sweet orange trees were determined and are presented in Table 7. Revealed that, the soil properties under declined sweet orange trees were declined. Particularly was more reduction in infiltration rate. It was dropped from 17.95 cm hr^{-1} to 9.12 cm hr^{-1} similarly water drop penetration time to 0.10 seconds more than the healthy sweet orange tree soil. Hydraulic conductivity was badly affected in soils of declined sweet orange tree orchard it was reduced from 19.16 to 17.77 cm hr^{-1}. Further soil moisture content at soil moisture constants was higher than the declined orchards soil.

Table 6
$CaCO_3$ (%) content of various soils

	Depth (cm)			
Treatments	*0-10*	*10-20*	*20-30*	*Mean*
SH (1-5)	3.6	5.0	7.6	5.40
SD (1-5)	4.6	5.9	4.7	5.07
A (1-3)	5.6	5.0	4.4	5.00
L (1-3)	8.8	8.4	6.6	7.93
SE (±)		1.030		
CD @ 5%		3.147		
GM		5.84		

Table 7
Soil properties under healthy and declined sweet orange trees

			Sweet orange trees	
	Soil properties	*Unit*	*Healthy*	*Declined*
1.	Infiltration rate	cm hr^{-1}	17.95	9.12
2.	Hydraulic conductivity	cm hr^{-1}	19.16	17.77
3.	WDPT	Seconds	2.89	2.99
4.	Calcium carbonate	%	5.40	5.07
5.	Soil texture			
	Coarse sand	%	15	16
	Fine sand	%	12	12
	Silt	%	13	13
	Clay	%	60	59
6.	Soil moisture retention			
	At 0	bar	90	87
	At 0.1	bar	40	35
	At 0.33	bar	33	31
	At 15	bar	16	15
	At 31	bar	11	10

These results showed that gradual degradation of favourable soil properties. This degradation was mainly because of addition of wax and organic substances which form of wax coat and clod/soil separates. This in turn blocks the macro and micro pores.

CONCLUSIONS

Among the soils *viz.* healthy sweet orange tree, declined sweet orange tree, acacia tree and lawn, soil from acacia tree species and from lawns showed inferior soil properties/parameters as compared to healthy and declined sweet orange orchards. The physical/ hydrophobic properties like infiltration rate, hydraulic conductivity, moisture content was reduced in acacia and lawn soil. However between healthy and declined sweet orange tree species, soils under declined orchard showed decrease in most of the soil properties. These results showed that gradual erosion of favourable soil properties.

In respect of sweet orange growing orchard soils, water repellent behaviour was more under declined sweet orange orchards as compared to normal/ healthy sweet orange orchard soils Infiltration rate and hydraulic conductivity was slightly affected in declined orchard soil. Lawn soil had highest water repellent properties followed by acacia tree species soils.

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