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Using geotextile mats to enhance the distribution of water and salinity under sprinkling irrigation

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Key words: Geotextile; Soil moisture distribution; Sprinkling irrigation.

Abstract

Field experiments were carried out to study the influence of geotextile mats using sprinkling irrigation on the availability of soil moisture content and salinity on top of 40 cm of the soil profile. Navel orange was planted in sandy soil since 10 years ago and was irrigated using sprinkler system. To achieve the objectives of this research, soil moisture content, water distribution, and different water relations such as water application efficiency, water use efficiency, and water stored efficiency were measured. The results indicated that the maximum fruit yield was obtained with mats placed at 20 cm depth, whilst the minimum fruit yield was recorded with the control treatment. The availability of soil moisture content in the root zone increased using geotextile mats at 20 cm depth. The results further showed increases in water use efficiency and water application efficiency using the geotextile mats. In addition, soil salinity in the root zone decreased by increasing soil moisture content. In conclusion, the use of geotextile mats is suitable in newly reclaimed areas to enhance the distribution of water and salinity in the soil profile.

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Introduction

Water application efficiency vary with the type of irrigation system used and with other factors such as soil, crop and climatic conditions. The choice of an optimal method for the application of irrigation water can also significantly improve the water use efficiency. In order to achieve sustainable agricultural development, irrigation should be planned and managed in a way that both water and energy can be conserved.

In newly reclaimed areas, the most type of the soil is sandy and itsuffer from some problems including low soil fertility, high deep percolation losses as a result of their light texture, wind erosion, and limited water resources. Therefore, using limited water resources is very important and efficientin obtaining maximum productivity. Recently, considerable attention has been focused on the fact that our national water supply has become a serious limiting factor in the field of agricultural expansion as a result of limited water resources. However, this emphasizes the importance of increasing the efficiencies of irrigation water. This goal could be achieved by minimizing water losses through different ways (e.g. using plastic sheets; adding clay, compost, and organic manure; using mulch and soil conditioners).

Environment and ecological sustainability become one of the prime issues in the modern developmental strategy. Without positive ecological sustainability the technology/product becomes obsolete. Utilization of geotextile in engineering is not a new technology. But their modern uses have started with the advancement of synthetic and polymeric products and their ever increasing application in different forms and areas of engineering was initiated only a few decades ago. Again uses of natural fibrous materials in the field of bioengineering, erosion control and agro-mulching are also recent practices. In geotechnical uses like fibre drain, separator, filter and reinforcing materials are mostly synthetic and non biodegradable with longer span of life.Mulching reduces surface evaporation and decreases the accumulation of salts in the root zone (Oster *et al.*, 1986). Mulching also reduces water evaporation and increases soil moisture content in the root zone (Robinson, 1988).

The soil water distribution pattern was investigated in an orange orchard under both drip and mini-sprinkler system (Bader, 1987). He found that the best water distribution in the soil profile was discovered using drip irrigation system (two laterals of in-line emitter), whilst the mini-sprinkler irrigation system produced the highest yield of orange.

The performance of a geosynthetics mat was evaluated by plant growth and mockup testing (Ahn*et al.*, 2002). They concluded that the use of mulching mats proved effective at physically stabilizing slopes by preventing sediment movement. Thus, they markedly contributed to the growth of plants.

Mady*et al.*, (2006) indicated that, increasing the amount of applied irrigation water to apple trees tends to increase the soil moisture content and decrease the soil salinity for different depths and mulching types. Meanwhile, the highest value of field water use efficiency was obtained with 16.92 $L.tree^{-1}.day^{-1}$ applied water and black plastic sheets. The lowest value of field water use efficiency of 1.29 $kg.m^{-3}$ was obtained by applying 33.8 $L.tree^{-1}.day^{-1}$in the case of bare soil treatment. The results also demonstrated that mulching with cut grass and the application of 25.4 $L.tree^{-1}.day^{-1}$can be used with no effect on soil physical and chemical properties.

The effectiveness of adding polyacrylamide to light-textured soils was used to increase the availability of soil water (Gomaa and Romian, 2011). They concluded that the application of polyacrylamide increased both the availability of water and water use efficiency compared to the control (without polyacrylamide material).

In case of sandy soil conditions, the infiltration rate is remarkably high, which causes water losses and reduces water stored in the root zone. In this context, reducing infiltration rate in such soil type is crucial particularly in areas suffering scarcity of water.Many mentioned literatures abovehas been donewith the mulch materials on the surface of soil. A very little works only made with geotextile under the surface layer of the soil. In addition, the geotextile mats never usedto catch the water during irrigation process in the top layer of sandy soils and re-feeding again the soil by waterin dry conditions.Therefore, the objective of this workwas to use the geotextile mats to enhance the distribution of water and salinity using sprinkler irrigation system under sandy soil conditions.

Materials and methods

The experimental work was carried out at private farm, Al-Tahreir (30.42.45 N, and 30.35.06 E), Al-Beheira Governorate, Egypt during 2012 winter growing season. Navel orange trees were defined randomly in the experimental plots. The distances between the trees and rows are 5×5 m, and the number of trees were 400 trees.ha^{-1}. The total amount of applied irrigation water was calculated for each treatment.The metrological data including maximum and minimum temperature, relative humidity, solar radiation, sunshine hours and wind speed were collected from agricultural research station at the site of the experiment. Different physical properties of the experimental site were determined according to (FAO, 1976) and (Black, 1983) and its values are presented in Table 1. The bulk density "P_d" was determined using the core method to a depth of 75 cm according to (Klute, 1986).

Characteristics of Geotextile Mats

The geotextile is a kind of synthetics material used in geotechnical and civil engineering applications. Geotextiles are mainly made from polyolefin, are light in weight and strong but cheap. Hence, the fabric is produced, by paving the filament net and concretion method. Its fibreis arrayedin a three-dimensional structure. Besides its fine mechanical characteristics, it has a chemical stability like fine drainage capacity in both directions, good capacity of elongation and high biology tolerance, alkali tolerance, acidity tolerance, weather resistance etc. Meanwhile, it has wider pore size, devious holes distribution, good permeability, and filtration. The geotextile mats are used for filtration purposes in water conservancy projects and slope protection projects as well as for the reinforcement and drainage in projects of earth slope and retaining walls. Thus, the technical characteristics of the geotextile mat are listed in Table 2. This material was buriedhorizontally at two different depths of 20 and 40 cm in the root zone around the trees.

Water Application Efficiency

Water application efficiency "E_a" was calculated for each treatment according to (Israelsen and Hansen, 1962) using the following formula:

$$E_a = \left[\frac{w_s}{w_f}\right] \times 100 \qquad (1)$$

Whereas, E_a : water application efficiency in %, W_s : stored water within irrigation in mm, and W_f : depth of water delivered to the irrigated area in mm.

Water Consumptive Use

Water consumptive use "C_u"was computed as the difference between soil moisture content before and after irrigation according to (Israelsen and Hansen, 1962) as follows:

$$Cu = \left[(\theta 2 - \theta 1) \times Pd \times D\right] / 100 \qquad (2)$$

Whereas, C_u : water consumptive use in m^3.ha^{-1}, $\theta 2$: soil moisture content (dry basis) after 24 hours in %, $\theta 1$: soil moisture content (dry basis) before irrigation in %, P_d : soil bulk density in g.cm^{-3}, and D : soil depth in cm.

Reference Evapotranspiration and Crop Coefficient

It was estimated using metrological data for the site of the experiments. However, the modified Penman method was used to calculate the evapotranspiration E_{tp}" as follows:

$$E_{tp} = c\left[(w \times Rn) + (1 - w) \times f(u)(ea - ed)\right] \qquad (3)$$

Whereas, E_{tp} : reference crop evapotranspiration in mm.day^{-1}, C : adjustment factor to compensate the effect of day and night weather conditions, W : temperature related weighting factor, Rn : net radiation in equivalent evaporation, mm.day^{-1}, $f(u)$: wind related function, and $ea - ed$: the difference between the saturation vapour pressure of mean air temperature and the mean actual vapour pressure of the air.

Therefore, the actual evapotranspiration was estimated as follows:

$$E_{tc} = E_{tp} \times k_c \qquad (4)$$

Whereas, E_{tc} : actual evapotranspiration, mm.day^{-1}, E_{tp} : potential evapotranspiration, mm.day^{-1}, and k_c : crop coefficient, dimensionless.

Water Use Efficiency

Water use efficiency "WUE" was calculated as reported by (Michael, 1978) as follows:

$$WUE = \frac{Y}{W_r} \qquad (5)$$

Whereas, Y : yield, kg.fed^{-1}(fed is national unit areaand its value equal 4200 m^2, 1 ha = 2.38 fed),and W_r : water delivered to the field, m^3.fed^{-1}.

Results and discussions

Soil Moisture Content

The average values of moisture content in different treatments were calculated throughout the root zone. The results revealed that the maximum value of moisture content was achieved when the mat was placed at 20 cm depth in different irrigations whilst the minimum value of the moisture content was recorded with the control treatment (without mats). Broadly, the results showed an increase in moisture content in the case of using mats. Data presented in Fig. 1 show that the highest net soil moisture content of 9.10% was obtained with the treatment of a mat depth at 20 cm in the second irrigation, whilst the lowest percentage of 4.33% was recorded with the control treatment in the second irrigation. The figure obviously demonstrates the effect of the geotextile material depth on moisture content at the first irrigation, second irrigation, and third irrigation. However, this increase in water availability can fundamentally increase crop productivity through decreasing soil salinity in the root zone.

Table 1. Different physical properties of the soil of the experimental site.

Depth, cm	*0-25*	*25-50*	*50-75*
Sand, %	82.05	86.92	89.87
Silt, %	10.31	8.29	6.07
Clay, %	7.64	4.79	4.06
P_d , g.cm^{-3}	1.40	1.52	1.56
Porosity, %	46.15	41.54	40.00
Field Capacity, %	14.00	13.31	12.05
Soil texture	sandy	sandy	sandy

Table 2. Technical characteristics of the geotextile mat.

Item	*Technical properties*
Width, m	4
Mass, g.m^{-2}	150±10%
Thickness, mm	1.7
Tensile strength, kN.m^{-1}	7.5
Tensile elongation, %	30-80

Soil Salinity

The average values of soil salinity were affected by the depth of the material under sprinkler irrigation (Table3). The soil salinity was a minimum value (0.94 dS.m^{-1}) in the layer from 25 - 40 cm using geotextile at 40 cm depth. Also, the maximum value of salinity

(1.4 dS.m^{-1}) was recorded at a layer depth from 0-25 cm in the case of treatment without mats. The average values of soil salinity were 1.10, 1.17 and 1.38 dS.m^{-1} using mats at 20, 40 cm depth and control (without mats), respectively.

Application Efficiency

Application efficiency for the first, second and third irrigations, at different mat depths is presented in Fig.2. The highest value of application efficiency was 99.6% obtained using mats placed at 20 cm depth in the second irrigation, while the lowest application efficiency of 94.7% was recorded with the control in the first irrigation. Generally, the highest application efficiency was recorded with mats placed at 20 cm depth in all irrigations. The higher application efficiency may have been the result of higher availability of moisture content in the root zone.

Table 3. Effect of using the geotextile mat on soil salinity in the root zone.

Treatments	Soil salinity, dS.m^{-1}		
	0-25	25-50	50-75
20 cm depth	1.20	0.95	1.15
40 cm depth	1.27	0.94	1.31
Control (without mats)	1.40	1.35	1.39

Table 4. Effect of the geotextile mat on the number of dropped fruits and yield.

Treatments	No. of dropped fruits.tree^{-1}	Yield, kg.tree^{-1}	Yield, Mg.ha^{-1}
20 cm depth	85	68.90	27.6
40 cm depth	84	67.00	26.8

Yield and Water Relations

Data listed in Table 4 demonstrated the number of dropped fruits and yield of orange at all treatments. However, the greatest number of dropped fruits per tree was recorded with the control treatment (121fruit.tree^{-1}), followed by the treatment of mats at 20 cm depth (85fruit.tree^{-1}), and mats placed at 40 cm depth (84fruit.tree^{-1}). This may have been attributed to placing the geotextile mats at 20 cm and 40 cm, whichleads to increasein the availability of soil moisture content around the trees. The fruit yield was 24, 27.6 and 26.8 Mg.ha^{-1} for control, mats at depths of 20 cm and 40 cm, respectively. The highest fruit yield of 27.6 Mg.ha^{-1} recorded with mats placed at20 cm may be due to the optimal soil temperature and soil moisture content. Broadly, the placing of the geotextile mats at 20 cm depth enhanced fruit growth rates compared with the other depth at 40 cm.

Table 5. Effect of the geotextile mats on water relations and water use efficiency.

Treatments	Applied water, m^3.fed^{-1}	Water stored, m^3.fed^{-1}	Application efficiency, %	WUE kg.m^{-3}
20 cm depth	4755.84	3422.39	99.2	2.43
40 cm depth	4755.84	3511.39	97.0	2.37
Control	4755.84	3785.68	95.5	2.10

Water relations and water use efficiency of orange as influenced by the geotextile mats are presented in Table 5. It is obvious that water use efficiency "WUE" increasedusing the geotextile mats at 20 cm and 40 cm depths in comparison with the control treatment (without mats). The highest WUE of 2.44 kg.m^{-3}was recordedwith mats placed at 20 cm depth. Also, the lowest WUE(2.12 kg.m^{-3}) was recorded with the control treatment. The increases in WUE were mainly due to offering the optimal growth conditions that directly increase the fruit productivity. Additionally, the water uptake by orange trees increased as well as the water stored between soil layers. Therefore, the obtained results are in full agreement with the findings of Harris-Murray and Lal,(1979)and Mohsen *et al.*, (1999).

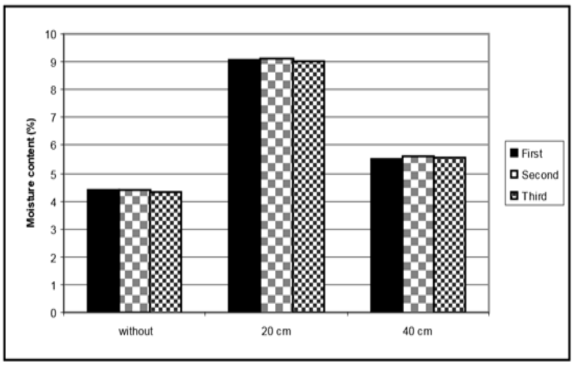

Fig. 1. Effect of the geotextile mats position on soil moisture content in the root zone during the first, the second and the third irrigation.

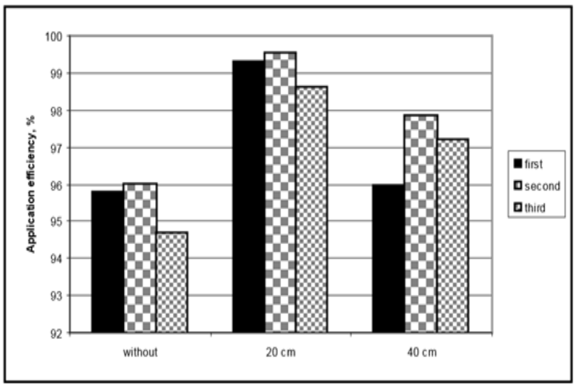

Fig. 2. The relationship between the geotextile mats position and the application efficiency during the first, the second and the third irrigation.

Conclusions

The obtained results from the present work could be summarized as follows:

The growers of citrus trees must keep the geotextile mats under the soil surface which led to increase in the availability of soil moisture content around the tree trunk in the upper soil layer, as well as to improve the productivity. Put the geotextile mats at 20 and 40 cm depth around the orange trees leads to decrease the salinity compared with the control treatment.Significant differences were observed when using the geotextile material at 20 and 40 cm depths on water use efficiency and crop yield.However, 20 cm depth is practically reasonable in terms of the cost to bury the material.This material can decrease the losses by deep percolation of irrigation water in sandy soil, which leads to increase in soil moisture content throughout the root zone of a tree. Therefore, it can be concluded that the geotextile matsare an effective way to decrease water losses, decrease the salinity in the upper soil layer and increase water productivity.

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