DETERMINATION OF ALFALFA'S EVAPOTRANSPIRATION WITH SUBSURFACE IRRIGATION

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ABSTRACT

Optimal use of water use in recent years is one of most important human problems. In this study Alfalfa's evapotranspiration was measured according to its activity in some cylindrical columns as laysimeter which their irrigation were carried out by some perforated pipes connected to some reservoirs. A gage with millimeter ruler was on each reservoir for measuring head of water in them.

Alfalfa (*Medica sativa*) was sawed in columns (25 cm diameter and 100 cm length) with clay-loam soil. All columns soil was filled by compaction (bulk density 1.35-1.39 gr per cm^3). A 3 cm sand layer (1.3-2.3 mm particle size) was laid at bottom of each column for draining and also in the top of all columns for reducing evaporation.

3 groups of treatments with internal treatments in each group were concerned. In group 1, soil column separated to 4 layers (20 cm soil and 3 cm sand layer and 0.5 cm wax layer (paraffin and Vaseline)). Sand and wax layer was for preventing water exchanging in soil layers. Four treatments (columns) were in group 1. In treatments 1 all four layers (*a*, *b*, *c* and *d* from top to down respectively) were irrigated with 4 perforated pipes connected by a plastic pipe to a reservoir (with 2 liter volume). In treatment 2, 3 and 4, layer *a*, *a* and *b* and *a*, *b* and *c* were not irrigated by reservoir respectively.

In group 2 (treatment 5, 6, 7 and 8) irrigation were the same as group 1, but there were not sand and wax layer in soil columns. In irrigating layers water content was around field capacity in unsaturated condition. In group 3, three columns (9, 10 and 11) were irrigated fully in columns 9, 80 and 60 present of soil water need for reaching to field capacity for columns 10 and 11, respectively. Soil water content in all columns was measured with Time Domain Refelectometeory (TDR). In groups 1 and 2 water consumption were measured with respect to differences in height of water level in each reservoir in deferent times and also with noting to water content difference. Results showed that, water consumed in group 1, was around 70 percent of its value in group 2. It was due to existence of sand and wax layer in group 1 that prevented water exchanging in their layers. But dry matter per wet matter (DPW) in group 1 and 2 were around 0.22 to 0.25.

In group 1, by drying upper layers water consumption in lower reservoirs increased. Also soil water content decreased in upper layers was lower compare to group 2. Use of subsurface irrigation with perforated pipes in greenhouse, by concerning that not having its application problems in field condition, can decrease water consumption and can prevent high humidity and as a result help us in pest and disease controlling.

Keywords: evapotranspiration, water requirement, subsurface irrigation, TDR and water stress.

INTRODUCTION

The need of water for human in is an important problem and countries pay more attention to water resources. Furthermore, optimal water consumption is very necessary with note to critical problems in water deficit. Irrigation systems affects on field hydrological conditions and also on root water uptake. Water requirement for each crop is different and optimal use of water can help us to increase irrigated levels. A method for decreasing water losses is preventing evaporation from soil. Some way such as mulch scattering on soil surface, irrigation with increasing water table in the field are applicable. The way of irrigation in this study is a type of partial root drying (PRD) technique (Davies et al [2], Saeed et al. [7], Kang and Zhang [4]).

PRD is a way to find optimal water need value which applicable in two methods. In first method, at first one part of root zone irrigates fore some days of irrigation period and then other part would be irrigated. But in second, one part of root zone was irrigated permanently. With PRD crop roots produces Abscisic acid and transfer it to shoots for growth control under stress condition. Depend on stress intensity (for example depth of root zone that under water stress), crop productivity would be deferent. Usually PRD lead to high water use efficiency (Davies et al. [2]). Stomata is preliminary crop device, adequate moisture and light are important factors of opening and closing of stomata and their low value (Liu et al. [5] ,[6]).

The main reason of decreasing water volume In PRD is due to decreasing leaf surface and number of opened stomata. There is an idea that crops can extract their water need only from a part of root zone. For exact investigation of this idea, soil columns were separated in group 1 with a compound wax (paraffin and Vaseline) around 0.5 cm and 3 cm sand layer (1.3-2.3 mm particles). This separation was for preventing water exchanging between soil layers of columns. Last studies showed that crop roots can easily pass through, wax layer without restriction (Albert et al. [1], Herkerlrass et al. [3]).

The main goal of this study was using of subsurface irrigation treatments with and without sand and wax layer for characterizing share of each layers root in crop water need and so if soil moisture in some parts of root zone be adequate the other parts of root zone could provided total need of evapotranspiration of crop.

9 soil columns with subsurface irrigation were irrigated according to planned water stress regime. Evaporation was low because of sand layer on top of all columns. Irrigation was done with perforated pipes which connected to some reservoirs.

Also for comparing to gravitational irrigation some columns were irrigated from top with and without deficit irrigation. With measuring water consumption in each layer which was under irrigation, other layers water consumption

Alfalfa was sawed in eleven columns (25 cm diameter and 100 cm depth) with clay-loam soil. All soil columns compacted to generate bulk density around 1.35-1.39 (gr/cm^3). Before water stress application all columns were irrigated normally. 4 month later and two cut period, the water stress was applied. For better draining and evaporation preventing, 3 cm sand layer was set at bottom and top of each columns.

Some water was uptake from perforated pipes and little from changing soil moisture content. Total water consumption was measured in each soil layers from their reservoir water head differences and also with respect to soil moisture differences. By using these values the need of water characterized in some cases and a pattern of root water uptake in no stress and stress conditions was found.

Water consumption in gravitational irrigation columns, was calculated according to total irrigation water volume and soil moisture content differences.

3 groups of treatments with internal treatments in each group were concerned. In group 1, soil column separated to 4 layers (20 cm soil and 3 cm sand layer and 0.5 cm wax layer (paraffin and Vaseline)). Sand and wax layer was for preventing water exchanging in soil layers. Four treatments (columns) were in group 1. In treatments 1 all four layers (*a, b, c* and *d* from top to down respectively) were irrigated with 4 perforated pipes connected by a plastic pipe to a reservoir (with 2 liter volume). In treatment 2, 3 and 4, layer *a, a* and *b* and *a, b* and *c* were not irrigated by reservoir respectively. (Figure 1)

In group 2 (treatments 5, 6, 7 and 8) irrigation were the same as group 1, but there were not sand and wax layer in soil columns. In irrigating layers water content was around field capacity in unsaturated condition. In group 3, three columns (9, 10 and 11) were irrigated fully in columns 9, 80 and 60 present of soil water need for reaching to field capacity for columns 10 and 11, respectively.

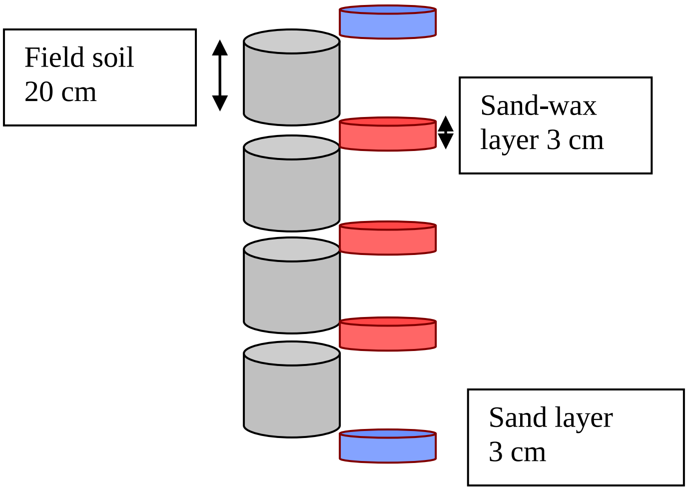

Figure 1 Arrangement of set up of soil layers (gray) and sand-wax (red) and sand layers (blue) in experiment columns (group 1)

Soil water content in all columns was measured with Time Domain Refelectometeory (TDR, TRASE model *6050X1*, soil moisture crop company, California). In groups 1 and 2 water consumption were measured with respect to differences in height of water level in each reservoir in deferent times and also with noting to water content difference.

In all irrigation layers of groups 1 and 2, water uptake by soil suction was due to of root water extraction and also due to water movement from their reservoirs that were connected to perforated pipes.

In subsurface irrigated layers, soil moisture was around readily available water points and roots could uptake water from soil with low energy consuming and no restriction for this root in water uptake were not be expected.

Soil moisture was measuring in each layer with a burialable wave guide and some wave guides were connected to TDR with a multiplexer. An autolog option in TDR menus enabled us to measure water content at times that we planned.

Measuring soil water content in all layers of each column enable us to determine exact water consumption in each layer with different water content at different times. Sand layer in column with and without wax could prevent water exchange between each layer with lower and upper layer because of low hydraulic conductivity of sand compare to clay-loam soil.

For characterizing capillary rise effect on redistribution of water at upper parts of soil columns, RWU of each layer in group 1 (with layered soil) was compared with its value in other columns in group2 and 3. Downward water movement under the effect of sand and wax layer only could if the upper soil layer is saturated and the wax be cracked. Because low hydraulic conductivity of sand compare to clay-loam soil prevent downward water moving. In other words because of high adhesive force between clay-loam soil particle and water compare to gravitational force on water, water moving to down would be omitted. This phenomenon was accurate if wax layer been damaged because of cracking or high weight of upper layers and some physical forces. By the way total water consumed in each layer and columns was calculated by measuring soil moisture and difference water head in each reservoir that connected with each layer. Furthermore, shoot wet material and root wet material were measuring after each cut (drying in oven at 75 degree Celsius for 48 hours). As whole, parameters such as soil moisture differences and water heads differences in each irrigating layers were measured and also wet and dried shoot mass and the dimensionless parameter, Dry mater Per Wet mater (DPW) was calculated in each cut period. these factors were measured in some periods include two conditions, first when water stress apply from initial stage of alfalfa growth (after cutting) and second when water stress apply two week after cutting. In all columns nutrient application was same and was according soil need that characterized after soil chemical analyzing. In order to summarization we represent two periods from of 6 cutting periods. Period 5 was adapted on initial stage of stress application and period 7 was adapted in developing stage stress application.

CONCLUSION

Comparing root water uptake in period 5 showed that alfalfa can growth normally with drying around 75 percent of its root zone. However soil moisture in residual part (25 percent) must be at optimal water moisture conditions around field capacity (treatment 4).

With application of water stress on layers *a*, *b* and *c*, the water content of these layers decreased by root water uptake until reached wilting points (12 percents). Then, water content of these layers was constant and crop consumed its water need from lower wet parts which were irrigated permanently as long as cutting period. Intensity of consumption from reservoirs increased more than when upper layers were wet in initial time of this period. This causes to high value water consumption in layer *d*.

Water consumption mechanisms in layers *c* and *d* in treatment 3, also layers *b*, *c* and *d* in treatment 2 were same as layer *d* in treatment 4.
This result was taken after investigation dry matter per wet matter (DPW) in group 1, which soil layers were separated so each layer water consumption value really was belonged to its layer.

Water consumption mechanisms in group 2 were different from Water consumption mechanisms in group 1, because water could exchanged between layers due to not existence of sand and wax layer in this group columns. DPW in this group were measured same as DPW in group 1.

In period 7 (after seventh alfalfa cut), water stress was applied after 14 days of growth of alfalfa from cutting. In all groups, the DPW in this period was more than its value in period 5, because in this period water stress was applied after initial stage which alfalfa is very damageable. In other word, alfalfa could adapt itself with water stress via developing stage than initial stage. But in all condition whether or not water stress applied from initial or developing stage, DPW of both of them increased with water stress intensity (or number of under water stress layers). In group 1 and 2, with increased stress layer numbers from treatment 2 to 4 (Figures 2 and 3) water consumption was decreased.

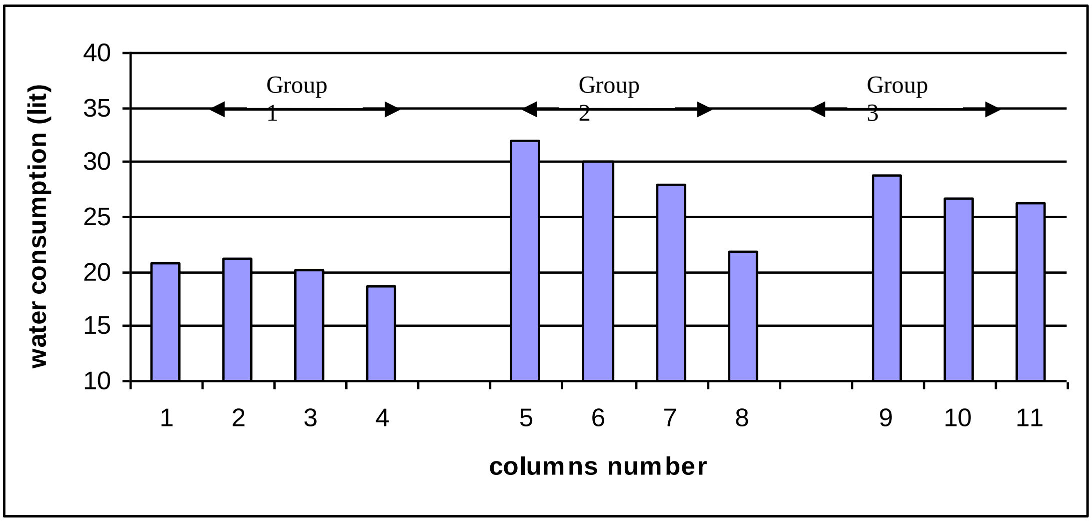

Figure 2 Water consumption in groups 1, 2 and 3 for period 5

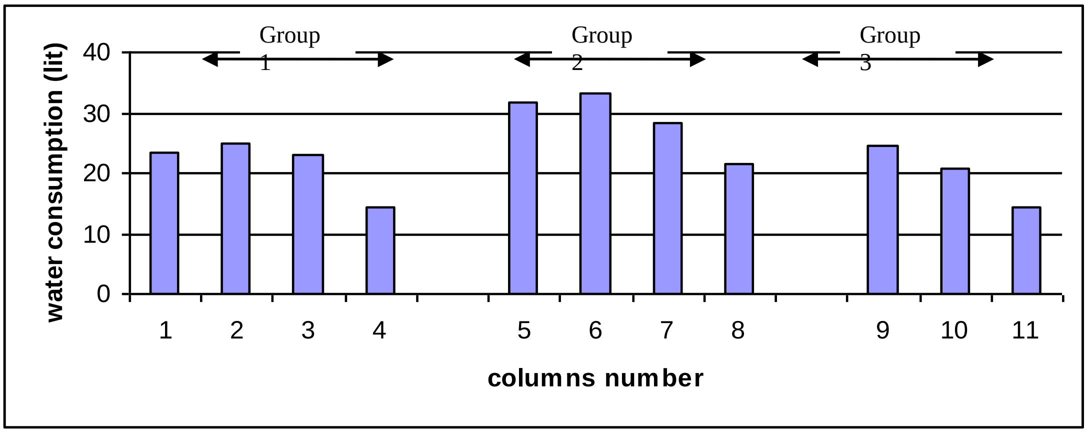

Figure 3 Water consumption in groups 1, 2 and 3 for period 7

Average value water consumption in group 1 was about 75 percent compare to its value in group 2 and 3 for period 5. It was for existing sand and wax layer in treatment group 1 which prevented water exchanging in soil layers, especially between wet layer and its upper dry layer. The intensity of this phenomena increased with respect to that dense root that usually develop in upper parts of root zone and in group 1 they were restricted and they could not to suck water from wet layers.

But about group 2 water consumption in both periods was not different. Because capillary force could exchange water from wetter layer to dry water and root could uptake water more than its need to produce DPW in compare to group 1 in both periods.

This also caused preventing probably water evaporation from top of layer *a*. however a three cm sand layer was on the top of each column for preventing evaporation. Furthermore, with no water exchanging between lower and upper layers, water content of low layers changed little and as a result little water consumed from their reservoirs. This was for lower hydraulic gradient between perforated pipes and wetter soil in columns of group 1 in compare to columns of group 2 in both period 5 and 7.

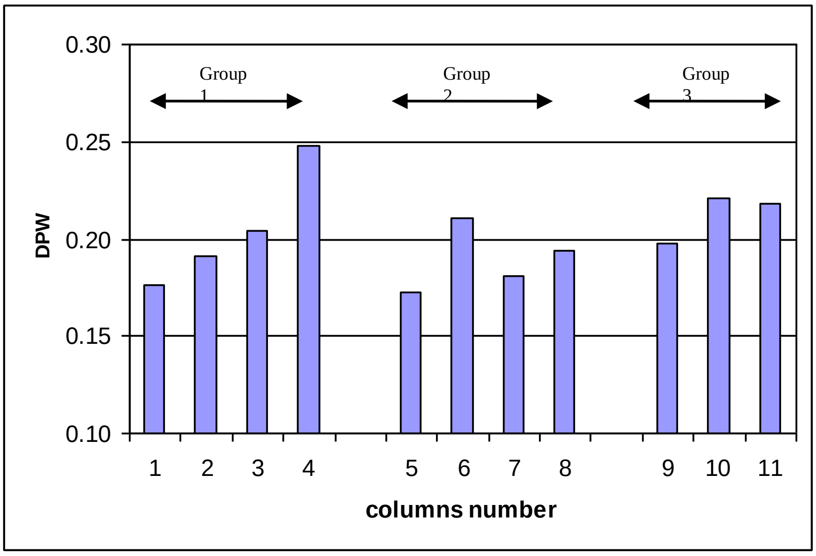

Figure 4 Dry matter Per Wet matter (DPW) in groups 1, 2 and 3 for period 5

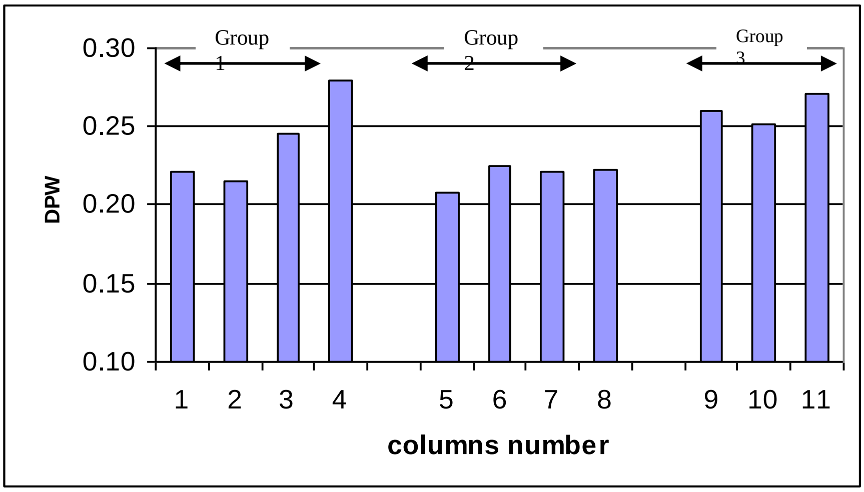

Figure 5 Dry matter Per Wet matter (DPW) in groups 1, 2 and 3 for period 7

Comparison of DPW for group 1, 2 and 3 showed that regardless of internal difference of DPW (because of differences in water consumption value) DPW in period 7 was more than DPW in period 5 in all three groups. It was for water added to columns before water stress application (day 14 day from cut) in period 7.

Figure 5 showed that in period 7 after 14 days that water moisture was at optimal condition in all columns, alfalfa could adapt its water stress that was applied after developing stages. In period 7, DPW in all columns was higher than 0.2, but in period 5, DPW in most of columns was lower than 0.2.

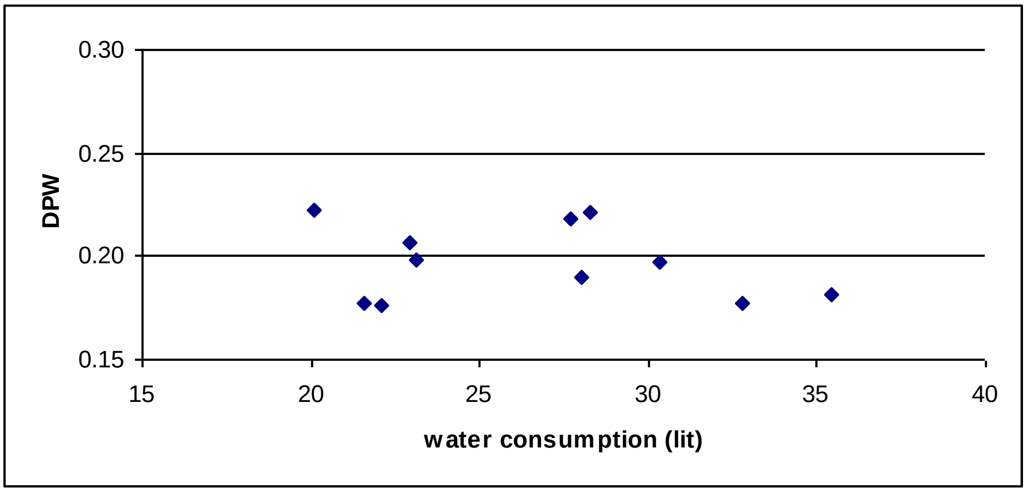

Figure 6 DPW and total water consumption in groups 1, 2 and 3 for period 5

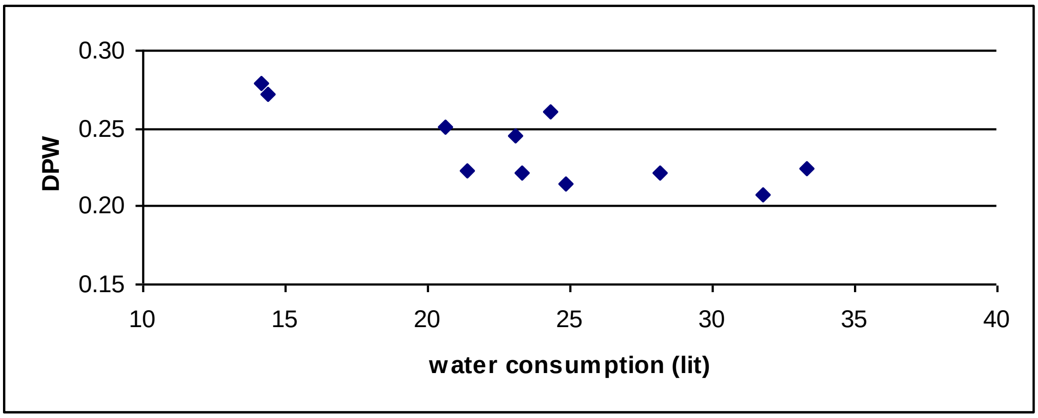

Figure 7 DPW and total water consumption in groups 1, 2 and 3 for period 7

Calculated water consumption before applying water stress and its value at the end of each period was done with measuring water content along all cutting periods and calculating water consumption in all reservoirs. (Figures 6 and 7)

Calculated Water consumptions showed that around 8 percent of water consumption of all columns was from decreasing water content in soil layers.

In treatment 4 and 8 (and also in 2, 3 and 6, 7) alfalfa could extracted its necessity water from wet layer by its lower dense (scattered) root in layer *d*, again it dense root upper layers that were dried. This is probably for that alfalfa could increase its low dense root layer uptake capability to extract water from wetter part of soil columns.

These phenomena could be named "compensation water stress by increasing uptake activity in low dense roots".

It is proposed that in future this phenomenon be researched with real data as that we obtained in separated root zone at least with sand layers.

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