Nominee Statement

Mahdi Sarai Tabrizi, assistant professor at the Department of Water Engineering, Science and Research Branch, Islamic Azad University, has been working on evaluating and improving measurement of crop water requirement for more than 3 years (since 2014). The interesting results obtained in this research can be used in arid and semi-arid regions with not only the least cost and equipment but also with precision, simplicity and water saving of about 10%.

1. Describe the innovation

Water scarcity and non-accurate measurements of crop water requirement create serious problems for agricultural water management in arid and semi-arid regions. Therefore, the proposed drainage-weighted micro-lysimeter is designed considering simplicity and accurate measurement of crop water requirements based on water and soil balance equation with available and relatively cheap equipment compared with the two common measuring methods (theta probes and pan evaporation methods) and is tested in the greenhouse (indoor) and pot and field studies. The results under indoor conditions (greenhouse) and outdoor conditions (pot study) and in field conditions were investigated and the superiority of this method in field conditions to the other two measurement methods was proven.

For development of the proposed micro-lysimeters first, three 10 liter buckets were chosen and one drainage hole was made. Next a domestic thick hose from each bucket was passed through the hole and connected to a small bucket with a lid. Then the 10 liter buckets were filled with one layer of coarse sand soil three centimeters thick and then covered with a soil passed through 200 mm sieve (Figure 1).

Figure 1. Construction, soil preparation and filling stages in the proposed micro-lysimeter

After comparing the three measurement methods with each other in pot study level, this study was conducted in a one-hectare experimental field with irrigation management scenarios including full irrigation treatment (FI) and three deficit irrigation treatments ($DI_{80\%}$, $DI_{60\%}$, and $DI_{40\%}$) at 100%, 80%, 60% and 40% of crop water requirement based on percentage of mean full crop water requirement of micro-lysimeters respectively in two agronomical years 2015 and 2016. During the entire growing season every twelve hours (6 am and 6 pm) micro-lysimeters and within the content of drainage water collected was weighed and drain water quality was measured using portable EC meter. This method for estimating crop water requirement was done based on water and soil balance, the theta probes method based on the soil moisture deficit compensation method, and the third method based on measuring evaporation from class-A pan evaporation method from the local synoptic station (Doshan Tappeh station) (figures 2).

Figure 2. View of the proposed micro-lysimeter, Theta probes, and U.S. class-A pan evaporation methods used in experimental farm

In micro-lysimeter and theta probes methods, first, the amount of crop-absorbable moisture should be calculated [Eq. 1] and then irrigation should be applied when the moisture reaches that level.

$$\theta_{CEC} = \theta_{FC} - (\theta_{FC} - \theta_{PWP}) \times MAD \quad (1)$$

in which θ_{CEC} is the crop available-moisture volume, θ_{FC} is the volume moisture at field capacity, θ_{PWP} is the volume of moisture at permanent wilting point and *MAD* is the maximum allowable depletion.
The depth of irrigation water was determined by using Eq. [2]. The rate of maximum available depletion (MAD) is considered to be 30 % (Ekren *et al.,* 2012).

$$I = (\theta_{FC} - \theta_{PWP}) \times MAD \times D_{rz} \quad (2)$$

in which *I* is the irrigation water depth and D_{rz} is root zone depth.
The amount of crop water requirement is calculated by using soil and water balance equation [Eq. 3].

$$ET_c = I - D_d - R_o \pm \Delta S \quad (3)$$

where ET_c is the crop water requirement, D_d is the drain water depth, R_o is the depth of runoff and ΔS is the rate of changes in soil moisture storage.
In class-A pan evaporation method, daily climatic data was used to calculate reference evapotranspiration (ET_o) by FAO-Penman-Montith equation and crop coefficient (K_c) was determined using ETc obtained by micro-lysimeter and ETo obtained using FAO-P-M reference evapotranspiration. Eventually the ET_c of class-A pan evaporation method was obtained using the equation below (Eq. [4]).

$$ET_c = E_{pan} \times E_d \times K_c \quad (4)$$

where E_{pan} is the coefficient of evaporation and E_d is the amount of daily evaporation from class-A pan evaporation.

2- Describe how the innovation saves water

Because this method estimates real crop water requirement directly compared to the other two common methods which do this indirectly, it can save irrigation water by about 10%. In addition, it can be beneficial in deprived areas which have limited facilities. In this research, the amounts of actual basil evapotranspiration and basil yield were measured by using three basic measurement methods both in pot and in field studies. The results indicated that not only the most basil yield but also the least water consumption was obtained using the first measuring method (micro-lysimeter method).

Table 1. The summary of statistical results for basil yield and actual basil evapotranspiration in three replications

Measurment of Method	Measured basil Evapotranspiration (mm) (Pot Study)				Basil Yield (g/pot) (Pot study)			
	Standard deviation	Max.	Mean	Min.	Standard deviation	Max.	Mean	Min.
class-A pan evaporation	0.307	545.800	545.447	545.240	2.285	64.980	62.540	60.450
Theta Probes	10.592	543.210	532.090	522.120	0.763	65.700	65.067	64.220
Micro-lysimeter	1.676	490.740	489.317	487.470	2.393	71.310	68.620	66.730

Table 1 indicated that the proposed micro-lysimeter had the most basil yield with the least consumption water. Table 2 shows the percentages of the reduction of water consumption in comparison to the two other crop water requirement measuring methods and the increase in crop yield.

Table 2. The amounts of the changes of water consumption and basil yield in three measuring methods

Method	Water Consumption (%)		Basil Yield (%)	
	Theta Probes	class-A pan evaporation	Theta Probes	class-A pan evaporation
Micro-lysimeter	-8	-10	5	10

Note: The positive sign shows the amount of increase and negative sign shows the amount of decrease.

In spite of the reduction in water consumption in micro-lysimeter method by about 10%, in relation to evaporation pan and theta probes method, crop yield was increased by about 10% (Table 2). The results of significant analyses are shown in table 3.

Table 3. The analysis results of the amounts of water consumption and basil yield in three measuring methods by T-test

Method	P_{value} -Water Consumption		P_{value} -Basil Yield	
	Theta Probes	class-A pan evaporation	Theta Probes	class-A pan evaporation
Micro-Lysimeter	0.002 at a 1% probability level	< 0.0001 at a 1% probability level	0.070 Non-significant (ns)	0.033 at a 5% probability level

The results indicated that this proposed drainage-weighed micro-lysimeter estimated less crop water requirement than evaporation pan and theta probes methods based on T-test and observed data. This result is an important achievement and presents four very important advantages for sustainable usage of farm water resources in arid and semi-arid regions:

1- Low cost (construction cost is one tenth of the cost of theta probes set)

2- The evaporation pan method needs a minimum standard area and it is an indirect method but the proposed micro-lysimeter is direct and can be installed in the farm and does not need a minimum standard area.

3- In evaporation pan and theta probes methods, data gathering and data recording need calibration of measurement instruments and is not very easy for farmers but preparation and operation of this micro-lysimeter are very easy for all farmers to learn.

4- The accuracy of theta probes set depends on soil type and is recommended for sandy soils but this micro-lysimeter is very easy to use in all types of soil textures.

3- Describe how the innovation was introduced and spread

This experiment is designed, considering the essential need to estimate actual crop water requirement for more accurate and suitable irrigation scheduling to achieve maximum crop yield with the optimum water consumption in arid and semi-arid regions. Therefore, the two methods of estimating crop water requirement were compared to the proposed micro-lysimeter method. The results indicated that this proposed method in addition to advantages of simple installation, easy usage and cheaper cost, can reduce water consumption up to 10%. In comparison with theta probes method, crop yield was increased and had a significant difference at 5% probability level. The proposed micro-lysimeter in this method can be constructed with minimum cost compared to the theta probes method that needs expensive soil moisture sensors and hi-tech equipment and be used more accurately in arid and semi-arid regions.

4- Describe the scope for further expansion of the innovation

To expand this innovation, these three crop water requirement measurement methods were tested in one hectare in the years of 2015 and 2016. The results indicated that the proposed method is best method for minimum irrigation water consumption and maximum basil yield and yield components under full and deficit irrigation conditions (Table 4). This method can be very effective in saving cost and water consumption in large areas in poor and under developed countries and is a practical method almost everywhere.

Table 4. Analysis of basil yield and yield components under full and deficit irrigation conditions in the agronomical years of 2015 and 2016

Micro-lysimeter Method

Treatments	green herb yield (Kg/ha)	drug herb yield (Kg/ha)	drug leaves yield (Kg/ha)	Leaf Area Index (mm^2)	Plant height (Cm)	Essential oil ratio (%)	Number of minor stem (dimensionless)	Number of leaves (dimensionless)
FI (100% CWR)$_{2015}$	5998^{a}	3782^{a}	3306^{a}	85861^{a}	84^{a}	0.81^{c}	29.3^{a}	127^{a}
DI$_{80\%}$ (80% CWR)$_{2015}$	3348^{b}	2298^{b}	2056^{b}	71488^{b}	72.2^{b}	0.87^{b}	23.6^{b}	118.5^{b}
DI$_{60\%}$ (60% CWR)$_{2015}$	2699^{c}	1754^{c}	1463^{c}	63521^{c}	66.4^{c}	0.88^{b}	20.2^{c}	110.5^{c}
DI$_{40\%}$ (40% CWR)$_{2015}$	2333^{d}	1221^{d}	729^{d}	54132^{d}	54.7^{cd}	0.97^{a}	15.4^{cd}	100^{d}
FI (100% CWR)$_{2016}$	5966^{a}	3698^{a}	3379^{a}	85853^{a}	86.2^{a}	0.81^{c}	31^{a}	128.5^{a}
DI$_{80\%}$ (80% CWR)$_{2016}$	3357^{b}	2304^{b}	2091^{b}	71441^{b}	73.6^{b}	0.87^{b}	24.2^{b}	119.6^{b}
DI$_{60\%}$ (60% CWR)$_{2016}$	2709^{c}	11721^{c}	1488^{c}	63496^{c}	68.5^{c}	0.88^{b}	21.5^{c}	112.4^{c}
DI$_{40\%}$ (40% CWR)$_{2016}$	2312^{d}	1191^{d}	756^{d}	54069^{d}	55.9^{cd}	0.91^{a}	17.1^{cd}	102.8^{d}

Theta probes Method

Treatments	green herb yield (Kg/ha)	drug herb yield (Kg/ha)	drug leaves yield (Kg/ha)	Leaf Area Index (mm^2)	Plant height (cm)	Essential oil ratio (%)	Number of minor stem (dimensionless)	Number of leaves (dimensionless)
FI (100% CWR)$_{2015}$	5232^{a}	3292^{a}	3114^{a}	85600^{a}	76^{a}	0.79^{bc}	27.5^{a}	121^{a}
DI$_{80\%}$ (80% CWR)$_{2015}$	3188^{b}	2008^{b}	2015^{b}	71228^{b}	70.2^{ab}	0.8^{b}	22.3^{b}	111.2^{b}
DI$_{60\%}$ (60% CWR)$_{2015}$	2239^{c}	1414^{c}	1322^{c}	63121^{c}	60.4^{c}	0.82^{b}	19.4^{bc}	102.1^{bc}
DI$_{40\%}$ (40% CWR)$_{2015}$	2113^{c}	1091^{d}	695^{d}	54012^{d}	49.7^{d}	0.90^{a}	13.2^{c}	98.4^{c}
FI (100% CWR)$_{2016}$	5218^{a}	3261^{a}	3097^{a}	85587	75.1^{a}	0.78^{c}	26.8^{a}	118^{a}
DI$_{80\%}$ (80% CWR)$_{2016}$	3171^{b}	2002^{b}	1988^{b}	71194^{b}	70^{ab}	0.79^{c}	22.5^{b}	110.5^{b}
DI$_{60\%}$ (60% CWR)$_{2016}$	2227^{c}	1409^{c}	1303^{c}	63065^{c}	59.6^{c}	0.82^{bc}	18.9^{bc}	100.1^{c}
DI$_{40\%}$ (40% CWR)$_{2016}$	2096^{d}	1083^{d}	685^{d}	53969^{d}	48.9^{d}	0.89^{a}	13.2^{d}	97.9^{c}

U.S. class-A pan evaporation method

Treatments	green herb yield (Kg/ha)	drug herb yield (Kg/ha)	drug leaves yield (Kg/ha)	Leaf Area Index (mm^2)	Plant height (Cm)	Essential oil ratio (%)	Number of minor stem (dimensionless)	Number of leaves (dimensionless)
FI (100% CWR)$_{2015}$	5205^{a}	3232^{a}	3080^{a}	85540^{a}	74^{a}	0.71^{c}	24^{a}	118^{a}
DI$_{80\%}$ (80% CWR)$_{2015}$	3145^{b}	1955^{b}	2000^{b}	70200^{b}	65.5^{b}	0.73^{c}	21.5^{ab}	107.5^{b}
DI$_{60\%}$ (60% CWR)$_{2015}$	2200^{c}	1400^{c}	1315^{c}	63004^{c}	58.2^{c}	0.77^{bc}	18.4^{b}	100^{c}
DI$_{40\%}$ (40% CWR)$_{2015}$	2025^{c}	1055^{d}	670^{d}	53028^{d}	46.5^{d}	0.95^{a}	10.5^{c}	92.6^{d}
FI (100% CWR)$_{2016}$	5197^{a}	3166^{a}	3076^{a}	85540^{a}	75.2^{a}	0.69^{c}	22.8^{a}	114.8^{a}
DI$_{80\%}$ (80% CWR)$_{2016}$	3084^{b}	1894^{b}	1965^{b}	70200^{b}	64.8^{b}	0.71^{c}	20.1^{a}	105.9^{b}
DI$_{60\%}$ (60% CWR)$_{2016}$	2175^{c}	1398^{c}	1287^{c}	63004^{c}	57.6^{c}	0.76^{bc}	17.5^{b}	98.5^{c}
DI$_{40\%}$ (40% CWR)$_{2016}$	2004^{cd}	1006^{d}	624^{d}	53028^{d}	45.1^{d}	0.87^{a}	10.2^{c}	89.2^{d}

Based on Duncan's multiple range test, treatments shown with the same letter are not significantly different.