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Optimum Water Management of Pitcher Irrigation under Iraqi Extreme Climatic Changes

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Abstract - An optimum water management study based on field test of pitcher irrigation system has been conducted to assess the amount of water demand for many local agricultural plants in Iraq and adoption the strategic scenario to irrigate water necessary for plant tissues provided that plant production is unaltered.

It is found that the hydraulic head more than 0 is not necessary to be used in pitcher irrigation system to supply the field with necessary water demand in this management study. Moreover, the maximum oozing water rate from clay jar is occurred in sandy soil

The field measurement study proved that the relationship of water oozing rates versus the applied hydraulic heads is linear in sandy and mixture soil and nonlinear in clayey soil.

Keywords: Clay Jar, Pitcher Irrigation, Oozing Water, Water Demand (WD), Water Consuming Rate (WCR)

1. Introduction

Monda (1976), Das (1983) and Bainbridge (2001) outline that Pitcher irrigation is a traditional system of irrigating plants and considered several times more efficient than a conventional surface irrigation system. Whereas Charles et al (1996) indicates that Micro-irrigation techniques can be used to improve irrigation efficiency on vegetable gardens by reducing soil evaporation and drainage losses. They carried experiments during 1985-1995 to evaluate the micro-irrigation technique. It is found that subsurface irrigation using clay pipes is particularly effective in improving yields, crop quality, water use efficiency, cheap, simple and easy to use. Good results were also obtained with subsurface irrigation when irrigation was carried out using poor water quality.

Altaf et al (2009) study the patterns and extent of soil wetting obtained by small and large pitchers. The work addresses three pitcher sizes: 20L, 15L, and 11L with pitcher walls hydraulic conductivity ranged between 0.07 to 0.14 cm/day. After 10 days water content at location 0, 20, 40, and 60cm away from pitcher center obtained by HYDRUS_2D simulation model found to be in the range 0.004-0.023.

Hossein M. (2014) estimated the water use efficiency for fruit yield of cucumber and watermelon, under furrow and clay pitcher irrigation methods. Field experiments are conducted to quantify crop water productivity (CWP) the considered crops. The comparison of the CWP of cucumber and watermelon indicates that in clay pitcher irrigation the CWP is 4.91 and 4.79 times as big as the furrow irrigation, respectively. Total fruit yield is 2.5 kg per plant for pitcher irrigation and 2.04 kg per plant for furrow irrigation methods. The watermelon fruit harvesting stage is 55 days from 16 June to 10 August. Total fruit yield is 8.61 kg per plant for pitcher irrigation and 7.86 kg per plant for furrow irrigation methods.

Padma (2007) indicates that "water flow through the pitcher is seen to be regulated by soil water tension, the magnitude of which increases with temperature and decreases with humidity. In the areas where temperatures are very high and other methods of irrigation fail, pitcher or clay pot irrigation can be a promising alternative due".

Najah (2014) A micro auto regulative irrigation technology has been examined in Iraqi soils namely *Hyro-Osmotic Irrigation System HOPIS*. Experimental field measurements have been conducted to investigate the physical Wetting front advance behavior (issued from ceramic jar) through three types of soil; they are clayey, sandy, and mixture of (40%clay, 40%sand and 20% fertilizer) soils under the effect of a variable hydraulic head of (2.5m). It is indicated that the Wetting front reaches a distance of 12.5cm with velocity 6 cm/hr after 6.5hrs since irrigation process is started under hydraulic heads of 2.5m respectively in clayey soil. It reaches a distance of 6cm, 13m, and 15cm with velocities less than 1cm/hr after 6.5hrs since irrigation process is started under hydraulic heads of 2.5m respectively in sandy soil. Whereas it reaches a distance of 12.8cm with velocities less than 0.35cm/hr after 12hrs since irrigation process is started under the same hydraulic heads in a mixture soil. Fahdil M. A. (2010) experimentally quantifies the effects of pot volume on water use efficiency and surface wetting front. Two types have been examined; large and small pot volume. The results show that large volume pot is more efficient than small pot. In this research the volume of clap pitchers is fixed to 8 liters to evaluate the oozing water occurrence to satisfy the WD in the vicinity of the pitchers.

2. Research Significant & Problem Dimensions

In recent decades, particularly Iraq country endures the problem of water changes as the extreme temperature rise in summer, frequent dusty storms, water scarcity, terroristic circumstances and searching for other alternatives of water resources become an inevitable challenge. Pitcher Vessels (clay jars) proves to be a fantastic auto regulative technology to save and oozes the needed water to plants roots wherever and whenever it is necessary meanwhile plant production is unaltered

3. Water management of Pitcher Irrigation System

The well-considered water management of pitcher irrigation system requires:

3.1 Estimation of Water Consuming Rate (WCR)

The estimation of WCR requires a serious field measurement to assess the amount of water to be oozed and consumed from the jars; water demand assessment and irrigable area surrounded the jar. Anyway the estimation of oozing water for special equipment to be arranged for the purpose of WCR estimation.

3.1.1 Device Arrangement & Setup

Once, the clay jar is setup by inserting it in the field soil before it has been connected to water tank by a suitable plastic pipe. The top of jar is close with a ceramic cover fixed by Mastic Polystyrene. The jar cover is provided with air escape valve to dispose the air bubbles before starting the volume of oozing water estimation. After the system has been installed the oozing water volume with time are recorded instantaneously. Fig.(1) presents the setup of the oozing jar category.

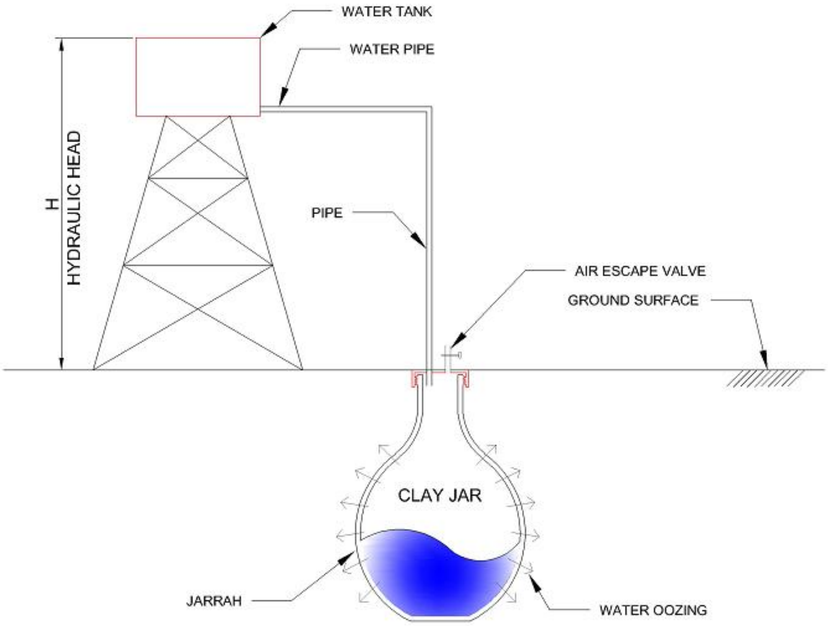

Fig.(1) Jar System Setup

3.1.2 Soil Textures Testing

Three soil textures have been used to evaluate water oozing through; they are :-

1- Clay:

A pure clay soil with a natural dry density of 15.39KN/m^3 is used.

2- Sand:

A river sand with natural dry density of 16.7 KN/m^3. The sieve analysis results for the sand are tabulated in Table (1).

Table (1) Sand Gradation

Sieve Diameter, mm	10	4.75	2.36	1.18	0.6	0.3	0.15
Passing by Weight %	100	98.5	97	96	95	94.5	93.5

3- Mixture:

Soil mixture of (40% clay, 40% Sand and 20% Fertilizer) is also used as a case study.

3.1.3 Osmotic Clay Jar Properties

Clay Jar represents the major unit in the current irrigation process. Briefly, it consists of two parts as shown in Fig.(1):-

1- Scorching clayey vessel (jar).
2- Ceramic or plastic cover with water divider.

In this technology, it is suggested to paint the lower parts of the clay jar to prevent downward deep percolation. See Fig.(1). Briefly, the volume of the tested clay jar is 8 liters with 2cm wall thickness and the wall hydraulic conductivity of 0.3 cm/day as tested.

3.1.4 Field Experimental Results of Oozing Water & Analysis

The water oozing from the jar is clearly affected by the surrounding soil. It is obviously suggested to use three types of soil under three hydraulic heads of (h=0m, 1.25m and 2.5m).

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1- Clay Soil

Fig.(3) shows the volume of water consumed from the jars with time in clayey Iraqi soil under extreme high temperature of 48c°. It is found that linear fitting curves between the consumed water and the elapsed time under the three considered head.

In order to find the Water Consuming Rate (WCR) the fitted equations presented in Fig.(1) are differentiated with respect to time to estimate WCR which is included in Table (2).

2- Sand Soil

Fig.(4) presents the water volume consumed in sandy soil which in turn offers the amounts of WCR which is tabulated in Table (2)

3- Mixture Soil

Fig.(5) presents the water volume consumed in mixture soil which in turn offers the amounts of WCR as shown in Table (2).

Table (2) WCR, Liter/hr

Soil Type	h= 0m	h=1.25m	h=2.5m
Clay	0.967	1.598	3.128
Sand	1.254	2.26	3.364
Mixture	1.046	2.1029	3.177

The WCR with the hydraulic Head Variation are presented in Fig.(5).

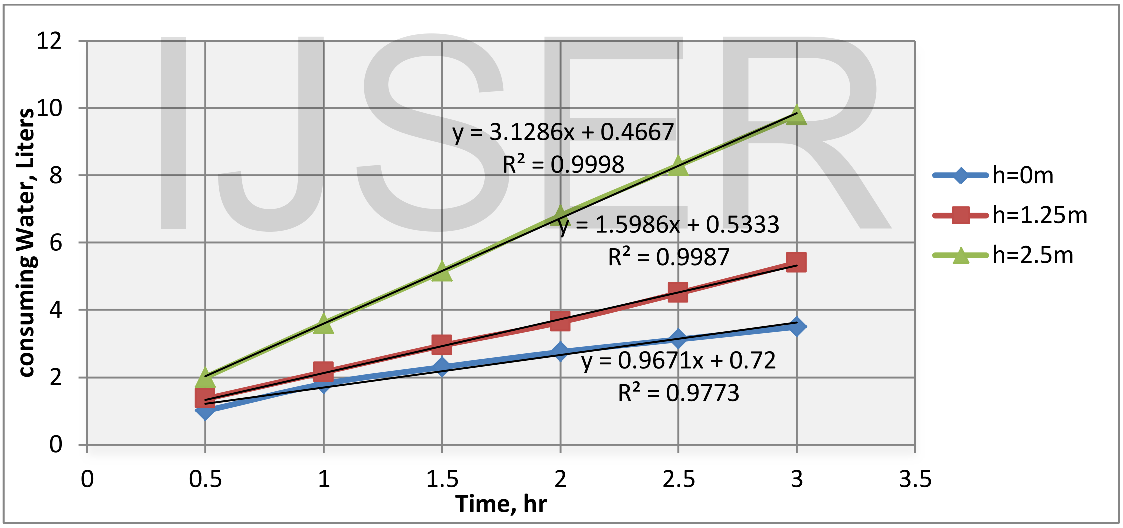

Fig.(2) Oozing WCR from a Single Jar in Clay Soil

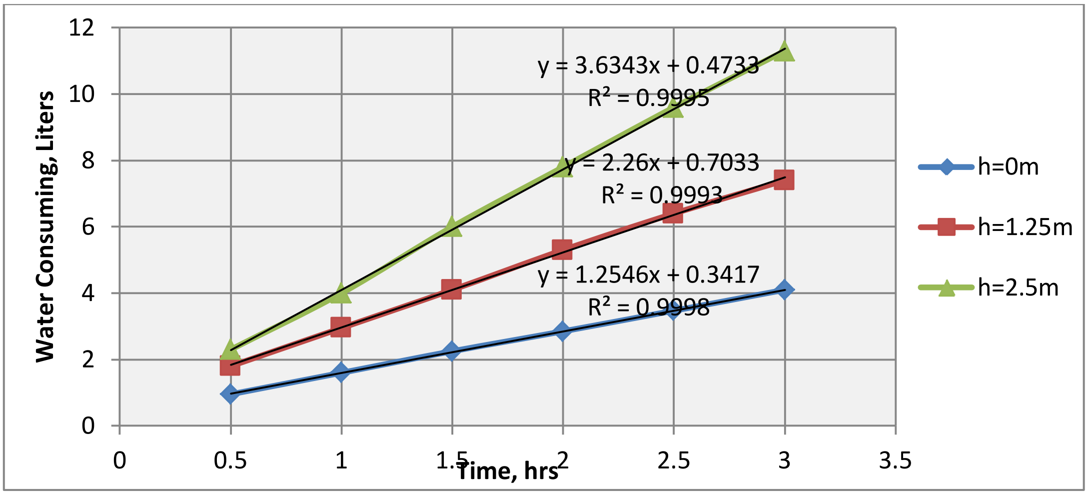

Fig.(3) Oozing WCR from a Single Jar in Sandy Soil

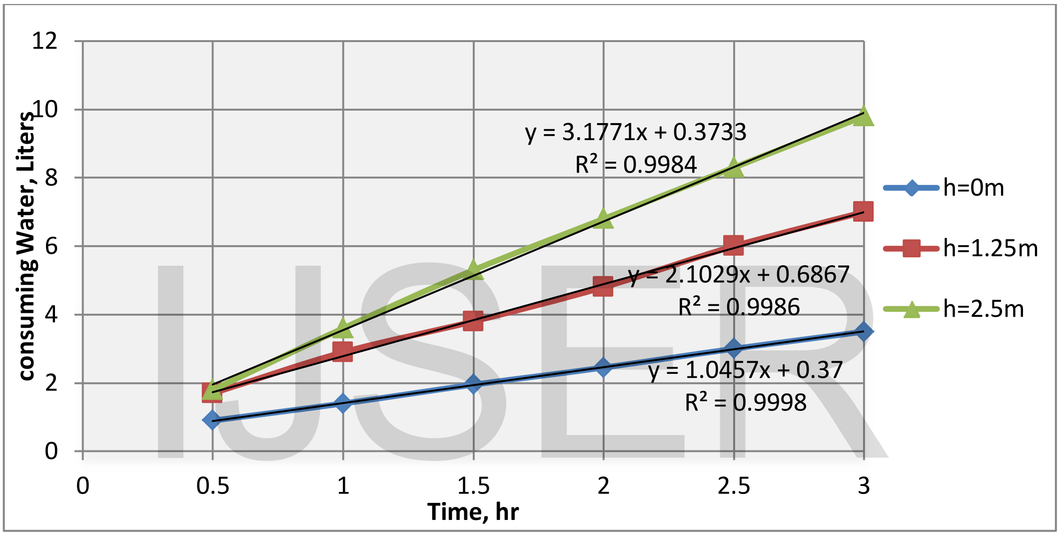

Fig.(4) Oozing WCR from a Single Jar in Mixture Soil

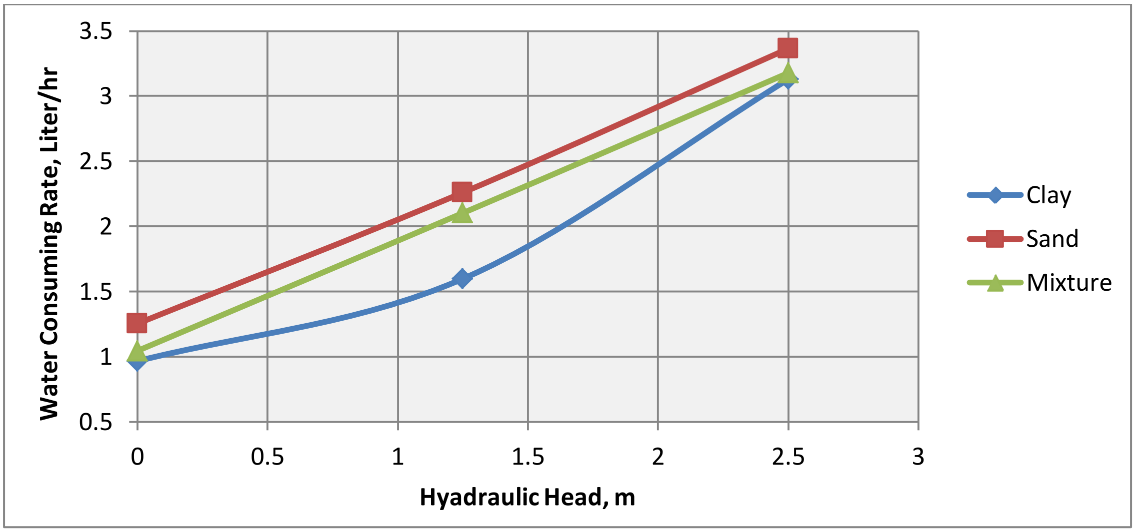

Fig.(5) WCR versus Hydraulic Head variation

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3.2 Water Demand (WD) Assignment of Jar's Area

In general, water demand depends mainly as outlined by many researchers on the evapotranspiration, local plant crops which are collected and listed in Table (3) and the irrigable area of the corresponding single jar.

Table (3) Evapo-Transpiration & Crop Coefficients in Iragi Extreme Climatic Changes

	Evapotra (mm)	Wheat	Barley	Cotton	Sunflower	Corn	Vegetable	Orchard
OCT	168	0.00	0.00	0.00	0.00	0.50	0.70	0.70
NOV	82	0.00	0.58	0.00	0.00	0.50	0.70	0.70
DEC	52	0.40	0.77	.00	.00	.00	0.50	0.50
JAN	41	0.80	1.01	0.00	0.00	0.00	0.50	0.50
FEB	55	1.20	1.14	0.00	0.00	0.00	0.60	0.60
MAR	101	1.20	1.12	0.6	0.58	0.00	0.80	0.80
APR	154	1.00	0.82	1.00	0.68	0.00	0.80	0.80
MAY	236	0.50	0.00	1.10	0.84	0.00	0.80	0.80
JUN	279	0.00	0.00	1.20	1.02	0.00	0.09	0.09
JUL	312	0.00	0.00	1.2	0.49	1.00	1.00	1.00
AUG	284	0.00	0.00	1.20	0.00	1.00	.90	0.90
SEP	223	0.00	0.00	1.00	0.00	0.80	0.90	0.90

3.2.1 Irrigable Jar's area estimation

Experimental field results of the irrigable jar area made by Najah (2014) are shown in Table (4). The table presents the radii of the inners and outers boundaries of the irrigable areas for clay, sand and mixture soils. Fig.(6) shows the inner and outer boundaries radii. Briefly the considered area can be calculated by Eq.(1)

Area (between R_{in} and R_{out}) $= \pi(R_{out}^2 - R_{in}^2)$ ....(1)

Table (4) Irrigated Areas

Soil Type	Jar Radius (cm)	Extreme Wetting Front Radius (cm)	Irrigable Area (m^2)
Clay		50	0.660
Sand	20	35	0.259
Mixture(Clay+Sand+Fertilizer)			

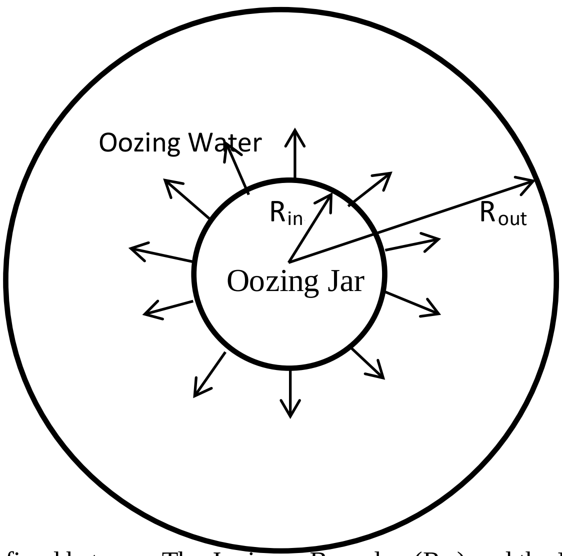

Fig.(6) Irrigable Area confined between The Jar inner Boundary(R_{in}) and the Extreme Wetting Front Bondary(R_{out})

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3.2.2 WD Estimation

The amount of the evapotranspiration as presented by Blaney- Criddle is used to estimate the WD (Israelsen & Hansen, 1962). Accordingly, equations (2, 3, 4 and 5) which reflect the effects of plant tissues and evaporation water need are employed:

$$E_o = k'\ f \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

In which,

$$f = p\,(0.46\ ^{\circ}c + 8.14) \qquad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$k' = 0.0311\ ^{\circ}c + 0.24 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

and

$$U = K_c\ E_o \qquad \ldots\ldots\ldots\ldots\ldots\ldots..(5)$$

Where:

E_o : potential evapotranspiration, mm/month, P : yearly percentage of monthly day light
C : average monthly temperature, $^{\circ}c$, K_c : crop coefficient, and U : monthly crop consumptive use, mm/month.

The estimated monthly WD are listed in Tables (6 & 7).

3.3 Water management Consideration

To achieve the management of irrigation water in pitcher irrigation properly, the measured water supply rates of Table (5) should be prepared. Whereas the estimated monthly WD in clay soil Table (6) and monthly WD of Table (7).

Table (5) Measured WCR of Jars, liter/month

h(m)	Clay Media	Sand Media	Mixture Media
0	696.312	903.312	752.904
1.25	1150.992	1544.4	1514.088
2.5	2252.592	2422.296	2287.512

The good cogitation of Tables (5, 6, &7) one concludes that the monthly WD for all plant crops can be satisfied by the oozing water of the jars at hydraulic head of h=0m. This leads us to insure that the use of hydraulic heads more than zero is not necessary.

Table (6) Monthly WD of Clay Soil (per Jar' Area) , liters/month

	Evapotra (mm)	Wheat	Barley	Cotton	Sunflower	Corn	Vegetable	Orchard
OCT	168	0	0	0	0	55.44	77.616	77.616
NOV	82	21.648	31.3896	0	0	10.824	27.06	27.06
DEC	52	27.456	26.4264	0	0	0	17.16	17.16
JAN	41	32.472	27.3306	0	0	0	13.53	13.53
FEB	55	43.56	41.382	0	0	0	21.78	21.78
MAR	101	66.66	74.6592	39.996	38.6628	0	53.328	53.328
APR	154	50.82	83.3448	101.64	69.1152	0	81.312	81.312
MAY	236	0	0	171.336	130.8384	0	124.608	124.608
JUN	279	0	0	220.968	187.8228	0	165.726	165.726
JUL	312	0	0	247.104	100.9008	205.92	205.92	205.92
AUG	284	0	0	224.928	0	187.44	168.696	168.696
SEP	223	0	0	147.18	0	117.744	103.026	103.026
Total		242.61	284.532	1153.15	527	577	1059.76	1059.76

Table (7)Monthly WD of Sand and Mixture Soil (per Single Jar), liters/month

	Evapotra (mm)	Wheat	Barley	Cotton	Sunflower	Corn	Vegetable	Orchard
OCT	168	0	0	0	0	21.756	30.4584	30.4584
NOV	82	0	12.3180	0	0	4.2476	10.619	10.619
DEC	52	5.3872	10.3703	0	0	0	6.734	6.734
JAN	41	8.4952	10.7251	0	0	0	5.3095	5.3095
FEB	55	17.094	16.2393	0	0	0	8.547	8.547
MAR	101	31.390	29.2980	15.6954	15.1722	0	20.9272	20.9272
APR	154	39.886	32.7065	39.886	27.1224	0	31.9088	31.9088
MAY	236	30.562	0	67.2364	51.3441	0	48.8992	48.8992
JUN	279	0	0	86.7132	73.7062	0	6.50349	6.50349
JUL	312	0	0	96.9696	39.5959	80.808	80.808	80.808
AUG	284	0	0	88.2672	0	73.556	66.2004	66.2004
SEP	223	0	0	57.757	0	46.2056	51.9813	51.9813
Total	1987	132.8144	111.6572	452.5248	206.9408	226.5732	368.8963	368.8963

Note: WD for sand and mixture soils are the same since they have equal irrigable areas.

3.4 Irrigation Schedule Preferences

It is preferred to use a weekly irrigation schedule to avoid the water shortage for plant needs and get away from wilting point and fulfilling a maximum production, therefore and to be in safe side it is suggested to change the monthly WD of Tables (6 & 7) into weekly WD as indicated in [Table (8) & Fig.(7)] and [Table (9) & Fig.(8)].

Table (8) Irrigable Water Schedule for Clayey Soil (per Single Jar), liter/week

	Evapotra (mm)	Wheat	Barley	Cotton	Sunflower	Corn	Vegetable	Orchard
OCT	168	0	0	0	0	14	20	20
NOV	82	6	8	0	0	3	7	7
DEC	52	7	7	0	0	0	5	5
JAN	41	9	7	0	0	0	4	4
FEB	55	11	11	0	0	0	6	6
MAR	101	17	19	10	10	0	14	14
APR	154	13	21	26	18	0	21	21
MAY	236	0	0	43	33	0	32	32
JUN	279	0	0	56	47	0	42	42
JUL	312	0	0	62	26	52	52	52
AUG	284	0	0	57	0	47	43	43
SEP	223	0	0	37	0	30	26	26
Total	1987	63	73	291	134	146	272	272

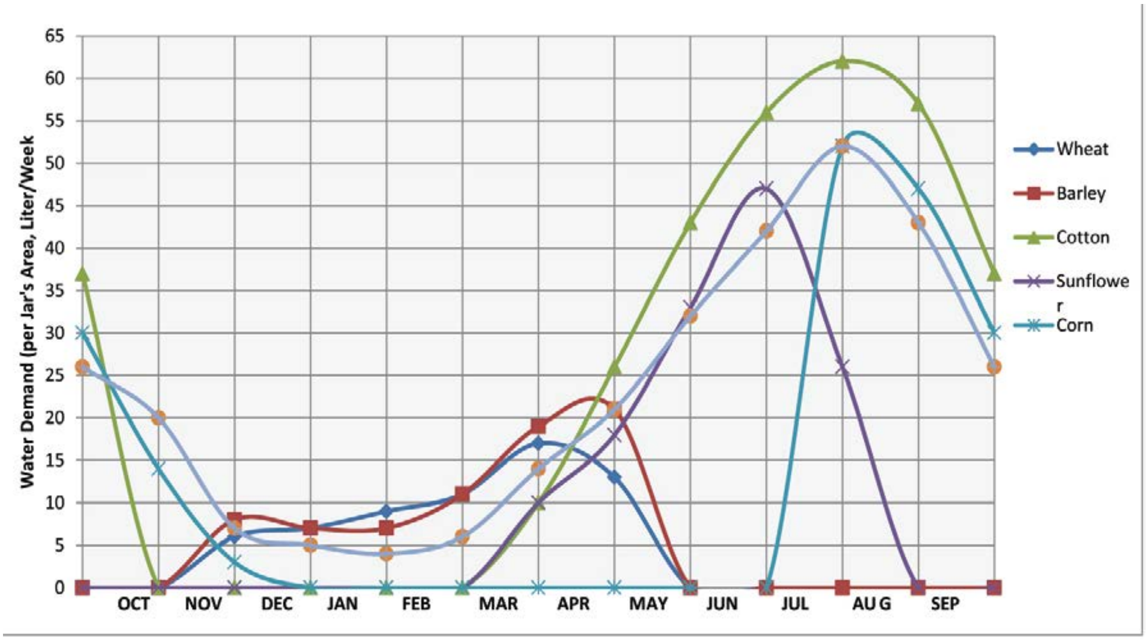

Fig.(7) Weekly WD in Clay Soil (Per Single Jar), Liter/week

Table (9) Irrigable Water Schedule for Sand & Mixture Soil (per Single Jar), liter/week

	Evapotra (mm)	Wheat	Barley	Cotton	Sunflower	Corn	Vegetable	Orchard
OCT	168	0	0	0	0	6	8	8
NOV	82	0	4	0	0	2	3	3
DEC	52	2	3	0	0	0	2	2
JAN	41	3	3	0	0	0	2	2
FEB	55	5	5	0	0	0	3	3
MAR	101	8	8	4	4	0	6	6
APR	154	10	9	10	7	0	8	8
MAY	236	8	0	17	13	0	13	13
JUN	279	0	0	22	19	0	2	2
JUL	312	0	0	25	10	21	21	21
AUG	284	0	0	23	0	19	17	17
SEP	223	0	0	15	0	12	13	13
Total	1987	36	32	116	53	60	98	98

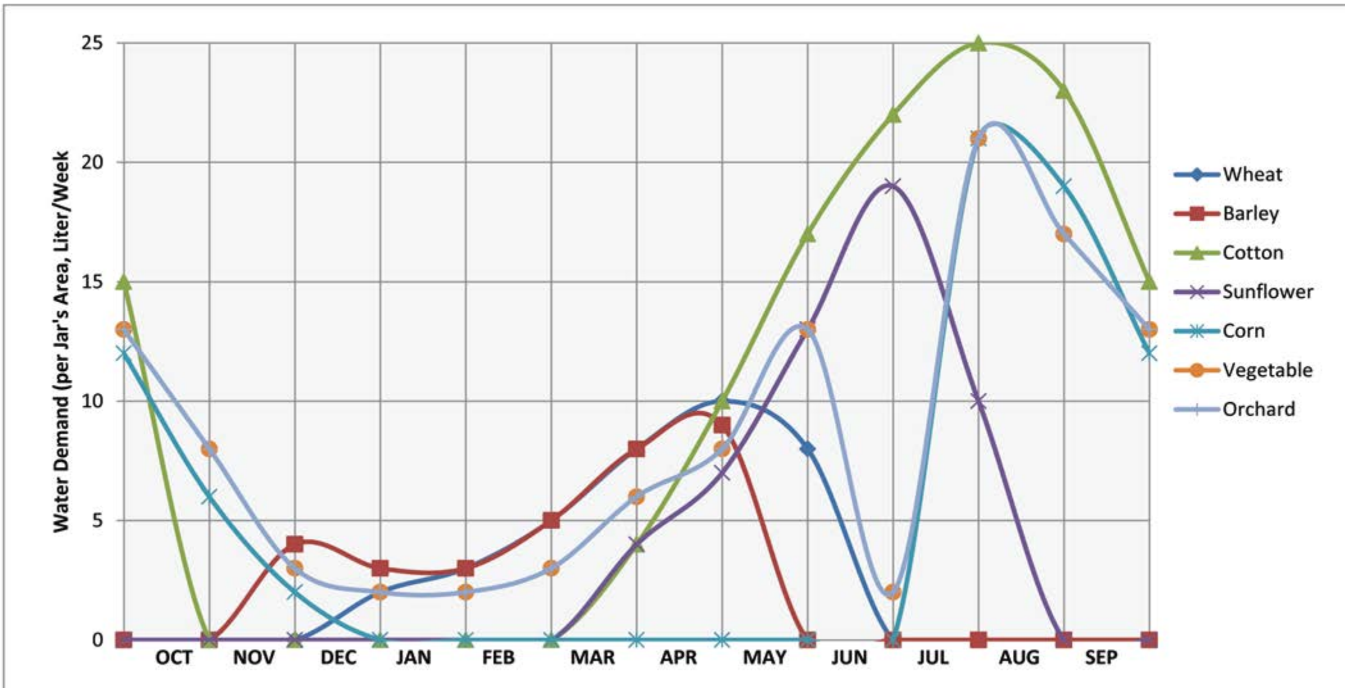

Fig.(8) Weekly WD in Clay Soil (Per Jar's Area), liter/week

3.5 Operational Consideration

To facilitate the irrigation process under the light of the current study, the farmer consults tables (8 & 9) to estimate the weekly volume of WD for the whole farm area (depending on the used number of jars in the field). Accordingly, the farmer should provide the total weekly quantity of water in the storage tank for all jars within the field which are connected to the storage tank as shown in Fig.(9)

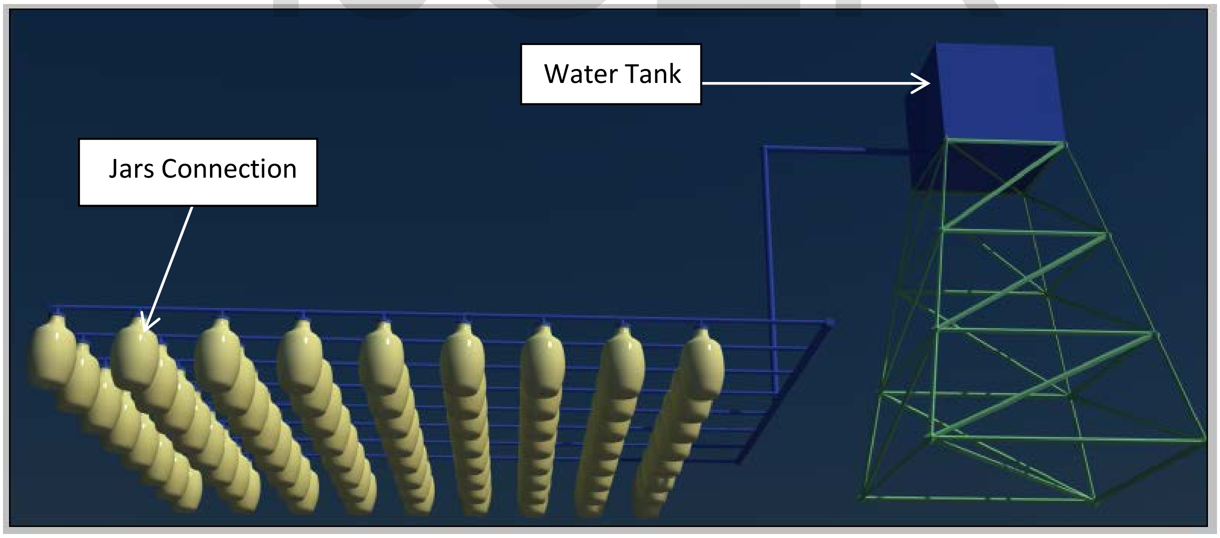

Fig.(9) Jars Connection with Water Tank

4. Conclusions

1- The hydraulic head more than 0 is not necessary to be used in pitcher irrigation system in this management study.
2- The relationship of water consuming rates with respect to the applied hydraulic heads is linear in sandy and mixture soils and nonlinear in clayey soil.

5. Recommendations

It is recommended to use the pitcher irrigation system using the local made clayey jar wherever and whenever water scarcity is dominant and the obtainability of water is too difficult.

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