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PITCHER OR CLAY POT IRRIGATION FOR WATER CONSERVATION

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ABSTRACT

Irrigation is a crucial input for growing plants and accounts for the high water demand in agriculture. Water conservation measures using techniques such as drip irrigation require significant investment. In this context buried clay pot irrigation which is a cost effective traditional technique, can be adopted for controlled irrigation. However, designing for controlled delivery of water through a clay pot, requires studies to correlate the rate of water flow from pitchers with its surfaces characteristics, hydraulic conductivity of the surrounding soil and soil water potential. These are controlled by climatic conditions such as temperature, humidity, rainfall and soil water availability. Some of these issues are discussed based on the measurements of water flow through buried clay pots over a period of several months covering different seasons.

Keywords: Clay pot, Water conservation, Irrigation.

1. INTRODUCTION

Irrigation may be defined in simple terms as supplying crops with water. More specifically, irrigation is the application of water (which could also be wastewater) to land areas to meet the water (and sometimes nutrient) needs of plants. Irrigation may be also defined as the application of water for cultural purposes through man-made systems to supply water requirements not satisfied by rainfall. Pitcher irrigation is a traditional system [1,2] of irrigating plants and considered several times more efficient than a conventional surface irrigation system [3]. This mode of irrigation was known traditionally in arid and semi-arid areas where besides acute water scarcity and extreme temperatures, problems of water and soil salinity have to be faced. This method of irrigation not only conserves water but also provides employment to the potters and labour.

1.1 Pitcher Irrigation: An Overview

This technique was being practiced in countries like India, China, Pakistan, Iran, Mexico, Brazil etc. to grow a wide range of annual and perennial plants. In India, the pitcher irrigation technique was revived by Mondal, Das and others [1,2]. Amongst many subsurface irrigation techniques available pitcher irrigation appears to be more economical and water saving [4].

Pitcher is a bottle like emitter made of porous baked-clay. When it is filled with water and buried into the soil it releases water through its wall into the surrounding soil. Water flow from the pitcher to the surrounding soil matrix is controlled by the permeability of the pitcher wall and soil suction gradient as normally expressed by Darcy law. In practice, generally the wall of the pitcher is in saturated condition; accordingly the suction gradient may be the main driving force controlling the water flow. Thus, this is a method for controlled release of water [2]. The soil suction itself changes in response to the evapo-transpiration process. The water diffuses through the pitcher or clay pot into the root zone and is absorbed by the plants.

The efficiency of irrigation depends on many factors including soil type, plant species, soil structure and soil fertility, weed competition, and site microclimate. Only a few scientific studies are available on pitcher irrigation relating to various controlling factors. There is still a lack of sufficient understanding of the system, which is necessary for evolving design criteria. In view of this studies have been conducted by the authors on the rate of water flow through buried pitchers under different climatic conditions. Some of these results are presented in this paper.

2. MATERIALS AND METHODS

A set of 6 pitchers (labeled 1-6) of almost the same volume (7.5-8.0 litres), surface area and height (about 30 cm) were taken and buried up to the neck at a selected plot on the ground at IIT, Delhi campus. The pitchers were closed with a tight fitting lid and covered by a plastic film to reduce evaporation from the exposed mouth of the pot (fig. 1). The water level was kept just below the neck and marked. The distance between the pitchers was 3 feet. There were two contiguous experimental plots (fig. 2). Plot I was 25 feet away from plot II. The experimental plot I housed pitchers 1-4 while the experimental plot II had pitchers 5 and 6. The experimental plots or the area did not have any other water source. One sapling each of plant *Tabernaemontana divaricata* (locally known as *Chandani*) was planted near each pitcher. The amount of water released from the pitcher was noted by measuring the volume required to fill the pitcher up to the marked level at the neck. The 24 hr average temperature and humidity was noted on daily basis from local meteorological data over the period, January to September 07.

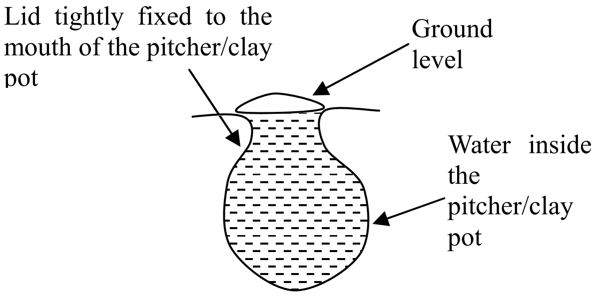

Fig 1: Schematic diagram of buried pitcher/clay pot

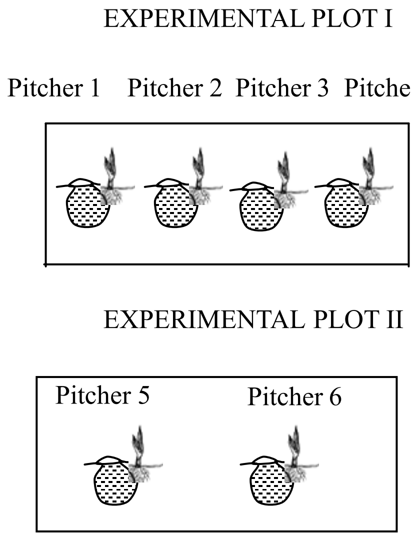

Fig 2: Relative location of pitchers

3. RESULTS AND DISCUSSION

The variation in the volume of water diffusing through the pitchers (1 to 6) with *monthly* average of temperature (T) and the relative humidity (H) over a period of 9 months (from Jan 07 till Sep 07) covering different climatic variations is shown in fig 3, fig.4 and fig. 5. T and H are shown by bars. In the same figure the line diagram depicts volume of water flow (scale indicated on the y axis to the right).

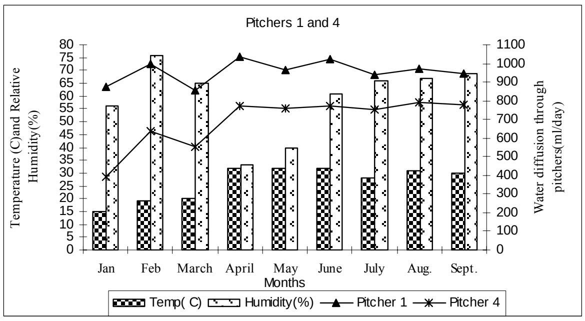

Fig 3: Effect of temperature and relative humidity on average diffusion of water through pitcher 1 and pitcher 4 (ml/day) from Jan-Sep, 07

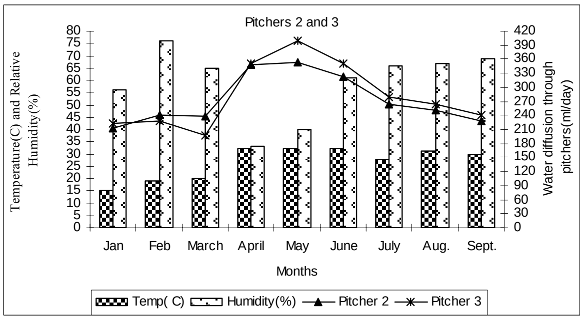

Fig 4: Effect of temperature and relative humidity on average diffusion of water through pitcher 2 and pitcher3 (ml/day) from Jan-Sep, 07

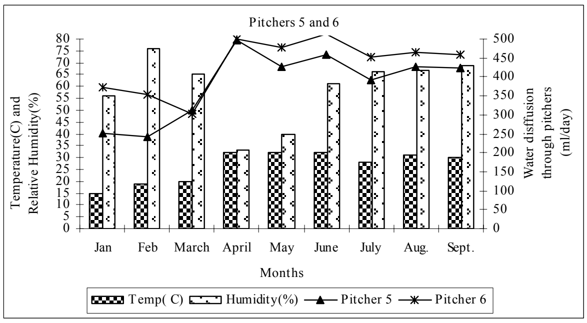

Fig 5.Effect of temperature and relative humidity on average diffusion of water through pitcher 5 and pitcher 6 (ml/day) from Jan-Sep, 07

From the above figures it is observed that the variations in the water flow rate over the months follow almost the same pattern for all the pots, however, the actual volume of water flow through pitchers differs significantly. Pitcher 1 allowed the highest flow followed by decrease in flow in the order 1>4> 5≈6>3≈2. The maximum water flow through the pots 2 and 3 was almost 4 times lower as compared to the flow through pitcher1. It may be noted that the pots were placed in the same locality and had almost the same volume, height and surface area. Since the climatic factors also remain the same for the pitchers, the variation of water diffused could be attributed to the soil porosity in the vicinity and pitcher porosity.

Further the period between January to September may be divided into 3 categories based on average temperature and humidity over this period. The water diffusion in the three periods (Jan-March, April- May and June-Sep, 07) is shown in table 1.

Table 1: Average volume of water diffusion through the pitchers (ml/day)

	T (°C)	H (%)	P1	P 2	P 3	P 4	P 5	P 6
Jan–March, 07	18	66	908	231	217	462	268	344
April–May, 07	32	37	1001	352	376	774	462	490
June-Sept., 07	30	49	969	266	285	764	425	473

T – Average temperature; H – Average humidity; P - Pitcher

January to March is the period with low temperature and high humidity. As compared to this April to May is marked by increase in temperature and decrease in humidity. June to September is the period with lower temperature and higher humidity as compared to April to May, but higher temperature and lower humidity as compared to Jan. to March.

From the above table it is evident that the maximum water diffusion is observed during April and May in all the pots which is the period with high temperature and low humidity followed by the period from June to September. The flow during January to March was the least, when the temperature was low with relatively high humidity. Since in the present study, the pots were completely buried inside the ground and covered with a plastic film held tightly, direct evaporation from the pot into air may be considered to be negligible. Hence, the factors that contribute to the water diffusion into the soil would be mainly soil water tension which in turn is governed by the atmospheric temperature and humidity. This is reflected by our data.

When there is a significant amount of rain the soil can get saturated to *field capacity*. Hence it is of interest to record the rain events and observe its impact on water release pattern. Fig. 6, 7 and 8 show the variation of water diffusion through the pitcher/clay pots to the soil in the months (Feb., March and June) when rain events occurred.

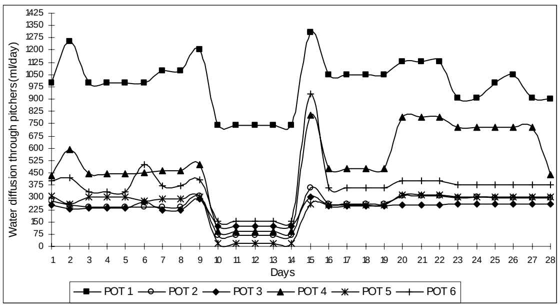

Fig 6: Water diffusion through the different pitchers in the month of February, 2007

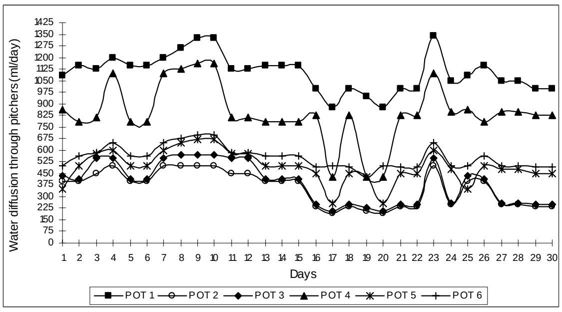

Fig 7: Water diffusion through the different pitchers in the month of March, 2007

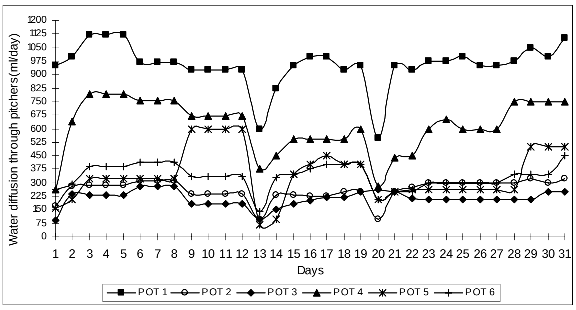

Fig 8: Water diffusion through the different pitchers in the month of June, 2007

It is evident form the fig. 6, fig. 7 and fig. 8 that during every rain event when the wall of the pitcher and the soil pores are both in saturated condition; there is a dip in the water diffusion through the pitcher walls. The actual volume of water released through the different pitchers during rainy days is shown in table 2.

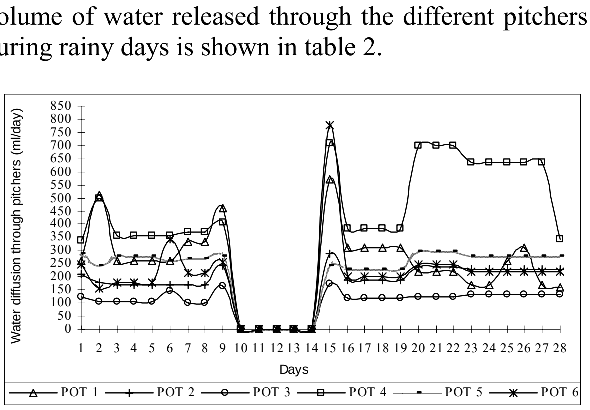

Fig 9. Water diffusion after subtracting the minimum value of flow for the month of February, 07

Table 2: Variation in water (ml) diffusion through the pitchers during rain events

Dates	Pitcher 1	Pitcher 2	Pitcher 3	Pitcher 4	Pitcher 5	Pitcher 6
February						
10th	740	92	126	155	70	20
11th	740	92	126	155	70	20
12th	740	92	126	155	70	20
13th	740	92	126	155	70	20
March						
13th	600	100	100	380	70	140
20th	550	100	260	280	210	210
June						
17th	875	190	210	430	260	500
20th	875	210	225	430	260	430

From these data it is evident that in the month of February, during a rain event, all the pitchers (1-6) showed a dip in the water flow with respect to their maximum. The minimum flow came down to 70-155ml/day except for the pitcher 1 that registered a flow rate of 740 ml/day in February and a minimum of 550ml/day in March. The minimum flow thus recorded was subtracted from the actual flow and these values are plotted in fig.9 for the month of february. It is seen that all the pitchers exhibit the same trend in day to day variation with a minimum at the time of rain followed by increase in flow reaching a maximum. These trends may be due to variations in the hydraulic conductivity of soils with moisture content. Water flow through pitcher 4 is somewhat different possibly due to different soil conditions due to presence of some gravel.

In table 3 the data on minimum flow at the time of rain event (from table2) and maximum flow in the summer months (from table1) obtained for the 6 pitchers are summarized.

Table 3: Difference between the maximum and minimum water flow recorded

Pitcher number	Maximum (April-May) (ml/day)	Minimum observed (Rain Event) (ml/day)	Difference (ml / day)
Pitcher 1	1001	550	451
Pitcher 2	352	70	282
Pitcher3	376	126	250
Pitcher 4	774	92	682
Pitcher 5	462	20	342
Pitcher 6	490	140	350

This minimum rate of flow may be attributed to water flow through macro pores when the surrounding soil is saturated with rain and hence does not exhibit suction. Scientific studies on the water release characteristics from the pitcher/clay pot are not many. Zreig et. al, 2004, 2006 [5,6] had reported the hydraulic conductivity of water through pitchers in saturated condition into *air*, but not into *soil.*

In soils there are 3 types of pores, transmission pores, storage pores and residual pores. *Transmission* pores are the ones the size having greater than 50μm. They are responsible for drainage after saturation of soil by water, for example after a rain event has occurred. The pores of the size 0.2-50μm are *storage* micro pores and are the ones responsible for holding the maximum water that can be drawn by the plants for their growth. The pores of the size below 0.2μm are the *residual* micro pores, which hold water but this water is not available for the plants [7]. The pore size distribution in pitcher walls may also be classified similarly.

In the case of pitcher 1, the high value for minimum flow may be due to more number of macropores present in the pitcher wall. Even minute cracks may be present. Due to this the overall flow through pitcher 1 is higher than that for others at all conditions. It may be noted that difference between the maximum and minimum rate flow is in the region 250 to 350 ml per day except for pitcher 1 and pitcher 4 (table3).

The difference between the maximum and minimum of flow may be attributed to the presence of storage pores (0.2-50 μm) in the soil as well as the pitcher wall. Further work is under way on the pore distribution and its effects on water flow. The level of decline during the rain event in different months shows that soil suction itself changes in response to the evapotranspiraton process. It is seen from the figures that in June and March, the rain events do not fully saturate the soil, leaving some storage pores of soil unfilled. This results in soil suction drawing more water from the pitchers than the amount drawn during a rain event in February where minimum flow was recorded.

Based on the above it may be surmised that when the wall of the pitcher is in saturated condition the macropores on pitcher are the main conduits for water flow. Mathai and Simon [8] studied pottery discs fabricated and baked by them, mixing clay with controlled variation in the quality and quantity of sand added and with and without addition of saw dust. The discs were baked at 1000°C to 1100°C for 50 hrs. From their optical micrographs, the discs are seen to have some macro pores of the size >50 μm and a number of micro pores (0.2-50 μm) corresponding in size to the storage pores. The authors also indicated that the porosity increased with particle size of the sand in the disc and also with increase in the organic matter used in the mix for the disc.

4. CONCLUSION

Pitcher irrigation seems to provide a good solution for controlled irrigation. The 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 to its self regulated water flow according to changes in soil water tension However in addition to this controlled flow, there may be a regular base line flow into the soil through the macro pores in the pitcher wall. This can be reduced by suitable measures for reducing the macropores at the time of fabrication of pitchers and consequent firing

5. ACKNOWLEDGEMENT

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