Possibility of Using Ceramic Pots Manufactured Locally in Irrigation Applications

امكانية استخدام الاوعية السيراميكية المصنعة محليا في تطبيقات الري

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Abstract

The improvement of water use efficiency in the agricultural field has a lot of importance in many countries, especially those with limited water resources. When applying the traditional surface irrigation or drip, sprinkler systems in sandy soils, a percentage of irrigation water lose as deep percolation that leading to reduction in water use efficiency. To overcome the above problem, ceramic pots can be applied to reduce water losses. The main objective of this study is to compare the seepage volume and seepage rate for three different cases of the ceramic pots are under atmosphere, buried in the soil, and buried in the soil with planting. The use of ceramic pots in irrigation is gaining considerable interest in sandy soils due to simplicity and auto-regulative capabilities of the ceramic materials. In this study, nine ceramic pots, of fixed shapes, volume was approximately 3150 cm^3, were selected from local producers in Iraq. The experimental site, which is located on a loamy sand soil, was set up to investigate the volume of water seeps out of ceramic pot in different states. The results showed that there is a similarity in the cumulative seepage volume behavior for the buried and buried with planting cases, while different from what it is the atmosphere case. The yield for green onion per pot under ceramic pot irrigation is between 2.5 *kg* and 3.4 *kg*. It is observed that the water requirement volume between 303.6 *l* and 336.9 *l* are achievable with the applying ceramic pot irrigation. The results showed that the water use efficiency of green onion crops irrigated by applying ceramic pot irrigation is between 8.2 kg/m^3 and 10.1 kg/m^3.

Keywords: *Ceramic pots, Irrigation, Radius of wetting, Seepage rate, Water use efficiency.*

الخلاصة

ان تحسين كفاءة استخدام الماء في المجال الزراعي له الاهمية الكبرى في العديد من الدول خصوصا ذات الموارد المائية المحدودة.عند استخدام طرق الري السطحي التقليدية او الحديثة كالتنقيط والرش في الترب الرملية فان نسبة لاباس بها من ماء الري سوف تفقد كتخلل عميق مما يؤدي الى تقليل كفاءة استخدام الماء.وللتغلب على هذه المشكلة فانه من الممكن استخدام الاوعية السيراميكية لتقليل الضائعات المائية.ان الهدف الرئيس لهذه الدراسة هو المقارنة بين حجم التسرب ومعدل التسرب لثلاث حالات مختلفة للاوعية السيراميكية وهي: تحت تاثير الضغط الجوي ولحالة دفنها في التربة ولحالة دفنها في التربة مع تاثير وجود النبات.ان استخدام الاوعية السيراميكية في الترب الرملية له اهمية كبيرة وذلك بسبب بساطتة بالاضافة الى قدرة السيراميك على التنظيم الذاتي للتسرب المار خلاله.في هذه الدراسة تم استخدام تسع اواني سيراميكية من الاسواق المحلية في العراق واختيرت ان تكون بشكل ثابت وحجم بحدود 3150 cm^3. تمت تهيئة موقع العمل الذي كانت تربته رملية مزيجية وجرى قياس الماء المتسرب ومعدل التسرب للحالات المختلفة. بينت النتائج بان هنالك تشابها في السلوك لحجم التسرب المتراكم لحالتي الاواني المدفونة في التربة والمدفونة مع الزراعة بينما تختلف عما هي عليه للاواني تحت حالة الضغط الجوي.كما اظهرت النتائج بان انتاجية البصل الاخضر للوعاء تراوحت بين 2.5 *kg* و 3.4 *kg* وان الاحتياجات المائية تراوحت بين 303.6 *l* و 336.9 *l*. كما بينت النتائج بان كفاءة استخدام الماء باستخدام نظام الاوعية السيراميكية تراوحت بين 8.2 kg/m^3 و 10.1 kg/m^3.

الكلمات المفتاحية: الاوعية السيراميكية، الري، نصف قطر الترطيب، معدل التسرب، كفاءة استخدام الماء.

1. INTRODUCTION

Improving an efficient irrigation technology for crop production particularly in arid, semi-arid areas is one of the main objectives of the majority of agricultural research programs and projects in the world. However, the initial cost and maintenance requirements of modern irrigation systems and the requirement of highly qualified people for management may hinder use of these high-technology systems in many developing countries, (Anonymous, 1997a ; Abu-Zreig, M. M. et.al, 2006). Clay pot irrigation, CPI, which also known as pitcher irrigation system, is an ancient irrigation system which seems to have originated in northern Africa and Iran. Buried clay pot irrigation is one of efficient traditional systems of irrigation, (Bainbridge, D. A., 2001). CPI is particularly useful in difficult conditions such as high salinity and limited water resources.

The main problems when applying traditional irrigation methods, such as border or furrow, or even drip or sprinkler irrigation methods, in arid and semi-arid regions of sandy soils, are evaporation from the soil surface and the deep percolation of water. CPI is one of the most efficient irrigation systems known and is ideal for many small farmers, (Bainbridge et al, 1998). In CPI unglazed clay pots are buried below soil surface and filled with irrigation water that continuously seeps slowly and directly to plant root zone through the clay pot's porous wall at a rate influenced by interaction between the clay pot and its environment, namely the climate, soil, and plants. Previous studies on CPI showed that controlling irrigation water by the clay pots leads to increase the water use efficiency, WUE, when applied in sandy soils compared with any other irrigation method due to high water savings and the great reduction in evaporation losses. WUE can be calculated as the ratio between crop production and water use during the period from planting to harvest, (Batchelor, 1996 ; Loch, 2005). Buried clay pots can either be filled by hand if labor is inexpensive or connected to a pipe network or reservoir. CPI can be useful in utilizing large areas of widespread sandy soils and could be used to stabilize sand dunes, restoration and preventing desertification of bare soils. Dahir, F.M., 2009, carried out a number of laboratory and field experiments to evaluate the viability of clay vessel irrigation system as a newly introduced system in Iraq. Al-Merib, 2014, investigated the adaptability of using vertically-installed ceramic pipes, leading irrigation water directly to the root zone. He concluded that the depth of wetting front in the vertical direction increases as the length of ceramic pipes increases, but the length of the ceramic pipe has little effect on the extent in the horizontal direction.

Studies on the hydraulic performance of the ceramic pots system are generally limited. Still there is a need to a lot of research efforts to understand the performance of this system and the factors affecting WUE for various crops and soils.

The main objectives of this paper are to examine seepage volume through the local manufactured ceramic pot's walls and surface wetting edge around the pots under different conditions and to study viability of applying ceramic pot irrigation in loamy sand soil.

2. MATERIALS AND METHODS

The irrigation trials were conducted in a plot of 10*m*x20*m*. The plot is located within technical institute of Karbala in Al-Furat Al-Awsat technical University, Iraq. Technical institute of Karbala is located in the central zone of Iraq 32˚ 34' 35" N, 44˚10' 24" E, elevation 28.5 m a.m.s.l. Soil texture was analyzed and was found to be loamy sand. General soil characteristics are given in Table (1). Experiments were supplied with water from a main tank which is supplied with water from the city main pipe of potable water supply network.

3. TEST PROCEDURE

Nine ceramic pots, of fixed shapes, 3150 cm^3 approximately volume, a height of 37 *cm* and the maximum outer diameter 19 *cm* were selected from local market as shown in Fig. (1). The average basal diameter of all ceramic pots was 10 *cm*. This type of ceramic pots is the most popular in Iraq. Seepage volume and wetting edge experiments were carried out in winter season during the period from 19-12-2013 to 8-4-2014 by using ceramic pots with three replications. Tests for comparison were done for three cases;

1. The first case, clay pots were exposed to atmospheric pressure,
2. The second case, clay pots were buried in the soil,
3. The third case, applying ceramic pot system that ceramic pots were buried in the soil with planting the wetted surface soil surrounding the ceramic pots with green onion transplants.

Table (1). Soil characteristics at the experimental site.

Depth *cm*	Bulk density *kg/m³*	Specific gravity	Soil moisture content, cm^3/cm^3, under:		Moisture holding capacity *mm/m*	Organic matter content %	pH	EC *dS/cm*
			-10kPa	-1500kPa				
0-25	1580	2.59	0.19	0.058	132	0.53	8.08	2.06
25-50	1550	2.64	0.17	0.056	114	0.15	8.1	1.93
50-75	1660	2.59	0.169	0.047	122	0.15	7.84	1.2
75-100	1510	2.62	0.172	0.049	123	0.11	8.02	0.96

Because of the difficulty to get ceramic pots with same hydraulic characteristics even in the laboratory and for doing the comparison for the different cases, this required that seepage volume values for all ceramic pots under the atmospheric pressure during any period must be equal. To achieve this, selected ceramic pots were saturated, put in a room and each pot was prepared to test by connecting it in a supply system as shown in Fig. (2). Daily seepage volume for each clay pot was measured for five depths of water in each ceramic pot.

The relationship between the daily seepage volume and depth of water for each ceramic pot was presented. Accordingly the depths of water that give equal daily seepage volume were selected for all ceramic pots. Then the part of the ceramic pot above the selected water depth was painted with white color, to reduce water evaporation. All of the seepage volume and wetting edge experiments were carried out according to the following steps:

1. Examining the external surface of the ceramic pots to be sure that there are no cracks; water supply tube was fixed tightly.
2. The ceramic pots under atmospheric pressure case were connected to supply net.
3. For the second and third cases, a planting hole about two times as deep and three times as wide as the ceramic pot was adopted.
4. The clay pots were connected to water supply tank and constant level tank to achieve the pre selected depth of water for each ceramic pot.
5. For the third case "buried ceramic pot with agriculture", green onion plants were planted in the wetted area surrounding the buried clay pots after three days of the operation of the ceramic pot system as shown in Fig.(3). Green onion plants were arranged with a unicenter circles in a radius 10 *cm*, 18 *cm*, and 26 *cm* in 12, 22, and 32 plants respectively. Crop spacing and cultivation procedure were as per horticultural recommendations, (FAO-onion, 2002; Splittstoesser, 1984).
6. Calculating seepage volume V_{se} through each ceramic pot's wall at any time by multiplying the vertical distance for water falls down by the cross sectional area of the water supply tank.
7. The wetted area that surrounding each ceramic pot was measured in 12 constant radial lines by using graded ruler, the average value was adopted.

4. RESULTS AND DISCUSSION

4.1 Seepage

Fig. (4) shows the relationship between time and V_{se} through subsequent intervals. This figure shows that V_{se} values for the first case increases gradually per the first 100 *hrs*, after that V_{se} values becomes relatively stable with oscillation. This is due to the stability of the hydraulic gradient resulting from the constant pressure in and out of the ceramic pots, while the oscillation is due to the continuous change in atmospheric temperature. Alga appearance has been noticed on the wall outer face for the first case pots after two months. Fig. (4) also shows that V_{se} values for the second and third cases increases at the beginning of the experiments, these values slowly decreased towards the end of the experiments. The initial sharp increase in V_{se} values for the second and third cases was due to the suction pressure of the soil surrounding the ceramic pots. V_{se} values for the second case depends on the suction pressure which decreases with time, while for the third case V_{se} values depends on the common effect of both, the suction pressure and the consumptive use of the green onion plants.

The results showed that V_{se} values vary with the interaction between the ceramic pot and its environment. The average accumulated seepage volume values for the first, second, and third cases are 159.6 *l*, 239.8 *l*, and 316.5 *l* respectively. The difference of accumulated seepage volume between the second and third cases is 76.6 *l*, which represent the effect of green onion consumptive use during the period from plants to harvest.

The accumulated seepage volume for each ceramic pot can be estimated by the following power formula:

$$V_s = at^b \qquad \text{……………………(1)}$$

in which

a=coefficient of seepage volume formula, *(L^3/T^b)*,

b=exponent of seepage volume formula, *(dimensionless)*,

V_s=accumulated seepage volume, (L^3), and

t=time of seepage opportunity, *(T)*.

By differentiating equation (1), an expression for calculating the instantaneous seepage rate may obtain, that is:

$$Q_{inst} = ct^f \qquad \text{……………………(2)}$$

in which

c=coefficient of instantaneous seepage rate formula, *c=a b*, *(L^3/T^{f+1})*,

f=exponent of instantaneous seepage rate formula, *f =b-1*, *(dimensionless)*,

Q_{inst}= instantaneous seepage rate, *(L^3/T)*.

Fig. (5) shows the observed variation of the accumulated seepage volume with time of the three cases. This result agrees with the results of Dahir, 2009. Table (2) shows the formulas for estimating V_s of clay pots with different states, in which V_s in *l* and t in *hrs*.

Table (2). Formulas for estimating V_s of the ceramic pots.

Cases	V_s formulas in liter	R^2
First case	$V_s=0.13t^{0.91}$	98%
Second case	$V_s=1*10^{-8}t^3-8*10^{-5}t^2+0.23t-1.47$	97%
Third case	$V_s=1*10^{-8}t^3-9*10^{-5}t^2+0.28t-5.9$	96%

Then, according to coefficients of formulas in Table (2), equation (2) may be written as shown in Table (3) for the three states, in which Q_{inst} in *l/hr* and t in *hrs*.

Table (3). Formulas for estimating Q_{inst} of the ceramic pots.

Cases	Q_{inst} formulas in *l/hr*
First case	$Q_{inst}=0.12t^{-0.087}$
Second case	$Q_{inst}=3*10^{-8}t^2-16*10^{-5}t+0.23$
Third case	$Q_{inst}=3*10^{-8}t^2-18*10^{-5}t+0.28$

Fig. (6) shows Q_{inst} functions of the first and the second cases of experiments. It also shows that Q_{inst} has high values at the beginning of the experiment. The Q_{inst} function of the first case becomes closer to straight line equation. The Q_{inst} values of the second state depend on the moisture content of the soil surrounding the ceramic pots. The moisture content is at its minimum at the beginning of operation, while, Q_{inst} is at its maximum value. As the water continually seeps through the ceramic pot's wall, the moistures content of the soil surrounding the clay vessels increases gradually causing a gradual decrease in Q_{inst} and until it reaches an approximately constant value. This result agrees with the results of Dahir, 2009.

4.2 Radius of Wetting Edge

Field observation shows that wetted surface area is surrounded the ceramic pots for the second and third cases. After 38 *days* it has been noticed that these areas became dry for the second state ceramic pots as shown in Fig. (7). Observation were shown that these wetted areas still continue for the third case ceramic pots which is due to the canopy which is responsible for decreasing the direct sunlight. Radius of wetting R_w may be defined as the horizontal distance between the axial line of the clay pot and wetted edge for the surface wetted area that surrounds the clay pot. Knowing R_w may help us designate the area which is used for planting different crops. The results showed that the average value of R_w after 35 *days* is 33.6 *cm*.

4.3 Yield Response

The yield of any crop depends on the interaction of many factors, type and category of crop, method of irrigation, and soil characteristics. Fig. (8) shows the green onion under ceramic pot system. Yield data for green onion, water requirement, and WUE for each clay pot of the third case are presented in Table (4). This Table shows that for all clay pots for the third state, the average yields, water requirements, WUE are 2.9 *kg*, 316.5 *l*, and 9.1 *kg/m³* respectively.

Table (4). Yield, water requirements, and WUE data for green onion under ceramic pot system.

Replication No.	**Yield** ***kg***	**Water Requirement** ***l***	**WUE** ***kg/m³***
1	**2.8**	**308.9**	**9.1**
2	**2.5**	**303.6**	**8.2**
3	**3.4**	**336.9**	**10.1**
Average	**2.9**	**316.5**	**9.1**

4.4 Root Distribution

At the end of the experiments, it was found that the green onion plants had formed mats of roots all around the ceramic pot without penetrating the wall of the ceramic pots as shown in Fig. (9). Daka, 2001 has noticed the same behavior of the green onion's root distribution. In this way the crop enjoyed direct abstraction of water as it oozed out of the vessel under atmospheric pressure head. Observations have also shown that the green onion have shallow rooting. Thin roots have relatively high surface area per unit cross-sectional area (Taylor, 1985). A concentration of roots in the confined wetted volume around ceramic pots under CPI will therefore have a tremendous capacity to supply water to the above ground canopy due to increased root surface area.

5. CONCLUSION

According to the results of the field work, the following conclusions were found:

1. The seepage volume for the first case increases gradually per the first 100 *hrs*, after that seepage volume values becomes relatively stable with oscillation.
2. The seepage volume values for the second and third cases increases at the beginning of trial, these values decrease slowly towards the end of the experiments.
3. Q_{inst} functions of experiments showed that Q_{inst} for all status has high values at the beginning of the experiment and after this these values decrease gradually. Q_{inst} function of the first case becomes closer to straight line equation.
4. Q_{inst} values of the second and third cases depend on the moisture content of the soil surrounding the ceramic pot.
5. After operation the buried ceramic pots, wetted surface area is surrounded each ceramic pot in approximately circular shape.
6. After 38 *days* it has been noticed that wetted surface areas became dry for the second cases ceramic pots, while these wetted areas still continue for the ceramic pots for the third case.
7. Ceramic pot system is a suitable irrigation system to irrigate green onion in loamy sand soil.
8. The average accumulated seepage volume values for the first, second, and third cases during the period of the work are 160 *l*, 240 *l*, and 361.5 *l* respectively.
9. Results for the third cases showed that the average yields, water requirements, WUE are 2.9 *kg*, 316.5 *l*, and 9.1 kg/m^3 respectively.
10. The average value of radius of wetting edge after 35 *days* is 33.6 *cm*.

6. RECOMMENDATIONS FOR FURTHER STUDIES

The following recommendations are suggested to provide a guide for further studies:

7. ACKNOWLEDGMENT

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Figure (1). A snapshot showing ceramic pot selected from local market**.**

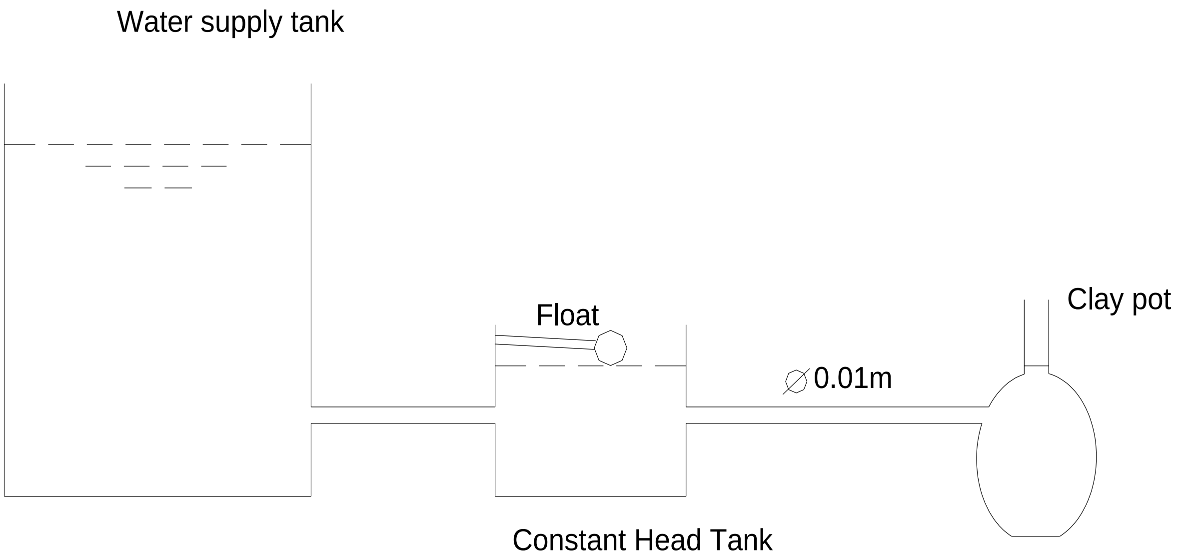

Figure (2). Schematic layout of seepage volume experiments configuration.

Figure (3). Asnapshot showing buried ceramic pot with agriculture**.**

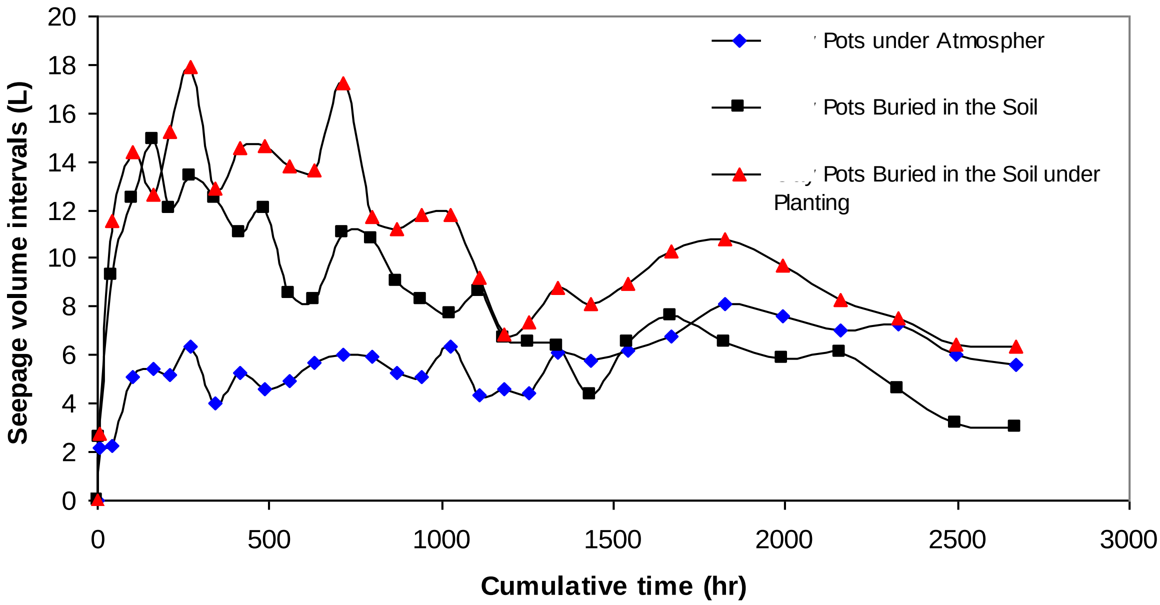

Figure (4). The relationship between time and seepage volume through subsequent intervals.

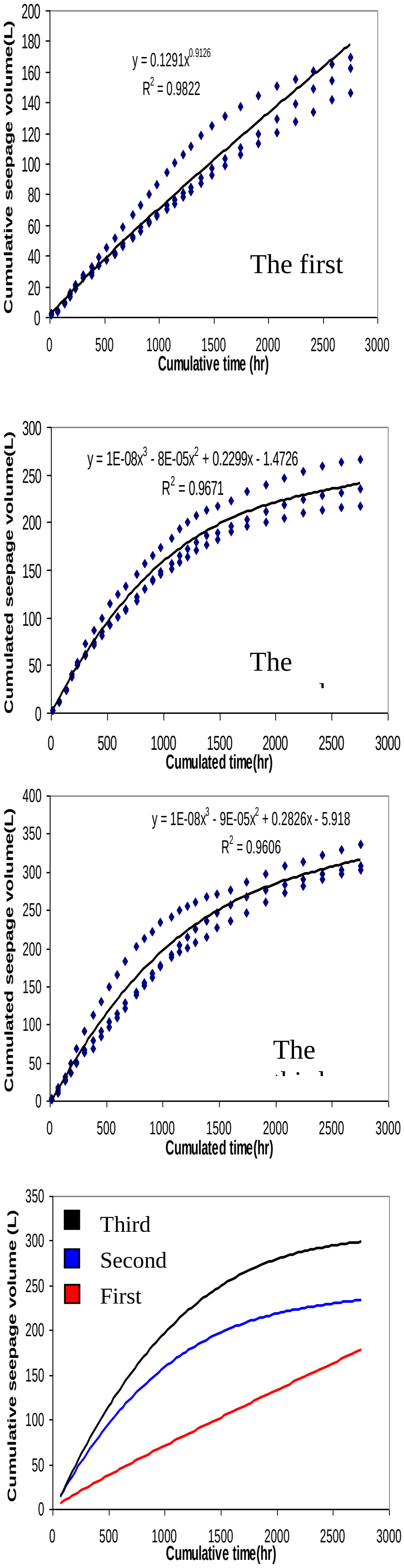

Figure (5). Variation of the accumulated

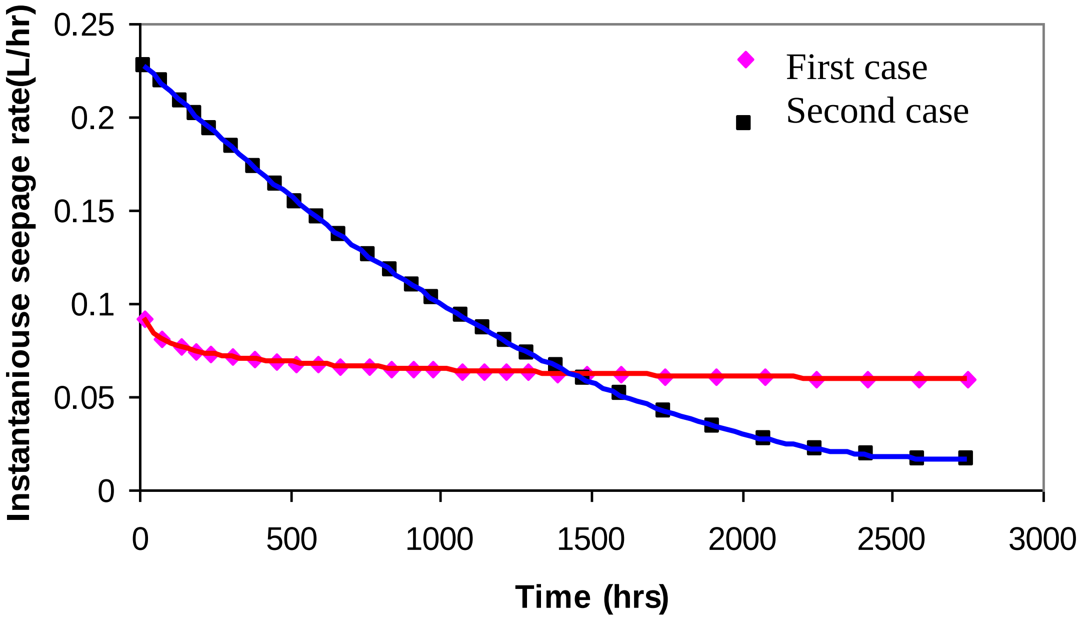

Figure (6). Instantaneous seepage rate of the first and second cases.

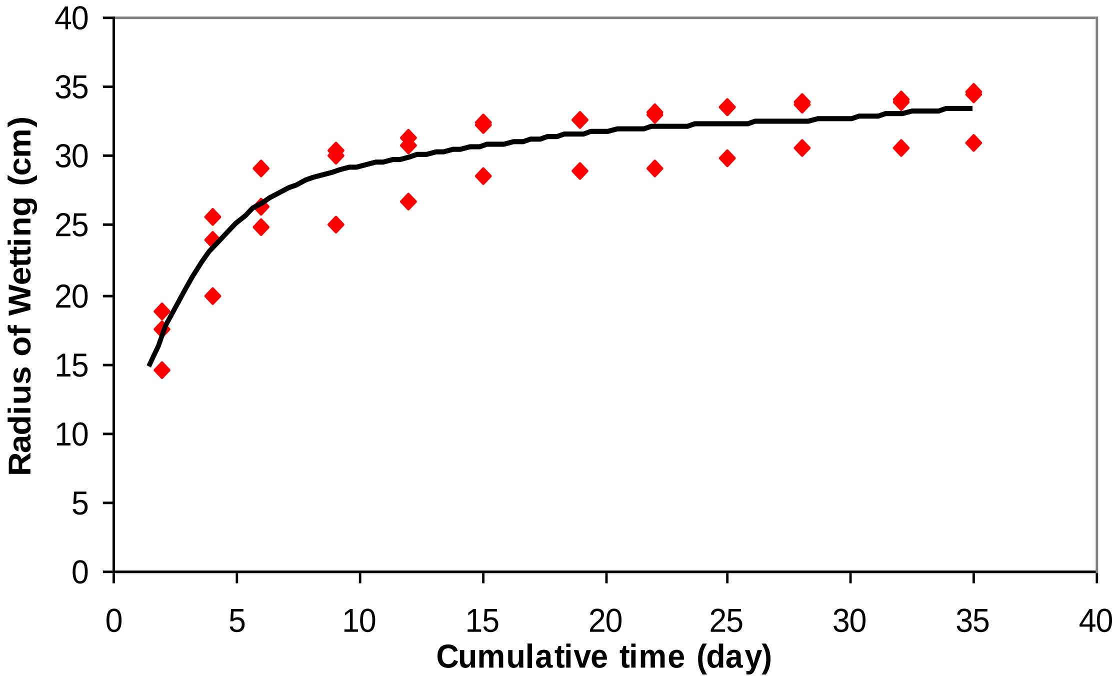

Figure (7). Surface radius of wetting of the ceramic pots.

Figure (8). A snapshot showing the green onion under ceramic system.

Figure (9). A snapshot showing the green onion planting and root distribution under ceramic pots system.