International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:8, No:11, 2014

Water Saving in Arid Regions: Comparison of Innovative Techniques for Irrigation of Young Date Palms

R. Bourziza, A. Hammani, M. Kuper, A. Bouaziz

***Abstract*—**In oases, the surface water resources are becoming increasingly scarce and groundwater resources, which generally have a poor quality due to the high levels of salinity, are often overexploited. Water saving have therefore become imperative for better oases sustainability. If drip irrigation is currently recommended in Morocco for saving water and valuing, its use in the sub-desert areas does not keep water safe from high evaporation rates. An alternative to this system would be the use of subsurface drip irrigation. This technique is defined as an application of water under the soil surface through drippers, which deliver water at rates generally similar to surface drip irrigation. As subsurface drip irrigation is a recently introduced in Morocco, a better understanding of the infiltration process around a buried source, in local conditions, and its impact on plant growth is necessarily required. This study aims to contribute to improving the water use efficiency by testing the performance of subsurface irrigation system, especially in areas where water is a limited source. The objectives of this research are performance evaluation in arid conditions of the subsurface drip irrigation system for young date palms compared to the surface drip. In this context, an experimental test is installed at a farmer's field in the area of Erfoud (Errachidia Province, southeastern Morocco), using the subsurface drip irrigation system in comparison with the classic drip system for young date palms. Flow measurement to calculate the uniformity of the application of water was done through two methods: a flow measurement of drippers above the surface and another one underground. The latter method has also helped us to estimate losses through evaporation for both irrigation techniques. In order to compare the effect of two irrigation modes, plants were identified for each type of irrigation to monitor certain agronomic parameters (cumulative numbers of palms and roots development). Experimentation referred to a distribution uniformity of about 88%; considered acceptable for subsurface drip irrigation while it is around 80% for the surface drip irrigation. The results also show an increase in root development and in the number of palm, as well as a substantial water savings due to lower evaporation losses compared to the classic drip irrigation.

The results of this study showed that subsurface drip irrigation is an efficient technique, which allows sustainable irrigation in arid areas.

***Keywords*—**Subsurface drip irrigation, Water conservation, Arid areas, Young date palms.

Bourziza Rqia (Corresponding author) and Hammani Ali are with Department of Water, Environnement and infrastructure Institute of Agronomy and Veterinary Hassan II, 10101 Rabat, Morroco (Phone: +212616130829; e-mail: rqia.bourziza@gmail.com).

Kuper Marcel is with CIRAD, UMR G-EAU, 34398, Montpellier, France.

Bouaziz Ahmed is with Departement of Vegetal Production Institute of Agronomy and Veterinary Hassan II, 10101 Rabat, Morocco.

I. Introduction

In oases, the surface water resources are becoming increasingly scarce and groundwater resources, which generally have a poor quality due to the high levels of salinity, are often overexploited. Water saving have therefore become imperative for better oases sustainability. If drip irrigation is currently recommended in Morocco for saving water and valuing, its use in the sub-desert areas is becoming debatable, as it does not keep water safe from high evaporation rates. An alternative to this system would be the use of subsurface drip irrigation. This technique is defined as an application of water under the soil surface through drippers which deliver water at rates generally similar to the surface drip irrigation [1].

On one hand, a comparison of the water use efficiency between different irrigation methods of date palm (drip, flooding and micro-jet) showed that drip irrigation system is the most efficient, followed by flood irrigation system and micro-jet [2]. Indeed, the optimal response of date palm on drip irrigation is due to the system operation in which water is delivered by drippers in slow process for a relatively long period. This process enables better water control and distribution through the soil profile, therefore, the losses due to evaporation and deep percolation are reduced and, the date palm can use almost all of the delivered water.

On the other hand, subsurface drip irrigation represents the recent improvement of irrigation, because it prevents, or in most cases, significantly reduces losses of direct evaporation, runoff and deep percolation [3], [4]. The precise application of water and fertilizers resulted in the increased water use efficiency, application uniformity of water and consequently the improvement in crop yield [5]. In addition, it prevents the growth of weeds around the crop [6]. Thus, subsurface drip irrigation is considered as the most effective way to provide water and nutrients directly to the plants and to increase productivity of crops [7]-[10]. A well-designed subsurface drip irrigation system provides values of the water use efficiency greater than 95% [11]; therefore, more than 95% of the supplied and maintained water in the root zone, is beneficial for crops.

The yield response of several corps under different climatic and soil conditions across the world showed a similar or superior performance under subsurface drip irrigation compared to other irrigation systems; as shown in the results of tomatoes studies [3], onion [12], corn [13], [14] soybeans, wheat and alfalfa [13], date palm [15], and other [16].

Many studies suggest the use of surface drip irrigation as a water saving technology in arid areas, but it is necessary to study the efficiency of the subsurface drip irrigation in these areas. The main objective of this study is to examine the efficiency of subsurface drip irrigation system for young palm trees in arid conditions. Our results will help to identify the most efficient technique for water conservation and the most efficient as well for young date palm in oases.

II. Materials and Methods

A. Experimental Test and Measurement

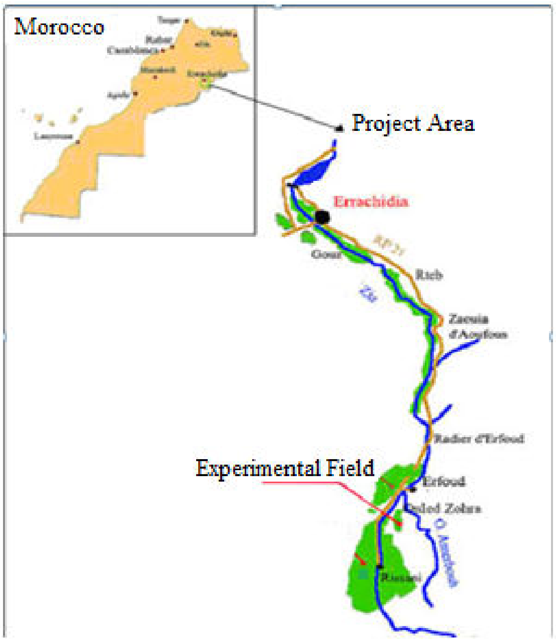

Fig. 1 Localization of the Field Experiments

Field experiments were conducted on a loamy soil containing an average of 52% silt, 27% sand and 20% clay in a profile of 1 m deep, with an average bulk density of 1.76 g/cm^3. The experimental and demonstrative field is located in south-eastern Morocco (Fig. 1), where is a fully equipped weather station to measure rainfall, temperature, wind speed, wind direction, humidity and solar radiation.

Concerning the plant material, the date palm varieties which are more resistant to water and soil salinity were selected. A mixture of 112 plants per hectare of vitro-plants and low offshoot purchased from farmers in the area are planted with a spacing of 7 m * 7 m. A supply of sand, manure and fertilizer background was added to the planting holes to reduce soil density which value became 1.17 g/cm^3. Finally, low offshoot from the process of "cleaning tufts" were prepared by cutting the fronds to half or quarter to avoid water loss through evapotranspiration, in order to plant them directly after weaning to avoid their dryness.

Water intake of this experimental site is done through a pump unit giving a flow rate of 5 l/s. A pressure regulator is used to deal with pressure fluctuations in the network. Two experiments were conducted to compare irrigation methods. 1st experiment took place with circular laterals buried (Fig. 2) at different depths from the surface (15 cm, 25 cm and 35 cm), the average flow of the drippers was 2 l/h at a pressure of 1 bar with spacing between drippers of 0.4 m. The second one was done with surface laterals (Fig. 3) with drippers of 2 l/h, with a spacing of 0.4 m. Irrigation was applied as per crops water requirements.

Fig. 2 Subsurface Irrigation System

Fig. 3 Surface Irrigation System

B. Uniformity Estimation of Subsurface Irrigation System

Regarding the water application uniformity test of subsurface drip irrigation system, we randomly choose a number of drippers from the beginning, middle, two-third and tail laterals. The uniformity of water application is determined from the volume collected in boxes for a known duration. The uniformity of application of water is calculated from the statistical distribution of dripper flow rates in terms of variation coefficient (CV) and distribution uniformity (DU).

To measure the DU, we chose two methods. The method of Karmeli Keller [17], which is based on measuring the volume of water delivered by the dripper based on time unit by using a timer and a container placed under the dripper. These measures focus on 4 retailers lateral on at least four laterals.

Fig. 4 Bin Used to Measure the Distribution Uniformity and Evaporation Water Losses

The flow of the dripper is often measured in free flow without the surrounding soil. This removes the counter-pressure against the surrounding ground and increase the flow throughput that it would have been in the presence of soil. The second adopted procedure is to measure the drippers flow in the presence of soil as described by [12] with some specifics of the actual study. Four bins (Fig. 4) of good quality plastic with heights and well-defined diameters will be used. Two holes of 16 mm diameter are made on diametrically opposite sides of the bins at 15, 25 and 35 cm of height from the top. In the first bin the lateral is positioned on the surface, while in the second, third and fourth bins, lateral is respectively placed 15, 25 and 35 cm deep. All bins are filled with soil and connected to the network with simple tubes inserted through the holes made on bins. The initial weight of the bin, laterals and soil are noted. The weight of the bin is taken before and after ending the irrigation system, and the difference between the weight of the bin before and after irrigation, gives the weight of the accumulated water in the bin. The operating pressure in the bin is that of exploitation.

C. Estimated Evaporation under Subsurface Drip Irrigation

The water economy in the subsurface drip irrigation system is achieved by reducing evaporation loss from the soil surface, which remains relatively dry. The lost part in the evaporated volume provided by the dripper is related to the depth of the dripper itself [18]. The procedure described above (section B) was also used to estimate evaporation. However, some changes were made. The weight of the bin (Fig. 4) with the soil is taken before and after the operation of the irrigation system. After 24 h, i.e. the day after, again the weight of the bin with the soil is taken. The weight difference gives the amount of water lost by evaporation.

D. Estimated Development of Young Date Palms

To compare the effect of two methods of irrigation, surface drip irrigation and subsurface drip irrigation, we randomly prepared plants for each type of irrigation, to follow some agronomic parameters (cumulative palms and roots growth numbers).

To assess root length by terms of spatial variability, we measured the cumulative root lengths. Since this method is destructive, we limited ourselves to three plants by laying depths. The technique is to carefully dig a vertical profile of the soil, where root length is measured thereafter. For the same trees, we measured the number of palms developed every four months.

III. Results and Discussions

A. Distribution Uniformity of Surface and Subsurface Drip Irrigation

During 2012, results of the demonstration test installed at the farmer's field refer to a hydraulic performance as per standards. Equipment used for surface dripping refers to a distribution uniformity of around 84%, while the subsurface dripping refers to distribution uniformity (DU) of 88%.

During 2013, the surface dripping refers to a distribution uniformity of 80% while the subsurface dripping refers to a distribution uniformity of 90%, 87% and 85% respectively for equipment installed at 35 cm, 25 cm and 15 cm of laying depth.

The results of uniformity coefficient, thus, show the good condition of the irrigation system. Added to this, coefficient of variation values are greater than 5% and less than 10% which confirm the correct uniformity of water application to the plot and the absence of any network failure.

Moreover, it should be noted that there is a clogging tendency following a decline in DU for surface drip caused by drippers clogging due to the high salinity in irrigation water, which was worsened by a flood (Fig. 5) that spread over the entire test plot. This is while the subsurface drip system was not affected by the flood and therefore the DU did not significantly decrease.

The distribution uniformity of irrigation water is considered adequate taking into consideration distribution network cleaning operations for both systems (as per the CEMAGREF classification).

Fig. 5 Flooded Plot

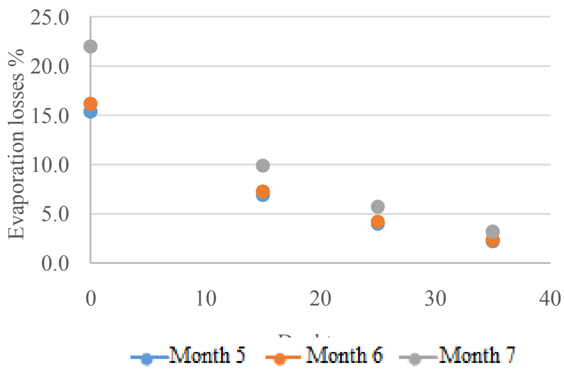

Fig. 6 Evaporation Water Loss at Different Depths

B. Water Loss through Evaporation

The evaporation loss in percentage of the total water applied by drippers in different placement depths in May, June and July 2013 is given in Fig. 6. The results show that the evaporation of water decreases along with the increase of laterals placement depths. Evaporative losses for drip irrigation at 0 cm, 15 cm, 25 cm and 35 cm installation depth are respectively of 17.9, 8.0, 4.6 and 2.6% .The reduction of water loss by evaporation for the buried laterals is caused by the less availability of water on the soil surface during the evaporation process. Reference [19] also concluded that the application of water at progressively larger and larger depths causes consequently progressive dry surfaces; which reduces the hydraulic conductivity of the surface layer of the soil, and preventing therefore the flow of water upward. References [20], [21] also reported similar findings, and explained that the transmission of water in the soil is limited to the surface as long as the surface is dry; this results in smaller losses by evaporation in case of deeper water source (i.e., laterals).

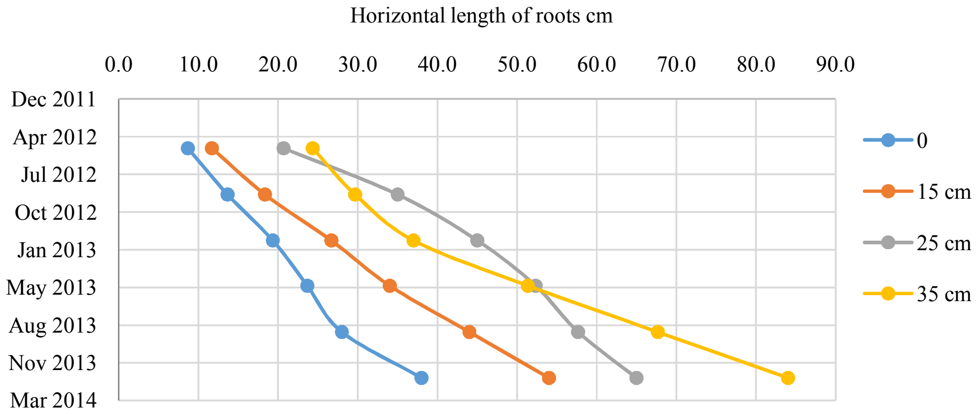

Fig. 7 Effect of Drippers' Burial Depth on the Maximum Horizontal Length of the Roots of Young Date Palms

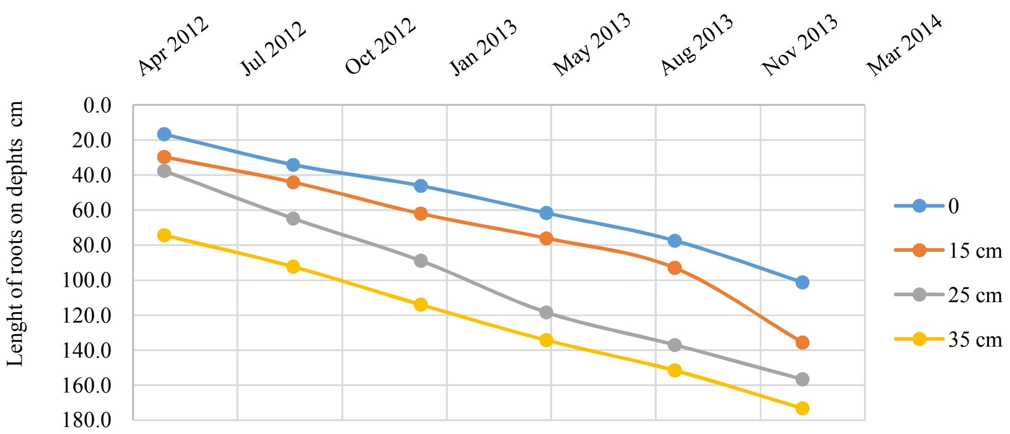

Fig. 8 Effect of Drippers' Burial Depth on the Maximum Vertical Length of the Roots of Young Date Palms

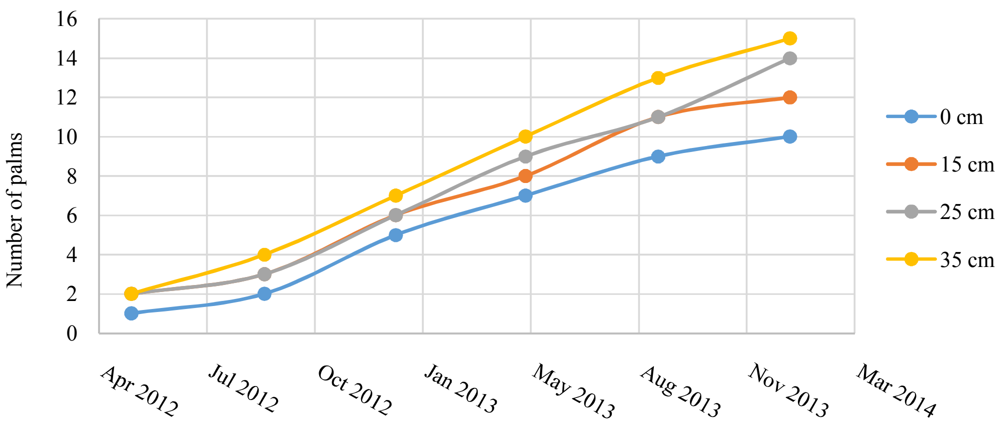

Fig. 9 Effect of Drippers' Burial Depth on the Number of Palms Grown Up from Young Palm Trees

C. Irrigation Effect on Date Palm Growth

Figs. 7 and 8 show the effect of irrigation on root dynamics and date palm development. The extent of soil occupation in depth increases more for the irrigation system buried at 35 cm to reach 173.3 cm of depth against 156.7 cm, 135.7 cm and 101.3 cm respectively for systems at 25 cm, 15 cm and 0 cm deep. In addition, the root development laterally (near the surface) is 84 cm, 65 cm, 54 cm and 38 cm respectively for 35 cm, 25 cm, 15 cm and 0 cm laying depth. So the availability of deep water promotes good root development either in depth or laterally.

The irrigation system has a significantly noticeable effect on surface palms growth as shown in Fig. 9. Certainly, the highest values were recorded for the SDI buried at 35 cm deep. The cumulative number of palms of three trees for each depth is 15, 14, 12 and 10 respectively for 35 cm, 25 cm, 15 cm and 0 cm of depth.

These results show that the greater the depth location of the laterals is, greater root development and palms increases. References [5], [22], [23] also showed that the SDI increases the development of agronomic parameters of crops. Root growth is more developed in the first two years of study, since the plant needs more to get fixed before getting developped on the surface. Reference [24] also concluded that proper drippers positioning can prevent the danger of trees uprooting by strong winds; since the roots are concentrated in the moistened area, by drip irrigation, and if the area is too small rooting may be insufficient.

D. Comparison between Surface and Subsurface Drip Irrigation in Saharan Areas

To improve the water use efficiency, the surface drip irrigation is a technique recommended as necessary to adopt in irrigated areas known of water shortage. However, the traditional gravity irrigation remains the most common system in oasis areas. For example, the rate of conversion to surface drip irrigation is only 6% in the palm grove of Tafilalet, which is considered one of the largest palm groves in Morocco. This leads us to reflect on the use of surface drip irrigation and its efficiency in the oasis areas.

Indeed, this irrigation system promotes optimum root development and plant growth on the surface, which subsequently improves both the yield and water use efficiency. So, the farmer can profitably irrigate more land on using best available water as the irrigation efficiency can reach more interesting levels by the right choice of the irrigation system. Several authors agree on the water use efficiency improvement by the subsurface drip irrigation for tomato crops [3], onion [12] maize [13], [14], date palm [15] and other crops [16].

The irrigation system contribute also to water conservation since it allows an increase of up to 15% of water compared to the surface drip irrigation; because it prevents, or in most cases, greatly reduces the direct evaporation losses, runoff and deep percolation [3], [4]. This allows a better water control and distribution through the soil profile and, accordingly, the date palm can use almost all of the delivered water.

IV. Conclusion

The results of the field experiments showed that the subsurface drip irrigation uses water more efficient compared to the conventional surface drip system in oasis areas. In addition, it allows a considerable development of date palms agronomic parameters compared to surface drip irrigation. The subsurface drip irrigation is an effective and convenient method for irrigation of young date palms where a considerable amount of water lost through evaporation can be potentially saved compared to other irrigation systems, including traditional surface drip irrigation system.

The next step in this research is to study the effect of burial laterals depth on the transfer of water into the surrounding soil to improve design strategies and management of subsurface irrigation systems.

Acknowledgment

The authors are indebted to the Millennium challenge account project for funding this research.

References

[1] ASAE Std., 1999. Soil and Water Terminology. S 526.1. ASAE Standards. American Society of Agricultural Engineers, St. Joseph M.I..

[2] A.I. Al-Amoud., M.A. Bacha and A.M. Al-Darby. Seasonal water use of date palms in Central Region of Saudi Arabia. Agricultural Engineering Journal 9(2), 2000 pp: 51-62.

[3] B. Hanson and D. May. The effect of drip line placement on yield and quality of drip irrigated processing tomatoes. Irrig. Drainage Syst N°21. 2007, pp: 109-118.

[4] Safi B., Neyshabouri M.R. and Nazem A.H., 2007. Water Application Uniformity of Subsurface Drip Irrigation System at Various Operating Pressures and tape Lengths. Turk J. of Agric.and Forest. 31(2007): 275-285.

[5] Singh D.K., Rajput T.B.S, 2007. Response of lateral placement depths of subsurface drip irrigation on okra (Abelmoschus esculentus). International Journal of Plant Production, 1, pp 73-84.

[6] Ayers J.E., Phene C.J., Schoneman R.A., Meso B., Dale F. and Penland J., 1995. Impact of bed location on the operation of subsurface drip irrigation systems. In: Proc. 5th int.Microirrigation Congress, ASAE, p.168-174.

[7] Tiwari K.N., MalP.K., Singh R.M.et ChattopadhyayA., 1998. Response of Okra (Abelmoschus esculentus"L." Moench) to drip irrigation under mulch and non-mulch condition. Agric. Water Manage. 38, pp 91-102.

[8] Thompson T.L., Doerge T.A.et GodinR.E., 2002. Subsurface drip irrigation and fertigation of broccoli: agronomic, economic, and environmental outcomes and environmental outcomes. Soil Sci. Soc. Am. J., 66, pp 178-185.

[9] Thompson T.L., WhiteS.A., Walworth J.L. et SowerG.S., 2003. Fertigation Frequency for Subsurface Drip-Irrigated Broccoli, Soil Sci. Soc. Am. J., 67, pp 910-918.

[10] Douh B. and BoujelbenA., 2010 (a), Water saving and eggplant response to subsurface drip irrigation. Journal of Agricultural Segment, 1 (2): 1525, pp 1-12.

[11] Payero J., 2002. Is subsurface drip irrigation right for your operations?. Crop watch new service web page, Univ. of Nebraska, Institute of Agriculture and Natural Resources Cooperative Extension.

[12] Patel N., Rajput T.B.S., 2008. Dynamics and modeling of soil water under subsurface drip irrigated onion. Agricultural water management 95, 1335 – 1349.

[13] Ayars J.E., Phene C.J., Hutmacher R.B., Davis K.R., Schoneman R.A., Vail S.S. and Mead R.M., 1999. Subsurface drip irrigation of row crops:

a review of 15 years of research at the Water Management Research laboratory. Agric. Water Manage. 42 (1999): 1-27. 1999.
[14] Enciso J., Jifon J.et Wiedenfeld B., 2007, Subsurface drip irrigation of onions: Effects of drip tape emitter spacing on yield and quality. J. Agr. Water Manage, 92, pp 126–130.
[15] A.I. Al-Amoud, “Subsurface Drip Irrigation for Date Palm Trees to Conserve Water”. Acta Hort. 882, ISHS 2010.
[16] Qassim A., 2003. Subsurface irrigation: A situation analysis. Intern. In: Prog. For Technology and Res. In Irrigation and Drainage (IPTRID), Tatura, Australia.
[17] Keller J. and Karmeli D., 1974. Trickle irrigation design parameters. Transactions of the ASAE Vol. 24(4): 678-684.
[18] Singh D.K., 2004. Performance evaluation of subsurface drip irrigation systems. Unpublished Ph.D. thesis, P.G. School, IARI, New Delhi, 135 pp.
[19] Meshkat M., Warner R.C., Workman S.R., 2000. Evaporation reduction potential in an undisturbed soil irrigated with surface and sand tube irrigation. Transactions of ASAE 43, 79–86.
[20] Philip J.R., 1991a. Upper bounds on evaporation losses from buried sources. Soil Science Society of America Journal 55, 1516–1520.
[21] Philip J.R., 1991b. Effect of root and sub irrigation on evaporation and percolation losses. Soil Science Society of America Journal 55, 1520–1523.
[22] Thompson T.L., Pang H, Li Y., 2009. The Potential Contribution of Subsurface Drip Irrigation to Water-Saving Agriculture in the Western USA. Agr. Sci. in China, Vol. 8, Issue 7: 850-854.
[23] Douh B., Boujelben A., 2007. Effet du système d’irrigation goutte à goutte souterrain sur une culture d’aubergine. Séminaire international, Exploitation des ressources en eau pour une agriculture durable. Hammamet-Tunisie 21 et 22 novembre, in Abstract book, p70.
[24] Vermeiren L., Jobling G.A., 1980. Localized irrigation: design - installation - operation – evaluation. FAO irrigation and drainage paper, 36, pp 8.