

LOW PRESSURE SUBSURFACE IRRIGATION WITH PERMEABLE PIPES FOR A PRECISION AND OPTIMAL IRRIGATION MANAGEMENT

IRRIGATION SOUTERRAINE A BASSE PRESSION OPTIMISEE AVEC DES TUYAUX PERMEABLES

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ABSTRACT

In a joint research project of the Department for Agricultural Engineering of the Kassel University (Germany) and the Scientific Research Center on Arid Regions (CRSTRA) in Biskra (Algeria) a buried auto-regulative permeable pipe was tested in greenhouse trials under semiarid to arid conditions. The new irrigation system works at low pressure to allow an auto-regulative functioning of the pipe, based on porous irrigation pipes as an upgrade of both subsurface and traditional pot irrigation. In clay pot (pitcher) irrigation unglazed porous clay pots are embedded in the ground and filled with water, which eventually drains through the porous pot wall. Savings of up to 70 % compared with conventional irrigation methods were observed. To compare the new irrigation system with the drip irrigation technique two greenhouses were equipped with drip irrigation and the permeable pipes respectively. Two types of irrigation water were tested; surface water from a local dam and groundwater with a higher salinity. Results show 60 % higher yield for the permeable pipe irrigation with 48 % less water consumed compared to drip irrigation when using poor quality / salty irrigation water.

RÉSUMÉ

Dans un projet de recherche conjoint du Département d'Ingénierie Agricole de l'Université de Kassel (Allemagne) et le Centre de la Recherche Scientifique sur les Régions Arides (CRSTRA) à Biskra (Algérie) un tube perméable autorégulant souterrain a été testé dans des serres. Le nouveau système d'irrigation fonctionne à basse pression pour permettre un fonctionnement autorégulant de la conduite, à la base d'un tuyau d'irrigation poreux comme une mise à niveau à la fois de d'irrigation souterraine et le pot en argile traditionnel. Pour comparer le nouveau système d'irrigation avec la technique goutte à goutte deux serres ont été équipés d'irrigation goutte à goutte et les tuyaux perméables respectivement. Deux types d'eau d'irrigation ont été testés; les eaux de surface à partir d'un barrage et l'eau souterraine avec une forte salinité. Les résultats montrent des récoltes de 60 % plus élevées pour l'irrigation de tuyaux perméables avec 48 % moins d'eau consommée par rapport à l'irrigation goutte à goutte avec l'eau d'irrigation salée mauvaise qualité.

Keywords: subsurface irrigation, precision irrigation, irrigation on plants' demand

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1. Introduction

The city of Biskra is located in the east of Algeria. Today Biskra is the first provider of vegetable products to the Algerian national market. Greenhouses have changed the image of Saharan agriculture in the province of Biskra. The main problem of agriculture in the province is the decrease in water availability due to overexploitation of water resources. To this problem is added the poor quality of irrigation water (high salt content, 4.69 dS m^{-1}) from the groundwater sources and from local dams with high contents of suspended solids.

Because of stressful climatic conditions, irrigation is the only way to satisfy the plants' water demand. The mainly used technique is ancient and not well controlled: 66 % of irrigated surface is occupied with flood and furrow gravity systems (Bettiche 2012). Against these techniques sub-surface irrigation could play an important role.

An efficient and very ancient type of sub-surface irrigation is the pitcher (or clay pot or jar) irrigation which is known since thousands of years in arid and semi-arid areas (Bainbridge, 2001; Batchelor et al., 1996). With this method, unglazed porous clay pots are embedded in the ground and filled with water which eventually drains through the porous pot wall. A special characteristic of this irrigation method is its ability for auto regulation, which arises from the close interaction between the pot and its environment, namely the plant, the soil and the pot material. Due to their specific material properties, the pots deliver water to the soil if it is dry and the soil water tension is high. Once the soil humidity rises, the soil water tension will decrease and the water flow eventually decreases or even stops.

Adopting these principles with modern materials leads to permeable pipes which operate responding to plants water demand. These pipes made out of membrane material were tested in greenhouse trials on the experimental station El'Outaya of the regional research center CRSTRA in Biskra (Algeria). The objective was to compare between this new technology (Auto Regulative Sub-surface Irrigation Technique = ARSIT) and the localized drip irrigation (DI) system in terms of water productivity and yield.

2. Materials and Methods

2.1 Location

The greenhouse trial was carried out at the experimental station of the Center for Scientific and Technical Research on Arid Regions (CRSTRA) El Outaya. The station is located 10 km northeast of Biskra (Algeria) at the border to the Sahara.

2.2 Climate

The climate of Biskra is semi-arid in the North to arid in the South (ABHS, 2011; cited in Boudibi, 2013) which is characterized by low and irregular rainfall with an average of 155.4 mm. Evapotranspiration is very high especially during the summer when it reaches 417 mm, the relative humidity is low with an annual average of 44.7 %, and wind has a general direction Northwest South (weather station Biskra, 2011).

2.3 Soil

The soil is of fine texture especially clayey and loamy, it is a saline soil with undegraded structure. The field capacity and wilting point coefficient are 26 and 20 % respectively.

2.4 Experimental setup

One greenhouse (50 m length, 8 m width) was equipped with drip irrigation (DI) and another one with the permeable pipes (ARSIT) respectively. Each setup had 12 replications (individual plots). The dimension of each plot was 10.0 by 2.0 m. The distance between the plots was 1.0 m. The ARSIT pipe was installed at a depth of 30 cm.

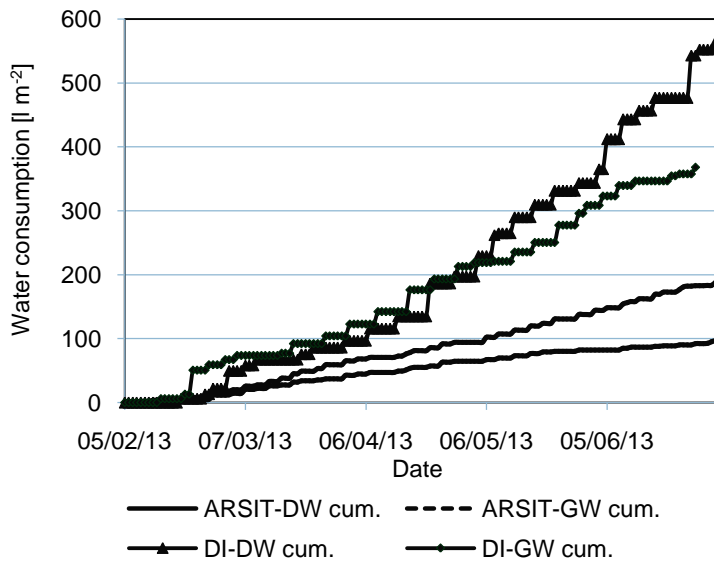
The irrigation with the ARSIT pipes is a continuous irrigation. Floater in the water supply tanks sustain a very low system pressure at around 0.01 cm and ensure permanent water availability.

The drip irrigation pipes were made of polyethylene and manufactured by Irritec/ Isiplast tape with distances between the emitters of 10 cm. The operation pressure was 0.7 bar. The distance between the pipes were 80 cm and between the plots 1.0 m. The irrigation scheduling in the drip irrigation greenhouse was managed based on results from previous research projects from this test site, which delivered values for an optimized drip irrigation management under the current climatic conditions (Kechabar et al., 2009).

Two qualities of irrigation water were used. One was groundwater (GW) from a nearby borehole with an electric conductivity value of 4.69 dS m⁻¹ and the second was dam water (DW) from the dam "Fontaine de Gazelle". The dam water is supplied to the experimental station via pipelines and collected in an open water reservoir built of concrete. Because of that the dam water has high loads of suspended solids and organic matter.

Tomatoes were planted and harvested; the yield from each plot was analyzed by weight and size.

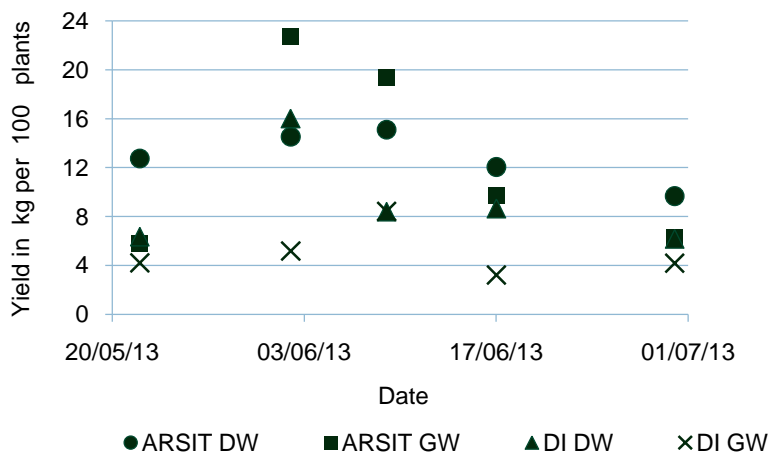
3. Results



During the experiment from the 25.02. to the 01.07.2013 the cumulative water consumption per m² on the dam water ARSIT plots was in average 67 % lower than on the DI plots. Considering the water consumption on the groundwater plots this average value is 46 %. Figure 2 shows the cumulative water consumption per m² on the dam water and groundwater irrigated experimental plots.

The ARSIT plots which were supplied with groundwater consumed in average 48 % more water than the plots supplied with dam water. Reasons for this could be a pipe clogging or biofilm creation at the inner surface of the ARSIT pipe, due to a high content of suspended matter in the dam water. Due to unavailable possibilities of water analysis this assumption could not be verified and should be subject to further research.

Figure 1: Water consumption of the ARSIT and Drip Irrigation plots in comparison, ARSIT – Auto Regulative Subsurface Irrigation Technique, DI – Drip Irrigation



Contrary to the high water consumption on the DI plots the yield there was low in comparison with the ARSIT plots (see Figure 2 **Erreur ! Source du renvoi introuvable.**). The results in the Figure 3 **Erreur ! Source du renvoi introuvable.** show harvest losses on the DI plots irrigated with groundwater. Reason for the reduced yield can be the high salt content in the groundwater as a stress factor for the plants development. ARSIT irrigation in comparison with DI generates a 60 % higher yield when using groundwater and with 48 % less water consumption.

Figure 2: Yield from the experimental plots normed to 100 plants, comparison of ARSIT and DI, ARSIT – Auto Regulative Subsurface Irrigation Technique, DI – Drip Irrigation, DW – Dam Water, GW - Groundwater

Water use efficiency (WUE) is defined as yield of plant product (kg of tomatoes) per unit of crop water use (applied irrigation water in m³). The WUE on the ARSIT irrigation plots was significantly higher than on the drip irrigation plots.

	WUE [kg/m ³]		
	DW	GW	Total
ARSIT	10.50	4.40	7.45
DI	2.12	1.62	1.87

4. Conclusion

In many countries water scarcity increases due to overexploitation of water resources, climate change, and population growth. In this work experimental studies were carried out to analyze a new sub-surface irrigation technique with membranes. Two water qualities were used: water from a dam with high loads of suspended particles and groundwater with high salt content. The water consumption with the ARSIT system was significantly less than with the drip irrigation. At the same time the yield was higher so the water use efficiency with the ARSIT system was 70 % higher than on the drip plots. Especially when using salty groundwater the yield was higher in comparison to the drip irrigation. When using dam water with high portion of suspended solids the membrane pipes show a decrease of water flow through the pipe.

Summarizing it can be stated that the innovative ARSIT approach has proven its capacity to significantly increase water use efficiency with respect to the conventional drip irrigation.

REFERENCES

- Batchelor, C., Lovell, C., Murata, M. (1996): Simple microirrigation techniques for improving irrigation efficiency on vegetable gardens. - *Agricultural Water Management* 32 (1996), 37-48
- Bainbridge, D.A. (2001): Buried clay pot irrigation: a little known but very efficient traditional method of irrigation. - *Agricultural Water Management* 48 (2), 79–88.
- Bettiche, F. (2012): Survey on agricultural practices in Biskra region. - Scientific and technical research center on arid regions (CRSTRA), Biskra, Algeria. 94p.
- Boudibi, S. (2013): Etude hydrogéologique des eaux de la nappe de l'Eocène de la région de Tolga (Biskra), Apport des méthodes statistiques. - Mémoire de master, E.N.S.A. El-Harrach. 94 p.
- Kechabar, M.S.A., Tabet, S., Roumani, M., Barbari, F., Djoudi, M., Salem A., Ziad, M.S. (2009): Influence du type d'irrigation sur les paramètres de productions de la culture de la tomate bio sous abri dans la plaine d'El Outaya. – unpublished paper at CRSTRA (Algeria)