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Material Investigations for an Efficient Auto Regulative Subsurface Irrigation Method with Permeable Pipes

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Introduction

There is increasing pressure on water resources due to an increasing irrigation water demand, climate change and population growth. In many countries, water consumption exceeds the renewable water resources, leading to widespread groundwater depletion and water scarcity. Many developing countries are characterized by economic water scarcity which can be described as a lack of investment in water technologies and human capacity to satisfy the demand for water. Symptoms of economic water scarcity include scant infrastructure development.

Agriculture accounts for 70 – 80% of global water use. Due to this fact, the water productivity in this sector needs to be improved. Increasing water productivity – gaining more yield and value from water - is an effective means to intensify agricultural production and reduce environmental degradation. Poverty and food are closely interlinked. The majority of extremely poor people, which are earning less than one dollar per day, live in rural areas. For a big portion of these people, farming is the main source of income. So there is a crucial need to invest in affordable innovative water technologies, enhancing food security and economic growth.

The paper presents a new and efficient irrigation technology based on a combination of common subsurface and pot irrigation.

Current irrigation methods

Currently applied irrigation techniques comprise surface and subsurface irrigation. Predominant is the surface irrigation which is cheap and easy to handle, nevertheless surface irrigation efficiency amounts to only approximately 40%, i.e. 60 % losses. Causes for the low water efficiency of surface irrigation are evaporation, deep percolation and management losses.

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Subsurface irrigation is an efficient irrigation method which is only rarely used due to high investment costs. With subsurface irrigation, the water is supplied beneath the soil surface. Different techniques of subsurface irrigation comprise the irrigation by drainage tubes, or water supply via porous pipes.

An up-to-date subsurface technique is the subsurface drip irrigation, or SDI. The SDI uses a permanently or temporarily buried dripper line located at or below the plant roots. The water is released through plastic emitters which are installed in the tube at different spacings.

Main advantage of the presented modern subsurface irrigation techniques is a relatively high efficiency. Their disadvantages comprise high investment costs and the need for a more or less sophisticated control. These constraints limit the application of current subsurface irrigation techniques to regions with high economic and human potential.

Another type of subsurface irrigation is the clay pot or pichter irrigation (Figure 1), which is known since thousands of years in arid and semi-arid areas.

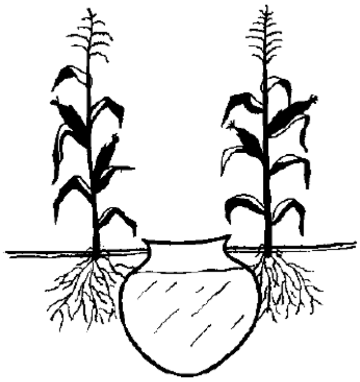

Figure 1: Clay pot irrigation (BAINBRIDGE 2001)

The unglazed porous clay pot is 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 matric potential is high. Once the soil humidity rises, matric potential will decrease and the water flow eventually decreases or even stops. Decisive parameters for the efficient operation of pot irrigation are the porosity and the hydraulic conductivity of the pot material which is controlled by the burning temperature and the raw material. Used pot materials are clay as basic substance, in order to regulate the porosity, sand, saw flour, cork flour etc. are added.

Another important parameter for the pot irrigation is the soil matric potential, depending on the type of soil and its water content. The water content is regulated by the evapotranspiration, which is controlled by climate parameters such as temperature, radiation, wind etc and the transpiration of the plant.

Thus, the soil matric potential and the pot parameters regulate the amount of water delivered by pot irrigation.

Disadvantages of pot irrigation are its mechanical sensitivity leading to an exclusion of mechanized agriculture, and a high level of labor requested. The longevity of the pots is often not satisfying.

Combination of subsurface and pot irrigation

The aim of the current investigations is to combine the advantages of both irrigation systems, while avoiding their disadvantages. Common advantages of both approaches are the water release in the plant rooting zone, dry plant surface, dry soil surface, and subsequently low losses by evaporation and deep percolation, operation independent of morphology and high water efficiency.

The main advantages of subsurface irrigation are the possibility of mechanized installation, the application at large scale and a long-life cycle. The main advantages of pot irrigation are its potential for auto-regulation, being a low cost technology easy to handle not depending on any sophisticated control.

Combining the known system advantages will result in a flexible, permeable porous pipe with a potential for auto regulation.

Important system parameters like hydraulic conductivity of the porous pipe material and the dimensions are known by now. The system functionality is attested by a numeric model, with minimization of losses to percolation and evaporation.

Historically known materials for porous pipes

Known porous subsurface irrigation methods vary in material, form of laying and duration of irrigation. The porous pipes may consist of porous materials like a mixture of concrete with sand or gravel with a water conductive crown (Figure 2), or a bitumen pipe with a sand-gravel mixture crown (Figure 3).

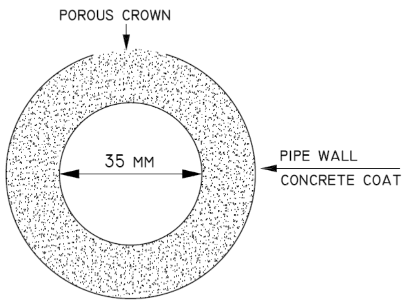

Figure 2: Pipe with a water conductive crown after STAUCH (changed by YOUSSEFI 1967)

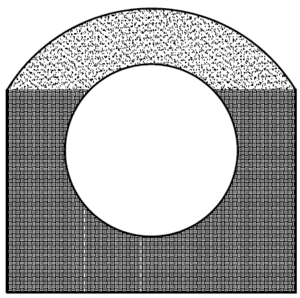

Figure 3: pipe with a sand-gravel mixture crown after STEIN (changed by YOUSSEFI 1967)

These techniques are history now. They have never been used at a larger scale in agriculture due to their high costs, water losses and mechanical sensitivity.

A new irrigation system is the porous hose. The hose consist of used tires granulate. The porous hose releases water due to the system operation pressure. This system is often used in horticulture. Nevertheless, the water flow in this system is a function of water pressure and thus needs to be controlled.

Requirements on the innovative auto regulative irrigation pipe

The irrigation system should be a low cost technology, to be used by smallholders in developing countries as well as in larger scale irrigated agriculture.

The pipe material should have an appropriate permeability that is the right hydraulic conductivity in relation to the dimensions – diameter and wall thickness- of the pipe. The material should have Darcy properties – that is a linear correlation between volume flow rate and the pressure gradient. Furthermore the system should be easy-to-use, allowing installation by both machinery and by hand.

Furthermore, the pipe material selection has to consider the economic and infrastructural border conditions of the region of use (industry, public roads, market structure, education level of the system user etc.). It is not wise to develop a more or less cheap and easy to handle pipe for developed countries because in developing countries the price and labor have another impact than in developed countries. So it is essential to investigate material technology for both developed and developing countries. Only in this context will the system adaption being successful.

Current material investigations

One solution currently investigated is a combination of polymer fibres and a mineral layer around a supporting shell formed as a pipe. Current research aims at mineral materials with an appropriate hydraulic conductivity and chemical inertia in contact with water. Another solution comprises a non-woven combined with a permeable membrane layer. An advantage of this material is the possibility to produce a pipe with rather small dimensions. For use in developing countries locally available materials and existing local infrastructure for production will be investigated in a research project in the near future.

References

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