Development and Revision of Design Criteria for Pitcher Irrigation Systems / (*translation of original title*)

Full reference

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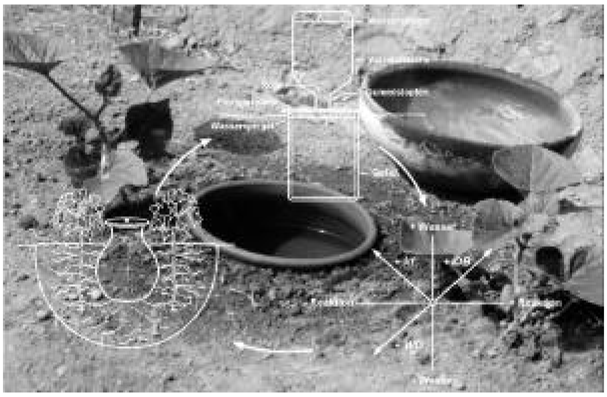
Summary

Pitcher Irrigation - an ancient irrigation system, not yet forgotten



Pitcher irrigation is an ancient irrigation system which seems to have originated in northern Africa and in Iran. It is widely thought to be a water saving and efficient irrigation system. The reasons for this properties are thought to lie in its high autoregulative capabilities which arise from the close interaction between the pitcher and its environment, namely the soil, climate and plants. Despite its apparent advantages, the reasons and factors influencing the system's performance have not satisfactory been described and proven. For the practical application of the system and its efficient use there is still a lack of basic information and understanding of the system which would lead to an understanding of the design criteria for pitcher irrigation. The objectives of this project were to elaborate and evaluate these principles of the system and then to develop design criteria for practical pitcher irrigation applications.

In the first section a comprehensive overview of the principles and techniques of pitcher irrigation is given and the current research in this area is reviewed. The experimental section is based on two year long greenhouse trials and on several years of laboratory experiments conducted at the Department of Rural Engineering and Natural Resource Protection at the University of Kassel in Germany. The main emphasis of the practical work has been on investigating the properties of the pitcher material and its changes over time. Secondly, the close interaction between pitchers and their environment is examined and other influencing factors are elaborated. In the last section special emphasis is put on the crop's development and its influence on pitcher performance.

It was found that the hydraulic conductivity of the pitcher material is the most important of the three design factors which influence the movement of water through the pitcher wall, followed by the size of the surface area of the pitcher and the wall thickness of the pitcher material. A mixture of sand and clay as the base material for pitchers has proven to be a very effective and practical method to increase the saturated hydraulic conductivity and hence the seepage rates of pitchers. The results

show a highly significant exponential increase of the saturation hydraulic conductivity of the fired pitcher material with increasing sand fractions. However it was found that even under laboratory conditions a reproduction of a given hydraulic conductivity could not be satisfactory achieved to the aspired extent. In addition, it was observed that, besides the material composition, the method of production and firing process had a substantial influence on the permeability of the pitcher material. Also, the saturated hydraulic conductivity is not fixed but varies with time when pitchers have been used extensively.

Despite other results, it became clear that pitchers used for pitcher irrigation where capable of adjusting their seepage rates according to changes in evaporation or crop water demands. In some cases, an increase of seepage rates by more than 200% could be observed. The degree and capability of adjustment may be defined as the "reaction capability" of a pitcher. This is determinated by the following three main interaction components: the hydraulic conductivity of the pitcher material, the size of the surface area and the wall thickness of the pitcher. Optimisation of the system with reference to its seepage rates and "reaction capabilities" can be conducted by using the interaction diagram shown in Figure 1 (below). This interaction diagram only allows a qualitative assessment of the interplay of the pitcher properties. A quantitative assessment is not possible. With reference to the soil-pitcher interaction it also has to be taken into consideration that the interaction is not a constant one. The increasing root growth around pitchers minimises the interaction potentiality over time. Hence the seepage rates and "reaction capabilities" decrease with the length of the irrigated crop grown. Under practical irrigation conditions, bot the seepage rate and "reaction capability" should be taken as being much lower than is potentially possible.

In an abridged cropping period of maize there was an increase in drymatter production with pitchers of higher water application . However it could also be shown that there was, for those pitchers with higher seepage rates, a decline of drymatter production closer to the pitcher walls. The results indicate that with increasing water application from pitchers a non-linear reduction in the increase rate of water use efficiencies is to be expected. Higher water application rates result in an increase of crop production but also in an increase of losses like those through deep percolation or reduced yield in the vicinity of the pitcher wall.

The square grid plant layout which was used showed itself to be suitable and enabled the the number of plants per pitcher plot to be easily adjusted according to the pitcher capacity. The "K.O. practice" used allows a well gradated approach toward an optimum number of plants per pitcher when designing the system.

For the transfer of the results into practical applications it has to be taken into account that the design process may not be based on standardised pitchers for irrigation. This difficulty arises because of the extreme complexity of pitcher production resulting in low predictiveness and reproducibility of seepage rates and "reaction capabilities" of pitchers. Pitchers do have a significant influence on the adequacy of the crop water supply, the degree of which depends on their individual properties. In contrast to other irrigation systems pitchers are functionally closely interconnected to the environment. Hence they are effected in a distinct way by the environmental factors (soil and climate) and the irrigated crop. It is therefore recommended to use an experimental (iterative) approach for the design, implementation and optimisation of pitcher irrigation systems. This allows an optimal adoption of the system to site specific and crop conditions. For the design and optimisation procedure it is recommended to follow the five step plan which is described into more details. For the improvement of the water use efficiency this plan takes into account both the adoption through the pitcher properties based on the interaction diagram, shown in Figure 1 (below) , as well as optimisation through the crop for instance by adjusting the number of plants grown.

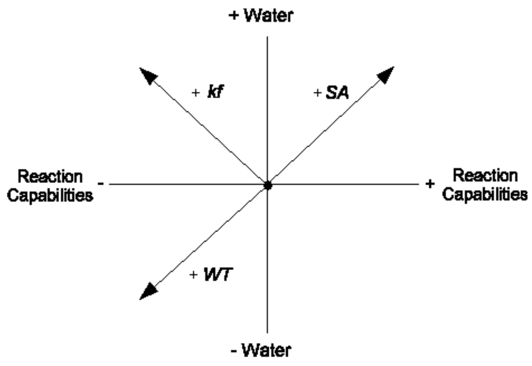


Figure 1:
Interaction diagram of seepage rates (+/- water) and "reaction capabilities"(+/- reaction capabilities) in relation to pitcher properties (kf - saturated hydraulic conductivity of the pitcher material; SA – surface areas of the pitcher; WT – wall thickness)

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