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Trickle irrigation using porous clay pots

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Abstract

Trickle irrigation can result in very high water use efficiency and is well-adapted to cropping on marginal land but is not an appropriate technology of the majority of small-scale, resource-poor farmers. Simple, low-cost applications of the trickle concept have received little scientific attention. This paper presents summary of an extensive laboratory, field and computer study into such a system based upon the use of porous clay pots.

Introduction

Pot irrigation is thought to have originated in North Africa (Barth, 1988) and provides a simple and efficient alternative to the highly sophisticated and expensive forms of trickle irrigation.

The general principle involves embedding unglazed earthenware vessels in the ground, to be periodically filled with water and covered with an earthenware lid (Barrow, 1987). Alternatively, a number of porous capsules may be automatically filled by a network of interconnecting pipes under pressure (Silva, 1980). The hydraulic permeability of the pot means that water flows into the soil surrounding the vessel, thus providing a moisture supply to the root zone.

Given that there is continuity through the wall of the vessel, then the rate of water release depends upon the potential difference between pot and soil. Therefore, the system is, in principle, able to respond automatically to changes in the rate of root water uptake. The nature of this response is, at least in part, dependent upon the properties of the ceramic material.

Experimental method

In this study, the behaviour of the pot-soil-plant continuum was investigated through

(i) measurement of hydraulic properties of ceramic pots,

(ii) field experiments over two seasons in Ghana, and

(iii) development of a computer model of the pot-soil-plant system.

The experimental methods are briefly explained below but full details can be obtained from Agodzo (1993).

Hydraulic properties of ceramic pot

The object of this investigation was to establish the manufacturing conditions ideal for clay pots used as irrigation supply units by examining the roles of firing temperature and clay texture in influencing the hydraulic properties of the pot.

Three general purpose smooth, medium and coarse clays were investigated. Using samples of the pot wall the porosity was determined by weighing of vacuum-saturated samples and the water retention curve measured using pressure plate apparatus. Smaller cylindrical pots were manufactured and the saturated hydraulic conductivity measured using standard falling-head permeameter procedures.

Field experiments

The field experiments were designed to study the pot-soil-plant continuum and to evaluate the effects of pot sizes and plant population on plant water use and yield. The experimental site (Kumasi, Ghana) experiences a sub-humid tropical climate with average annual rainfall of 1300 mm and potential evaporation of 1260 mm. The field experiment comprised four blocks each of six randomly assigned plots (4 m x 7 m). The treatments were factorial combinations of three water treatments and two planting densities. Watering treatments consisted of a control (rainfed) and two sizes of pot (3 and 4.5 L respectively). There were either one or two plants/pot. Two test crops were used, pepper (Capiscum frutescens) grown in the dry season (1 November 1990 - 28 February 1991) and okra (Hibiscus esculentus) grown in the wet season (8 May - 14 August 1991). Plants (with their associated pot) were grown on a 1 m x 1 m grid.

Results and discussion

Hydraulic properties changed both with clay texture and firing temperature (Agodzo et al. 1990). Coarse clay resulted in the largest porosities and smooth clay the lowest. As firing temperature increased from 850°C to 1250°C the porosities decreased from 26% to 15% in the case of the coarse clay through to 21% to 0% in the case of the smooth clay. Water retention curves indicate that, for all three clays, the majority of pores have an equivalent cylindrical radius $< 0.3\mu m$. However, with increasing firing temperature pores $< 0.3\ \mu m$ are lost and the proportion of pores between 0.3 and 1 µm increases with the largest such increase occurring for the coarse clay.

Hydraulic conductivities of material fired at 850°C are similar ranging from 0.1 to 0.3 mm/d. They increase with increase in firing temperature to a maximum in the range 950°C to 1150° and then fall. This increase is much the greatest for the coarse clay which rises to 1.8 mm/d.

In using the pot as an irrigation device, there is the need to thoroughly investigate the hydraulic properties of the pot since the malfunction of the pot as a water application device may result in crop failure. From the investigation it was concluded that a temperature range of 950°C - 1050°C is required for the production of the irrigation pot, corresponding to 18% to 24% porosity and hydraulic conductivity 1.4 mm/day is achievable using coarse clay. Limited investigation of traditional clay pot firing techniques in villages around Kumasi indicated that firing temperatures seldom exceed 750°C and consequently hydraulic conductivity values are likely to be relatively low.

Pots were filled on a weekly basis with demand varying between 1.4 to 2.5 l/week. The field experimental results showed the pot regulating itself to maintain a balance between water supply and demand (figure 1). Plant density per pot was the dominant factor in overall fruit yield, given that other growth factors were adequate. Pot size did not affect yield, but irrigated treatments showed a clear improvement over the rainfed control.

Under irrigation, commercial yields of pepper are in the range of 1.10 to 1.25 t/ha fresh fruit (Tindall, 1983) for a minimum economic life of 6 months. Pepper yields for the irrigated trials lasting 4 months ranged between 1.0 to 1.3 t/ha. According to Tindall (1983), commercial okra yields can be up to 2-3 t/ha. Up to 2.0 t/ha of okra were realised for the irrigated treatments.

Maximum irrigation effectiveness of 1.73 kg/m^3 and 3.86 kg/m^3 were obtained for pepper and okra respectively. Irrigation was more effective during the dry season than the wet season. No previous figures have been reported in the literature for the irrigation effectiveness of pepper and okra.

Laboratory-based lysimeter studies indicated a zone of influence extending radially some 10 cm beyond the perimeter of the pot. Field observations indicated that the majority of roots grew as a sheath immediately around the pot. Clearly the pot distorts the normal root growth habit. It is thought that root suction may control pot outflow directly.

Conclusion

Production methods clearly influence the hydraulic properties of the ceramic material used. In particular, firing temperatures may be crucial in determining the resulting hydraulic conductivity.

Under the conditions of these field experiments, the volume of irrigation water supplied by the pots was small, amounting to approximately 50% of the pot volume per week. Nevertheless, the pot supply was responsive to demand and this was important as reflected in the increased yields.

Rooting habit is strongly perturbed by the presence of a pot. This places a premium on consistent pot maintenance as the soil water reserves will be less readily available to the rooting system. While no problems apparently arose in these experiments, it might also mean that, under more arid conditions, water supply to the roots might be limiting. This is being explored using a mathematical model of the pot-soil-plant system.

Acknowledgements

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