Comparative study of wetting patterns of drip emitters developed for microirrigation systems

W M K Peries, C P Gunasena, C M Navaratne
Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya

Abstract

A research study was conducted to introduce two water saving emitters for surface and subsurface irrigation systems using low cost and freely available materials. Subsurface emitter has a special feature named textile interface which was used to increase the potential gradient between the textile interface and the soil matrix. Present study was conducted to estimate the soil volume wetted by each emitter. In order to compare the performances, commercially available surface drip emitter was also tested.

Laboratory experiment was designed using a box having a transparent sheet of glass fixed to one side of the box to observe the wetting patterns. The design box was filled with soil to maintain the bulk density within the box at 1.3 g/cm^3 *for each and every test. Achievable minimum flow rates of the newly developed surface and sub surface emitters were maintained as 11 cm*^{3} *min*$^{-1}$*. Flow rate of commercially available emitter was measured and achievable minimum flow rate was about 26.13 cm*^{3} *min*$^{-1}$*. Time of irrigation was fixed as 30 minutes for the three experiments. Applied amount of water was measured in each irrigation and it was about 330 cm*^{3} *for surface and sub surface emitters. Amount of water applied by the commercial emitter was about 783.9 cm*^{3} *during 30 min irrigation time period.*

Assuming that the volume and geometry of the wetted soil under a point source is best represented by a truncated ellipsoid, wetted soil volumes were calculated. Maximum diameter of the ellipsoid was measured and the distance to that level from the soil surface was also measured as a parameter which is required for the calculations. Vertical extent of the soil volume was also measured. Time taken to achieve the maximum height and diameter was also quantified at the beginning of the irrigation. The emitter having textile interface achieved 1648.8 cm^3 *of wetted soil volume within 57 minutes and emitter which was used as a surface drip achieved 641.92 cm*^{3} *of wetted soil volume within 40 minutes. Whereas commercially available surface drip emitter consumed 453.9 cm*^{3} *more water and achieved 3351 cm*^{3} *of wetted soil volume within 55 minutes.*

Key words: emitter, textile interface, micro irrigation system, wetted soil volume

Introduction

Drip or trickle irrigation was developed by an Israeli engineer named Symcha Blass credited with inventing drip irrigation in the 1940s (Peiris, 2006). Since then various drip irrigation methods were developed by scientists in various parts of the world. Water can be applied very effectively and efficiently over the soil surface or directly to the root zone using these drip irrigation systems. Application of water is done through specially designed emitters to reduce the flow rate. These emitters can be classified into two major categories namely surface emitters and subsurface emitters (Navaratne, 2003).

The Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna designed and fabricated two types of emitters which can be efficiently used in surface and sub surface micro irrigation systems. The subsurface emitter has an especial feature named textile interface which was used to increase the potential gradient between the textile interface and the soil matrix (Gunasena and Navaratne, 2004). In order to compare their performances with what is available, a commercially available surface drip emitter was also tested. Field layout or spacing between emitters was decided with respect to the wetting patterns of each emitter. The present paper discusses the experimental procedure adopted to obtain the wetting patterns of selected emitter types. Commercially available emitter was also used as an indicator to represent available technology.

Objective

The objective of the research was to determine the maximum wetted soil volume by selected surface and subsurface drip emitters

Materials and methods

Construction of surface emitters

In order to construct the surface emitter a bolt of 1"x 3/16 and micro tube having internal diameter of 3mm were used (Figure 1). Water was allowed to drip through the spiral pathway of the bolt.

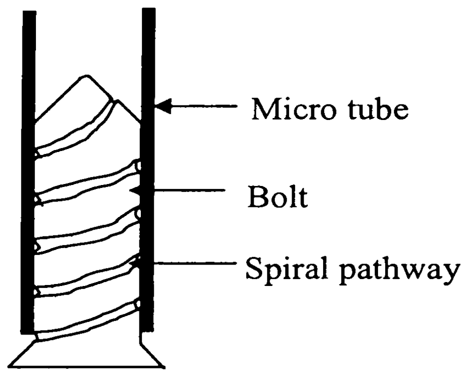


Figure 1 - Cross section of the constructed surface emitter

Based on the preliminary studies, the achievable minimum flow rate was taken as 11 $cm^3\ min^{-1}$(Peiris at.el 2006). Eight threads of bolt were inserted into the micro tube to get the above flow rate.

Construction of subsurface emitter with textile interface

In the subsurface emitter with textile interface, previously constructed surface emitter explained above was used as the water emitting component. Textile interface was constructed to increase the potential gradient between the textile interface and the soil matrix. As shown in (Figure 2), textile interface was constructed using a PVC conduit tube 25 cm long and 1.25 cm in diameter and synthetic textile material. Textile material that was 1 meter long and 4 cm width was used to wrap around the conduit to develop a saturated water surface or a region having higher water potential gradient than the soil matrix. Holes having 1 cm diameter were drilled along 17.5 cm of the tube to facilitate the moisture migration. This perforated tube was filled with coir dust to increase the water retention capacity. Textile interface was the only component installed in the soil media in this irrigation system. Height of the textile interface was determined by considering the average root zone depth of vegetable crops. Textile interface was inserted to the soil box allowing the upper part of the interface (about 2.5cm), to remain just above the ground surface (Figure 2). The water emitting component was inserted to the upper part of the textile interface to supply water to the system. Ground clearance (5 cm) was kept to minimize moisture migration to the surface of the soil and minimize water evaporation through the soil surface (Figure 2). The water emitting component was then connected to the water supply system.

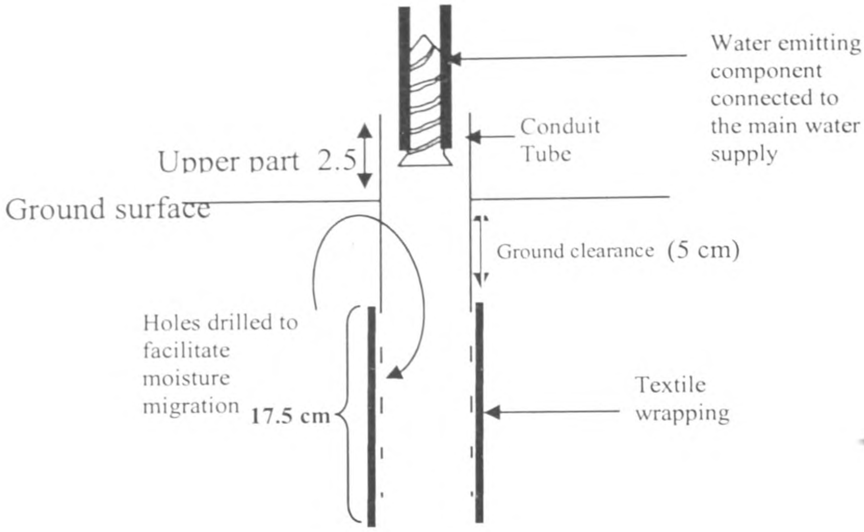


Figure 2. Cross section of the textile interface with the water emitting component inserted to the upper part of the interface

Specifications of the commercially available emitter

Commercially available adjustable on line drippers shown in Figure 3 were used as commercial emitters with 26.13 cm^3 min^{-1} of minimum achievable flow rate to represent the available technology.

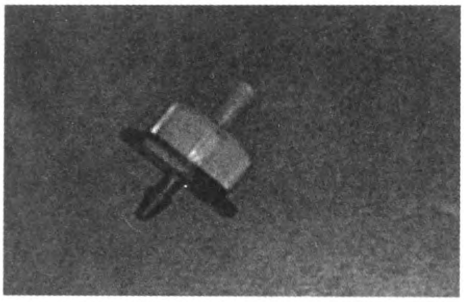


Figure 3. Commercially available on line surface dripper

Specification of the experimental box

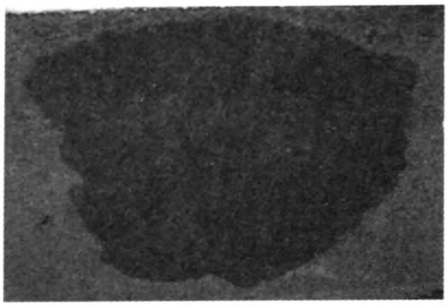
Regiform boxes having a sheet of glass for one side, 45x43x45 cm, were used for the experiment. Red yellow podsolic soil available in Mapalana Research Farm was used to fill the boxes and bulk density was maintained as 1.3 g/cm^{-3} for each experiment.

Experimental procedure

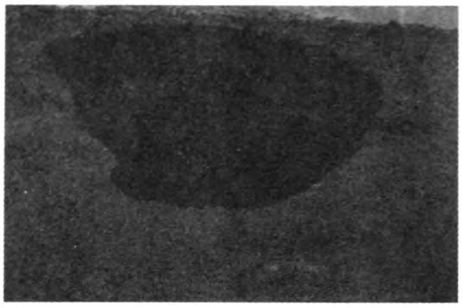
Three experiments were conducted to determine the wetting patterns of the three selected emitter types. Surface and commercial emitter were used to irrigate over the soil surface. Thus, each emitter was placed over the middle of the soil surface of the experimental box and irrigated for 30 minutes one at a time. Textile interface of the sub surface dripper was inserted through the middle of the box into the soil allowing upper part to remain on the soil surface. Irrigation was done for 30 minutes as in the earlier method. Measuring the dimensions of the wetted soil volume was started just after seeing the wetted area through the sheet of glass. Diameter of the wetted soil volume (d), Depth (z) and Depth (h) up to the maximum diameter level from the soil surface were measured with time for the calculation purposes.

Calculation procedure

As shown by Zur (1996) it was assumed that the shapes of the wetted soil volumes (Figures 4a and 4b) are mostly represented by a shape of a truncated ellipsoid (Figure 5). Theoretical equation (Equation 1) was used to calculate the wetted soil volume (V) is given below.



a) Emitter with textile interface



b) Surface emitter

Figure 4. Different shapes of the wetted soil volumes

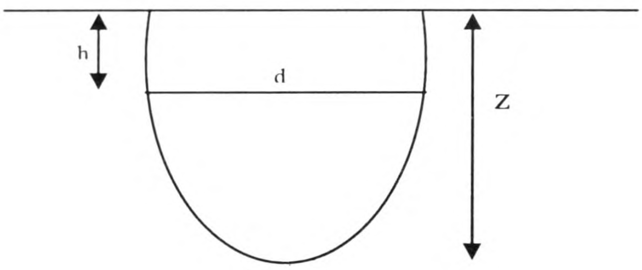


Figure 5. Truncated ellipsoid showing the measured dimensions

$$V = \frac{\pi}{12} d^2 \left[2z + h - \frac{h^3}{(z-h)^2} \right] \quad \text{............} \quad 1$$

Maximum diameter achieved of the wetted soil ellipsoid is denoted as (d) and maximum depth achieved is denoted by (z). Distance from the soil surface up to the maximum diameter is denoted by (h). All measurements were taken after the stable wetting front is observed.

Results and discussion

Maximum values of time after irrigation, maximum diameter, maximum depth, the distance from soil surface to the point where maximum diameter occurred and amount of water used by three emitters are given in Table 1. The subsurface emitter having textile interface, the constructed surface emitter and commercially available emitter achieved 1648.8 cm^3, 641.92 cm^3 and 3351 cm^3 of wetted soil volume respectively. Commercially available emitter consumed 454 cm^3 more water than the other emitter systems during 30 min of irrigation time period.

Table 1: Maximum values achieved by the three experiments and amount of water used to reach maximum values

Emitter type	Time of irrigation in min	Time taken to achieve maximum diameters in min	Maximum diameter achieved in cm	Maximum depth achieved in cm	Distance from soil surface to point where maximum diameter occurred in cm	Amount of water applied for 30 min of irrigation in cm^3	Wetted soil volume in cm^3
Sub surface emitter with textile interface	30	57	14.5	13.5	5.5	330	1648.8
Surface emitter	30	40	14.25	5.5	2.3	330	641.92
Commercial emitter	30	55	23.5	10.5	2.4	784	3351

Conclusions

The designed subsurface emitter achieved the maximum wetted depth with textile interface within 30 min irrigation time using 330 cm^3 of water. The maximum wetted diameter was recorded by the commercially available emitter within 30 min of irrigation time with 784 cm^3 of water. The results revealed that the soil volume wetted by using 1 cm^3 of water was 5 cm^3, 1.94 cm3 and 4.27 cm3 by the subsurface emitter with textile interface, the newly constructed surface emitter and the commercial emitter respectively. Therefore it can be concluded that the subsurface emitter with textile interface wetted soil more efficiently than the other two surface emitters.

References:

Gunasena C P and Navaratne C M.(2004), Designing and testing of an emitter for sub surface drip irrigation systems using testile materials. On line at <http://www.pgia.ac.lk/events/wp/acrobatpapers/C-Gunasean-13.pdf#search>

Navaratne C M. (2003), Low cost auto irrigation system for home gardens intensification, PhD thesis in irrigation and water management, University of Ruhuna Sri Lanka

Peiris H W K, Gunasena C P, Navaratne C M. (2006), Comparative study of three different micro irrigation systems to select suitable irrigation system for home gardens in Mapalana area, Symposium proceedings of the water professional's day, Postgraduate Institute of Agriculture, University of Peradeniya. Sir Lanka.

Zur. B (1996) , Wetted soil volume as a design objective in trickle irrigation , Agricultural Engineering Department, Israel Institute of Technology, Haifa 32000, Israel, page Sci 16: 101-105.