# Performance Evaluation and Adoption of Trickle Irrigation in Water Scare Areas

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## Abstract

Trickle irrigation, usually called drip irrigation, is among the latest irrigation methods and is quite popular in areas with water scarcity and coarse soils having high infiltration rate but due to high installation cost it has yet to find its way in the countries like Pakistan. Under this system, required amounts are frequently applied at many points of a field surface/subsurface near the plants. A significant feature of trickle irrigation is that the uniform distribution of water is possible, which is one of the most important parameters in the design, management, and adoption of this system. A well designed system applies nearly equal amount of water to each plant, meets its water requirements, and is economically feasible. Water application efficiency is another key factor in system selection, design, and irrigation management.

An experiment was conducted near the Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam to evaluate the performance of trickle irrigation system in terms of water distribution pattern, emission uniformity, field application efficiency, and water losses through deep percolation. Two types of locally made emitters (smooth and spiral) were tested in this study.

The results suggest that both the emitters generally performed well. The emission uniformity ranged between 80 and 90% for two types. However, the uniformity coefficient values were slightly lower with smooth emitters than the spiral ones suggesting that the spiral emitters are superior to smooth ones thus could be used with great degree of confidence for better performance.

The wetted perimeter was function of emitter discharge and application time. Water movement below the emission point was more pronounced in vertical rather then horizontal direction. In most cases, the wetting front followed an axially lop-sided pattern. The water movement pattern showed that the wetting front was about 0.35 m wide and water seeped to 0.57 m depth. The root zone for many short rooted crops is located in this range hence the percolation losses would practically be negligible under such situations. The operational time under this system is at the liberty of farmer hence it can be decreased or increased if water movement at any stage departs beyond root zone to avoid deep percolation.

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## Introduction

Trickle irrigation, usually called drip irrigation, is among the latest irrigation methods and is quite popular in the areas with water scarcity and soils having high infiltration rates. It can apply frequent and required amounts of irrigation water at many points of a field surface/subsurface near the plants (Youngs et al., 1999). The conveyance and other conventional losses such as deep percolation, runoff and soil water evaporation are negligible as water is conveyed through pipes and directly applied near plant through drippers/emitters. The system consists of water pumping unit, mixing chamber, mainline, sub-main, laterals and emitters. The main line delivers water to the sub-mains and they discharge into the laterals. Irrigation is accomplished by emitters made up of small diameter polyethylene tubes installed in the lateral lines. They deliver water drop by drop to the soil surface near the base of the plants at a desired rate. Though the system slowly and partially wets the soil near the plant root zone but, it is practically impossible, and economically unfeasible to apply the same amount of water to all plants within a field. Therefore, in most cases, even a well designed system gives poor uniformity as a consequence the yields are pretentious (Bhatnagar and Srivastava, 2003). The trickle irrigation system offers the highest irrigation uniformity compared with other irrigation systems but it is function of physical and hydraulic design characteristics of emitter tubing (Al-Amound, 1995). A well design system applies nearly same amount of water to each plant, meets its water requirements, and is economically feasible. The uniform distribution of water is reflected by the values of uniformity coefficient which in turn relates to the performance parameters associated with the variability in the whole system. A system with uniformity co-efficient of at least 85% is considered appropriate for standard design.

Water application efficiency is another important parameter in system selection, design, and irrigation management. The ability of an irrigation system to apply water uniformly and efficiently to the irrigated area is a major factor influencing the agronomic and economic viability of the farming enterprise. Attainable water application efficiencies vary greatly with irrigation system type and management, however with a well designed trickle system an efficiency of 90% is attainable (Solomon, 1983). The system efficiency is associated with application uniformity that is evaluated by direct measurements of emitter flow rates.

Though, the trickle irrigation method is simple and pretty forgiving of errors in design and installation, however proper design guidelines are prerequisite for a better system performance. As soon as a system has been installed in the field, the evaluation must be carried and periodically repeated with time if the best performance is desired (Keller and Blisner, 1990). This study was aimed to evaluate the performance of a trickle irrigation unit in terms of water distribution uniformity, water movement pattern, application efficiency and deep percolation so that it can be adopted in the water scare areas.

## Materials and Methods

The experiments were conducted at the experimental site near Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam. A 25 m long and 14.5 m wide plot was utilized to install a trickle irrigation system as shown in Figure 1. The plot was equally divided into three subunits and 18 laterals with 8 m length were laid in each plot. The laterals were made from 12-mm diameter polyethylene rubber tubes. The orifices were made in the laterals at 30 cm spacing and emitter tubes with 3.2 mm diameter were fixed in them. The

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flow measurements were taken at various emitters in two ways. In one case, three laterals in each subunit were randomly selected and flow measurements were taken on all emitters. In the second case, 54 emitters were randomly selected at different positions distributed along 18 laterals. The randomization represented all the positions i.e., the beginning, 1/3, 2/3 and the end of a lateral line. The containers were placed beneath the selected emitters to collect the water flowing through them. The collected water in a given time was then measured using a graduated cylinder.

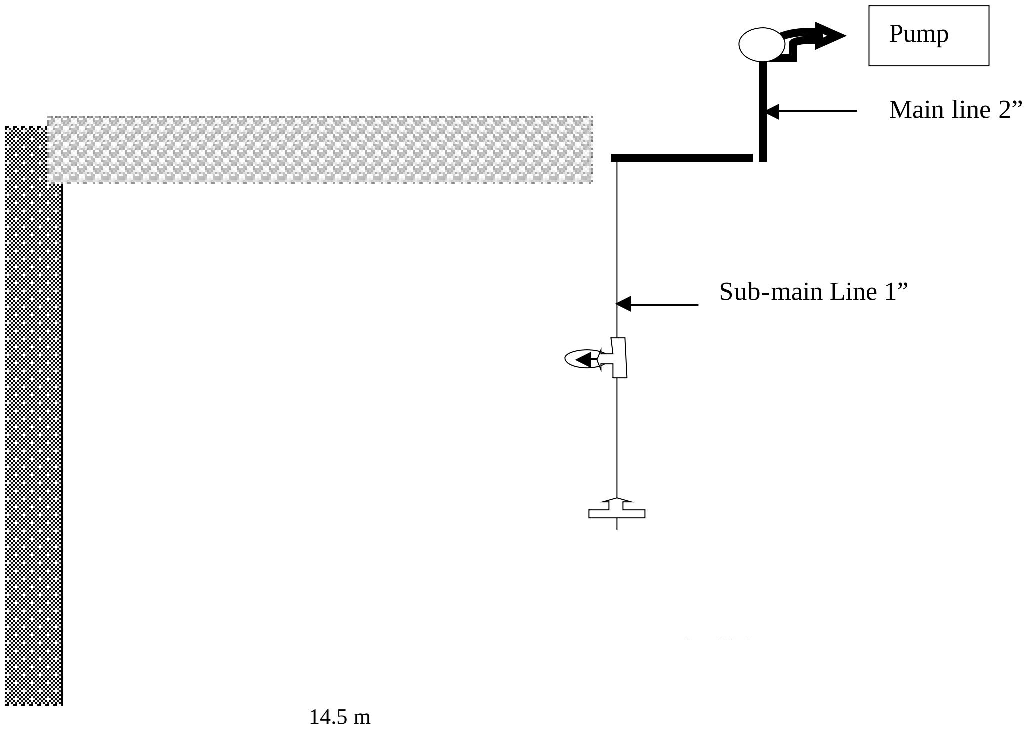

Figure1. Layout of the experimental plot

## Soil moisture distribution pattern

Soil samples were colleted before and after 24 hours of water application at different depths and distances on the both sides of the emission points. The wetting front in x and y directions was measured to determine the moisture distribution pattern in the soil profile. The irrigation application efficiency (Ae) and deep percolation (Dp) were evaluated using methodology described by Anyoji and Wu (1994) and subsequently followed by Soccol et al. (2002) using following equations:

$$Ae = \frac{Vs}{Vd}\,100 \qquad \text{and} \qquad Dp = \frac{Vp}{Vd}\,100$$

where,

Vs – volume of water stored in the root zone after irrigation;
Vd – volume of water delivered to the subunit;

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Vp – volume of water percolated below the root zone.

## Results and Discussion

The flow pattern through smooth emitters along a lateral line is illustrated in Figure 2 which portrays that the flow along the lateral length ranged between 0.021 and 0.05 lit/minute with an overall average of 0.035 lit/min. The emitters located at the beginning of a lateral showed slightly higher flows as compared to those located towards the end. This is anticipated because the pressure reduces towards the end of lateral due to head losses. Figure 3 shows flow through locally made spiral emitters. The flow along the lateral length is quiet consistent and the variation is small as compared to smooth emitters. Flow fluctuated between 0.02 and 0.039 lit/min with overall average of 0.31.

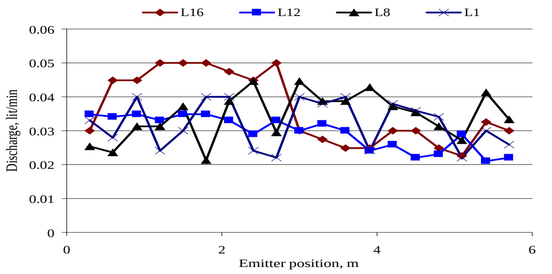

Figure 2. Discharge through smooth emitters for randomly selected laterals

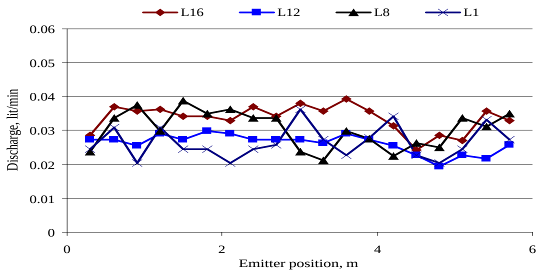

Figure 3. Discharge through locally made spiral emitters for randomly selected laterals

The flow through emitters was used to calculate coefficient of uniformity (CU) and results are given in Table 1. The smooth emitters showed lower CU than the spiral ones. The CU of randomly selected laterals with smooth emitters ranged between 0.71 and 0.79 with an average value of 0.78. However, it ranged between 0.82 and 0.87 with average value of 0.84 with spiral emitters. These results suggest that the spiral emitters were performing well and the systems with spiral emitters would give reasonable uniformity thus could be preferred over smooth emitters. However, the variation through smooth emitters could also be reduced by adjusting the length of run of individual emitter. The system achieved an overall field application efficiency of 82.7% with smooth emitters compared to 89.4% with spiral emitters (Table 1). These findings are in agreement with the previous results by Solomon (1983) and Mirjat et al. (1999) who reported efficiency in the same range. In a recent study, Soccol et al. (2002) suggested that the application efficiency could even be increased over 90% by adopting new management procedures.

Table 1. Application efficiencies and coefficient of uniformity

| Lateral Position | Application efficiency (%) | | Coefficient of Uniformity | |
|---|---|---|---|---|
| | Smooth emitters | Spiral emitters | Smooth emitters | Spiral emitters |
| L1 | 86.2 | 90.5 | 0.76 | 0.88 |
| L7 | 83.4 | 91.4 | 0.71 | 0.84 |
| L13 | 79.8 | 86.3 | 0.77 | 0.85 |
| Random | 81.4 | 89.4 | 0.79 | 0.82 |
| Average | 82.7 | 89.4 | 0.78 | 0.85 |

The moisture distribution pattern was determined by removing the soil wetted beneath the emitters and the actual shape and the diameter of wetted perimeter with depth was measured.

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Water movement below the emission point was more pronounced in vertical direction rather than in horizontal direction (Fig. 4). As expected, the wetted perimeter followed an axially symmetric pattern. The percolation depends upon soil physical properties (soil texture, permeability and porosity), irrigation operation time, and flow rate through the emitter. This study focused only on trickle design parameters and crops were not grown thus root depth of a particular crop could not be used to determine the percolation losses. However, it was observed that water front reached a maximum of 0.56 m depth. Under this situation, deep percolation losses would be practically negligible for the crops having roots within this range. Further, between 30 and 35% of the total surface area was wetted leaving 65 to 70% area dry. Based on area wetted, over 60% of the water could be saved through this method. In a study previously conducted by Mirjat et al. (1999) trickle irrigation saved over 63% of water as compared to furrow irrigation. In another study Memon et al. (1996) observed about 49% saving in water under trickle irrigated mango orchard as compared to traditional irrigation methods.

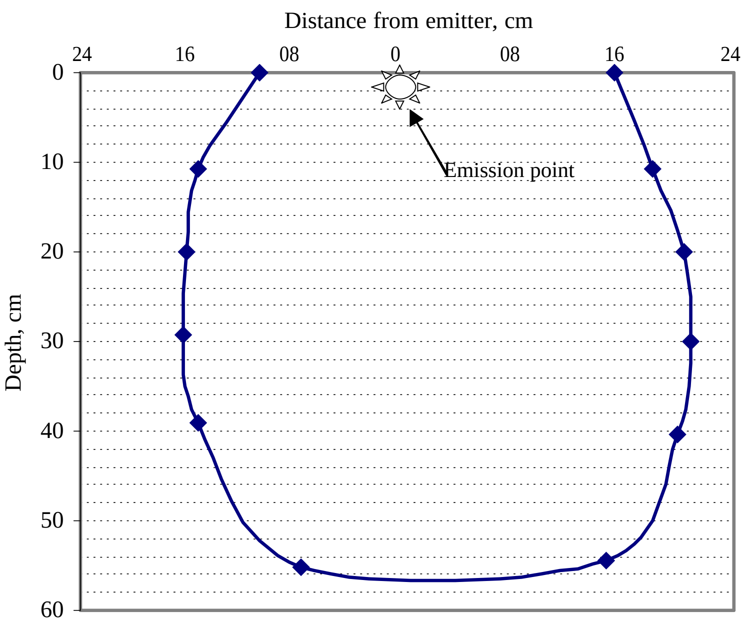

Figure 4. Water movement patterm beneath the emitter

## Adoption Potential of Trickle Irrigation

The trickle irrigation seems to have better future in the area with water scarcity. Under this method, water is directly applied to an individual plant instead irrigating the entire area thus it saves water which is otherwise lost by the use of traditional surface irrigation methods. The method is more suitable for production of orchards and high value vegetables where 40-60% water could be saved. A major economic factor of this method is yield increase per unit water; fertilizer and pesticide application are other added benefits.

Since, the system is cost intensive and the farmers are reluctant to use it. However, the progressive farmers have adopted this method in water scare areas. Further it has potential to be adopted in the following areas:

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The arid zone areas including Kohistan, Nangar Parker, Thar, Kharan, Quetta Valley, Thal and Cholistan deserts.

Fringe areas where water is either saline or extremely scarce including inland basins having very thin layer of fresh groundwater in Sindh and Southern Punjab.

Areas within Indus basin with high elevations that require huge investments for surface irrigation.

Undulated riverbanks with steep slopes in NWFP and barani lands on steep slopes with very coarse textures in the Northern Areas.

Urban agricultural areas where high values vegetable, fruits, cut-flowers and nursery plants could be grown with premium water.

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