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Investigation on Soil Wetting Patterns of Low Cost Drip Irrigation Systems Developed in India

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Abstract: The present investigation has been carried out to determine soil wetting pattern of four Low Cost Drip Irrigation System (LCDIS), namely traditional dripper, surgical tube, perforation, perforation (coir winded), under 2.5 and 3.5 m water heads for sandy clay loam soil. The study revealed that under 2.5 and 3.5 m water head and 0.65 to 1.22 L h^{-1} discharge rate, these four types of LCDIS produced average 28 to 33 cm radial influence area with an average influence depth of 25 to 35 cm. It has been found that in most of the cases, small discharge rate with more application time resulted more wetting area in vertical axis and high discharge rate with less application time resulted wider wetted area in lateral axis. So from the vertical and lateral wetting pattern of the LCDISs, it can be stated that these LCDISs are suitable for only shallow rooted crop like cauliflower, cabbage, lettuce, onion, potato etc.

Key words: LCDIS, dripper, soil wetting pattern, discharge rate, pressure head

INTRODUCTION

Approximately one out of three of the world's population lives with water stress, i.e., in areas where the withdrawal of freshwater exceeds 10% of the renewable storage. The key factors causing increasing water demand over the last century are population growth, industrial development and expansion of irrigated agriculture. Agricultural operations require about 70% of the total freshwater use globally (UNEP, 1999, 2002). If the same consumption patterns continue, two out of three people on earth will live under water-stressed conditions by the year 2025 (Karlberg and Penning de Vries, 2004). Again concerns about best management practice of water application for agriculture are increasing because mismanagement of nitrogenous fertilizers can lead to contamination of ground and surface water sources as well as soil degradation. High nitrate concentrations can cause health problems (Environmental Protection Agency, 1990). A way of managing nitrate pollution is to introduce an alternative irrigation method that reduces chemical transport through soils, as well as the amount of applied water (Li *et al*., 2000). Drip irrigation, a low volume practice, can offer such a technology (Li *et al*., 2004). Benefits of drip irrigation in reducing nitrate loss resulting from deep percolation and reduced water use without negatively affecting yield and quality of products have been recorded by different researchers (Geleta *et al*., 1994; Sharmasarkar *et al*., 2001).

India has already crossed one billion population mark and it is also estimated that within 2050 the population will reach 1.64 billion. At present food grain production in India is 200 million tonnes (average) per year. With a Moderate consumption level of 750 g per capita per day the required food grain productions will be 280 million tones and 450 million tones by the year 2010 and 2050 respectively (Mondal and Kundu, 2001; Mondal *et al*., 2006). So it is imperative that for meeting this demand the land resources will have to be exploited through judicious management of the critical inputs like water.

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Average rainfall of India is 119 cm. But due to spatial and temporal distribution of rainfall, one third of the country is always under threat of drought. Hard rock terrain with porosity of about only 1 to 3% covers 70 to 80% land area of south India thus limiting the availability of water. In fact due to continuous extraction of more water than what is recharged to aquifer, vast area of the state of Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka, Rajasthan and some part of Punjab and Haryana is going to be declared as over exploited and dark category (Rajput and Patel, 2001). So abandoned use of water for agricultural farms, must be controlled to avoid grey consequence in coming days.

It is already proven that in India the most used irrigation technology, diversion of water channel to field and then gravity controlled flow, provides only 50% efficiency. It is also proven that drip irrigation technology is an excellent solution with lot of proven advantages. Increasing water use efficiency is considered as one of the main advantage of drip irrigation (Ngigi *et al*., 2001). Experiments and farm trials using micro-irrigation have been conducted in India for about 30 years. Progressive farmers in Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra states started using micro-irrigation in the late seventies. Subsequently due to the sustained efforts taken by Government agencies, Universities and manufacturers, the use of micro-irrigation started spreading in the Southern and Western states (Sivanappan, 1994). But mass application of drip can give solution to the threat of water scarcity and India's future massive need of food grain which is some what unachievable with present technology level. It is estimated that about 27 million ha land can be brought under micro irrigation in India. Compared to the available potential only a fraction of the area (2.6 million ha) has been covered so far (Anonymous, 2006). But main obstacle of large scale adoption of drip irrigation is high capital investment at the initial stage (Mondal *et al*., 2006).

For a long time drip-irrigation was perceived as technique too sophisticated and costly to be operated and managed by small-scale farmers (Chitsiko and Mudima, 2002). So continuous search of alternative low cost drip technology, which will be applicable for developing countries, is of paramount importance. Now Low Cost Drip Irrigation System (LCDIS) is emerging as one of the popular alternative of traditional drip irrigation system in many developing and under developed countries. Some researchers have tried to develop LCDIS. A performance evaluation of drip irrigation system made of bamboo mains, laterals and sub-laterals was done in India. But the system was not durable (Biswas, R.K., 1998). The potential for LCDIS in sub-Saharan Africa has been shown in several publications (Musonda, 2000; van Leeuwen, 2002). Many countries in sub-Saharan Africa, have implemented LCDIS successfully. Du Plessis and van der Stoep (2000) report on partly successful implementation in South Africa. In Zimbabwe the technique is recently being implemented (Chitsiko and Mudima, 2002), whereas in Kenya it was rapidly spread between 1996 and 1999 (Kabutha *et al*., 2000). LCDIS is also labour saving in nature, since the irrigation process involves simply filling up the bucket or overhead tank (van Leeuwen, 2002). Due to the very low pressure used to force water out through the laterals, the systems are sensitive to ground elevation differences, causing non-uniformity of the emitter discharge (Ngigi *et al*., 2001). To achieve the expected development of this LCDIS technology, there are many issues, like improvement in design, refinement of technology and articulation of mechanism for its efficient utilization (Singh, 2000; Mondal *et al*., 2006).

The knowledge on depths and widths of wetted zone of soil under LCDIS application has a great importance in design and management of LCDIS to decide emitter spacing and system pressure for delivering required amount of water to the plant. The wetting patterns of drip irrigation depend on discharge and soil type (Dasberg and Or, 1999). Very few or no study has been done to investigate soil wetting pattern of LCDIS. The present investigation has been carried out to study the soil wetting pattern of four LCDISs under two different heads for sandy clay loam soil.

MATERIALS AND METHODS

LCDIS Installation

Four LCDIS set-ups have been developed for the experiments in the Instructional farm of B.C.K.V. in New alluvial agro-climatic zone of West Bengal state of India. Main and Laterals of drip

Table 1: Details of water emission systems

Types	No. of lateral used	Details of dripper
Conventional dripper	2	By sub-lateral of 4 mm diameter and 0.5 m length
Surgical tubes (1 mm) (knotted)	2	Directly to lateral by adhesive
Perforation (0.2 mm)	2	Holes were made directly on lateral by red not needle
Perforation (coir-winded)	1	Coconut coir was used to wind around holes

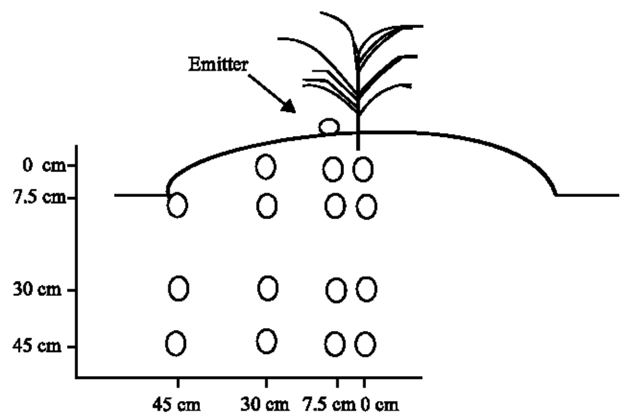

Fig .1: Soil sampling location for soil wetting pattern determination

network were made of PVC pipe. The main length was 19.8 m with 40 mm inside diameter. There were 8 numbers of lateral, each 13.5 m long and of 12 mm inside diameter (Mondal *et al*., 2006). All four LCDISs are identical except the used water emitting systems. Details of water emission systems are presented in Table 1. The main of drip system was connected to two water reservoirs through the GI pipes of 40 mm diameter, almost at the middle of the main. The source of water was a lift and force pump. By manually operating the pump, water was lifted to the water reservoirs which were empty diesel barrels of 200 L capacities each, placed on the bamboo platform of 2 and 3 m height. Each reservoir was 1 m high. So the average head of water developed were 2.5 and 3.5 m (Kundu *et al*., 2002). Selected test crop for the experiment was brinjal (*Solanum melongena* L.).

Soil Condition

The soil sample was collected from the 10-70 cm depth and air dried for analysis. Particle size analysis yielded an average value of 52.4% sand, 22.1% silt and 25.5% clay. The soil of the experimental field was sandy clay loam with bulk density of 1.57 g/c.c. The field capacity and permanent wilting point were 23.5 and 7.7%, respectively. The saturated water content was 44.1%.

Sampling Pattern

For comparison of soil wetting pattern for different emitting system operating with different pressure head, soil samples were collected from the bed profile at the locations shown in Fig. 1. Most sampling locations were chosen for symmetry with the planting bed. However, the dripper was located 7.5 cm off the center of the bed to allow the plant to be placed at the center of the bed. Soil sampling occurred on October 15th and on November 12th after 4.5 h of stopping of water dripping from emitter for 2.5 m head and October 18th and 15th for 3.5 m head. Every emitter emitted approximately 2.5 L of water under 2.5 and 3.5 m head. To maintain constant volume of water, application times were different, under different heads for different emitter systems. The soil samples were collected with an auger and every sample was a mixture of six replication samples collected from different sites to minimize error. Soil moisture content was determined by gravimetric method (Michael, 1997).

RESULTS AND DISCUSSION

Dripper LCDIS

Lateral and vertical movement of water determines the wetting pattern of soil. It was noticed that soil wetting pattern of dripper with 2.5 m head was slightly different from that of dripper with 3.5 m head (Fig. 2). Vertical movement of water was slightly deeper with 2.5 m head than 3.5 m head. For example we can see that at 7.5 cm lateral distance at 30 cm depth for and 3.5 m head moisture contents were 17 and 15.1% , respectively. But lateral movement of water was slightly more for 3.5 m head than 2.5 m head. For example, we can see at 30 cm lateral distance at 7.5 cm depth for 2.5 m and 3.5 m head moisture contents were 18.5 and 21%, respectively. At application point of water, at surface and 7.5 cm depth, moisture content exceeded field capacity and at surface and 7.5 cm depth for 7.5 cm radial distance the moisture contents were near to the field capacity. A lower dripper discharge rate (0.85 L h^{-1}) for 2.5 m head resulted in longer application irrigation periods and potentially higher soil evaporation. However, a lower discharge rate created a more vertical wetting pattern than a high discharge rate of 1.19 L h^{-1} for 3.5 m head, which created smaller wetted area in vertical axis and wider wetted surface area in lateral axis. It was further noticed that at 37.5 cm radius from dripper, very little or no soil wetting took place. At 45 cm lateral distance from plant, surface soil was drier than deep soil due to more evaporation from surface soil.

Surgical Tube LCDIS

It was recorded that at 37.5 cm radius from water application point, very little or no soil wetting took place. At application point of water, at surface and 7.5 cm depth, moisture content exceeded field capacity and at surface and 7.5 cm depth for 7.5 cm radial distance the moisture contents were near to the field capacity (Fig. 3). At 45 cm lateral distance from plant, surface soil was drier than deep

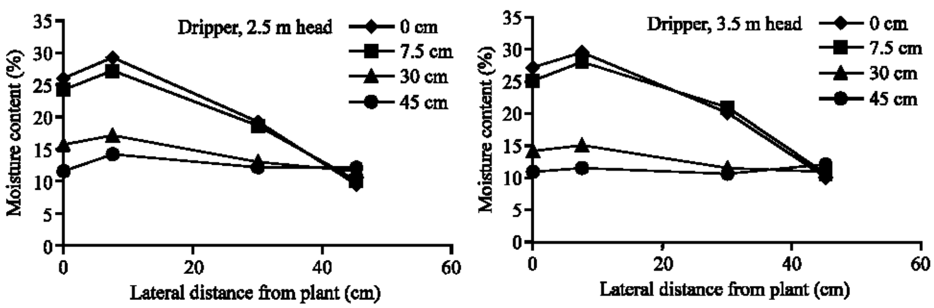

Fig. 2: Comparison of soil wetting patterns of dripper with different heads

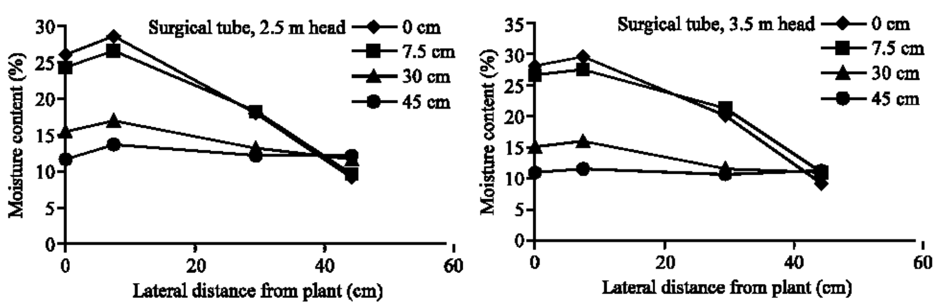

Fig. 3: Comparison of soil wetting patterns of surgical tube with different heads

soil due to less evaporation from deep soil. Vertical movement of water was slightly deeper with 2.5 m head than 3.5 m head. For example we can see that at 30 cm lateral distance at 30 cm depth for 2.5 and 3.5 m head average moisture contents were 13 and 11.6%, respectively. But lateral movement of water was slightly more for 3.5 m head than 2.5 m head. For example, we can see at 30 cm lateral distance at 7.5 cm depth for 2.5 m and 3.5 m head moisture contents were 18.2 and 20.1%, respectively. A lower discharge rate (0.65 L h^{-1}) from surgical tube for 2.5 m head resulted in longer water application time and created a more vertical wetting pattern than a high discharge rate of 0.92 L h^{-1} for 3.5 m head, which created smaller wetted area in vertical axis and more wetted surface area in lateral axis.

Perforation LCDIS

Vertical movement of water for 2.5 m head was more than 3.5 m head (Fig. 4). Below the plant at 30 cm depth for 2.5 and 3.5 m head average moisture contents were 16.1 and 15%, respectively. It was noticed that at 37.5 cm radius from water application point, very little or no soil wetting took place for both the cases. At application point of water, at surface and 7.5 cm depth, moisture content exceeded field capacity and at surface and 7.5 cm depth for 7.5 cm radial distance the moisture contents were near to the field capacity for both the cases. But lateral movement of water was slightly more for 3.5 m head than 2.5 m head. It is apparent from Fig. 4 that at 30 cm lateral distance at surface for 2.5 and 3.5 m head moisture contents were 19.9 and 23.1%, respectively. A lower dripper discharge rate (0.95 L h^{-1}) for 2.5 m head resulted in longer water application time and more vertical wetting pattern than a high discharge rate of 1.22 L h^{-1} for 3.5 m head, which created narrow wetted area in vertical direction and wider wetted surface area in lateral direction.

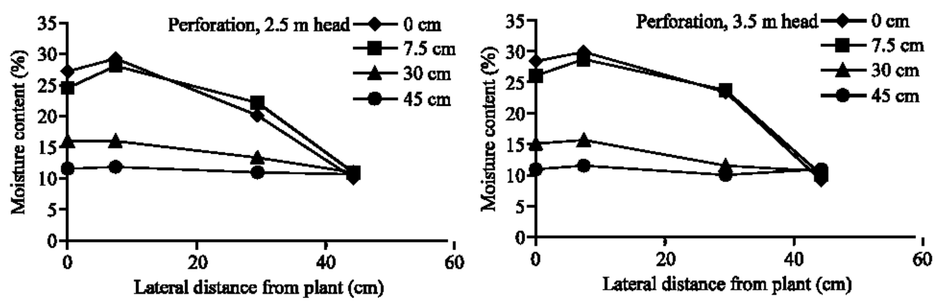

Fig. 4: Comparison of soil wetting patterns of perforation with different heads

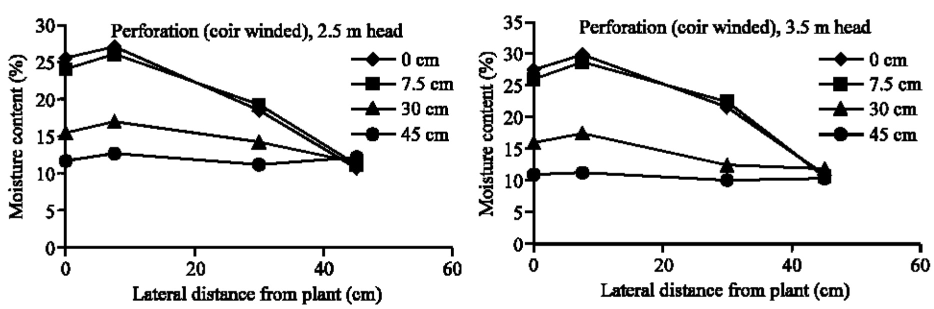

Fig. 5: Comparison of soil wetting patterns of perforation (coir winded) with different heads

Perforation (Coir Winded) LCDIS

It was recorded that at 37.5 cm radius from water application point, very little or no soil wetting took place (Fig. 5). At application point of water, at surface and 7.5 cm depth, moisture content exceeded field capacity and at surface and 7.5 cm depth for 7.5 cm radial distance the moisture contents were near to the field capacity. At 45 cm lateral distance from plant, surface soil was drier than deep soil due to less evaporation from deep soil. It was noticed that soil wetting pattern of perforation (coir winded) with 2.5 m head is slightly different from that of perforation with 3.5 m head. Vertical movement of water had not been influenced by change in water head. It is clear from the Fig. 5 that at water application point, at 30 cm depth for 2.5 and 3.5 m head average moisture contents were 15.7 and 15.5%, respectively. But lateral movement of water was slightly more for 3.5 m head than 2.5 m head. For example, we can see at 30 cm lateral distance at 7.5 cm depth for 2.5 and 3.5 m head moisture contents were 19.1 and 22.4%, respectively. Difference of discharge rate had little or no effect for perforation (coir winded) in vertical wetting pattern. A high discharge rate of 0.98 L h^{-1} for 3.5 m head created wider wetted surface area in lateral direction due to less application time than 2.5 m head condition.

CONCLUSIONS

Soil wetting pattern of a manually operated LCDIS, suitable for small farm sizes of developing countries, has been investigated. It was found that in most of the cases, small discharge rate with more application time resulted more wetting area in vertical axis and high discharge rate with less application time resulted wider wetted area in lateral axis. For 2.5 m head and 3.5 m water head condition, for sandy clay loam soil, with 0.65 to 1.22 L h^{-1} discharge rate of these four types of low cost LCDISs produced average 28 to 33 cm radial influence area with an average depth of 25 to 35 cm. It was also found that vertical and lateral wetting pattern distribution of all these four LCDISs are suitable for only shallow rooted crops like cauliflower, cabbage, lettuce, onion, potato etc., as average moisture-extraction pattern of these crops shows that 90% of the total moisture used, is extracted from top 75% of root zone (Michael, 1997). So the information obtained from this investigation, about soil wetting pattern of LCDISs can be helpful to decide emitter, lateral spacing and system pressure for delivering required amount of water to the plant root zone. Thus this investigation can be instrumental in design and management of LCDIS, which is slowly becoming a promising agricultural water management practice to tackle the huge food productivity problem and environmental issues of developing and under developed countries.

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