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Research Article

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Effect of Emitter Discharge on the Wetting Pattern of a Subsurface Drip Irrigation System

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Abstract A study was conducted to evaluate the effect of dripper discharge on the water distribution pattern of a subsurface drip irrigation system. An intravenous (I. V.) giving set was adapted as the emitter with the drip chamber filled with a sand sizes of 1 mm and 2 mm, respectively. The drip chamber was perforated with holes of 0.5 mm to allow the flow of water to the soil via the sand. The emitter was inserted at 0 to 5 cm depth in to a glass box (60cm by 40 cm by 60 cm) as soil tank. A plastic Bucket was used as an overhead tank to supply the required discharge. The soil was collected from the field and was sun dried for 4 days before each experiment. The emitter discharge was established by calibrating the I.V giving set before it was inserted in to the soil. The wetting pattern in the soil was then determined by measuring the longest width and the depth of the water distribution. Ten different values of emitter discharge ranging from 0.83 l/h to 2.81 l/h were randomly selected and tested in the study. At 0.83 l/h the soil wetting width and depth were 7.60 cm and 6.80 cm, respectively. However, at discharge of 2.81 l/h soil wetting width and depth recorded were 23.47 cm and 16.03 cm, respectively. The results obtained from this study showed that the I. V. giving set apparatus can be used as emitter for shallow subsurface drip irrigation system and achieve a required soil wetting.

Keywords Flow rate, wetting pattern, subsurface drip irrigation, emitter

Introduction

The enormous water resources available in Nigeria face challenges especially from the inefficient use of water by irrigation agriculture. These resources need to be properly utilised to ensure optimal use for maximum benefits to the Nigeria's fast growing population. Improved soil and water resources management is a pre-requisite for sustainable agriculture, which is itself a necessary condition for economic growth, poverty reduction and environmental conservation in Nigeria [1]. Drip irrigation has been used for crop production since the middle of the 20th century and it is the most effective way of applying water and nutrients directly and efficiently to the root of the crops. It save water and increases yields [2]. In many developing countries of the world, and particularly in semi-arid and arid regions [3] traditional methods of subsurface irrigation can help conserve scarce water resources. Subsurface drip irrigation systems are capable of applying small amounts of water directly to the plant root zone where the water is needed, and these small amounts can be applied frequently to maintain favourable moisture conditions in the root zone. Some of the potential benefits of subsurface irrigation are improvements in yield and quality and the reduction of production costs [4]. To conserve more water for other economic activities, traditional methods of subsurface drip irrigation were introduced. Subsurface drip irrigation methods also supply the needed amount of water frequently and directly to the roots of the plants to maintain an adequate moisture condition in the root zone [5]. Subsurface drip irrigation methods were found to improve water use efficiency by reducing evaporation losses and eliminating runoff and deep percolation [6]. Quality of water bodies is also ensured. Similar to subsurface drip irrigation, indirect subsurface drip irrigation (ISDI) is a type of partial root zone irrigation that has a limited soil wetting area [7]. Design of subsurface drip irrigation system depends on size of the soil wetted zones [8]. To make proper decision on the design spacing between emitters and laterals, the wetting pattern dimensions need to be established [9]. Dripper discharge is one of the most important elements in local irrigation design with its size affecting not only the shape and moisture distribution of wetted zone [10], but also the salt leaching and salt distribution in wetted soil [11]. Indirect subsurface drip irrigation (ISDI) is the most effective water saving irrigation technology being considered recently to further reduce losses still associated with subsurface irrigation systems. The main components of such technology include a surface lateral and a device attached to the lateral to transmit water directly to root zone of the crops [12]. It has been established that, ISDI eliminates water loss due to evaporation as well as improving water use efficiency of field crops [13]. The aim of this work was to evaluate the effect of dripper discharge on the soil wetting pattern of an indirect subsurface drip irrigation system.

Materials and Methods

Study Area

The study was conducted in Bauchi, Bauchi State Nigeria. The area is located at an altitude of 616 m between the latitudes of 10.17 ^{0}N and 10.22^0 N and longitudes of 9.47^0 E and 9.48^0 E. The average annual rainfall is about 1,095 mm with average temperatures of 25.4 ^{0}C to 30.0 ^{0}C.The daily humidity increases to 94% in the middle of the rainy season and drops drastically to less than 10% during the harmattan period in the dry season [14].

Sample Preparation

A Sandy loam soil was collected from the field at different points in the field to a depth 20 cm. The soil was sun dried for 5 days initially and each time an experiment was carried out, the soil was allowed to dry for 4 days before the subsequent experiment.

Laboratory set up

The materials used for this experiment included soil tank made from a transparent glass as show in Fig. 1, I.V. giving set (Fig. 2.) as the emitter and a plastic bucket as overhead water supply. The size of the soil tank is 60 cm (length) by 40 cm (width) by 60 cm (height).The water chamber of the I. V. giving set was adapted to serve as a sand tube emitter. Two forms of the emitter were used for the experiment. Their water chambers were perforated with 56 and 24 holes of orifice size, 0.5 mm each as shown in Fig. 3. They were then filled with 1 mm and 2 mm sand, respectively. The emitter was inserted at 5 cm depth into the soil sample near the glass wall to enable the visibility of water movement in the soil. The water supply was placed at a constant height of 78cm height.

Figure 1: Soil tank containing the test sample

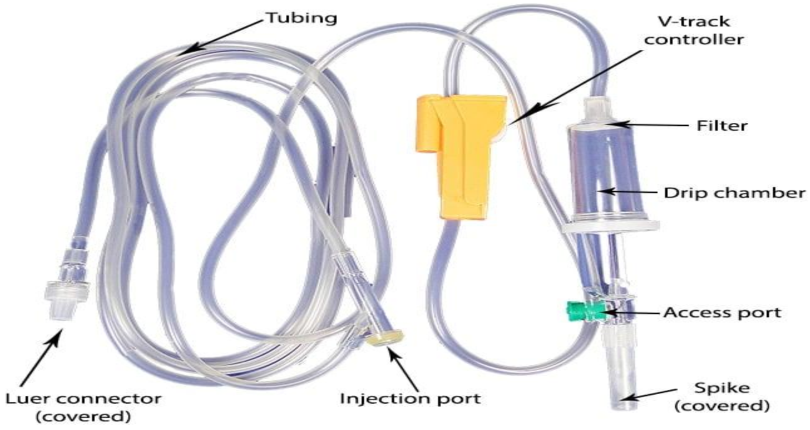

Figure 2: I. V. giving set showing the drip chamber [15]

Figure 3: I. V. giving set drip chamber filled with a sand

Measurement of dripper

The flow rate was established by calibrating the emitter just before the experiment.Water was allowed to flow from the supply through the sand filled drip chamber in to a container of known volume for a particular period of time. The flow rate was then determined using equation (1).

$$Q = \frac{volume\ (v).}{time\ (t).} \quad (1)$$

Measurement of the width and depth of the wetting pattern

The longest time of application used was 20 minutes. The wetting pattern produced by each application was determined by measuring the longest depth and width.

Results and Discussions

The results of the laboratory experiments to evaluate the effect dripper discharge on the wetting pattern of a subsurface drip irrigation were analysed using Microsoft Excel and are presented in the following sections

Effect of dripper discharge on wetting pattern of subsurface drip irrigation system

Enough time of application was allowed for each experiment to obtained sufficient wetting for ease of measurement. The longest time used was 20 minutes. The wetting pattern produced by each application was determined by measuring the longest depth and the width of the pattern.

Different values of dripper discharge selected randomly were tested on two different sizes of sand and two different number of holes on the drip chamber. The flow rates ranged from 2.47 l/h to 2.81 l/h for the sand tube (drip chamber). filled with 1 mm diameter sand and perforated with 24 holes.Si et al., (2006). tested flow rate of

1, 2, 3 and 4 L/h. The largest wetting pattern obtained from this dripper was at flow rate of 2.81 l/h. Width and depth of the pattern observed were 23.47 cm and 16. 03 cm, respectively. However, the smallest size of a wetting pattern was obtained at flow rate of 2.47 l/h. The width and depth were 11.40 cm and 6.77 cm, respectfully. The details of the results for this emitter are as presented in Fig. 4.

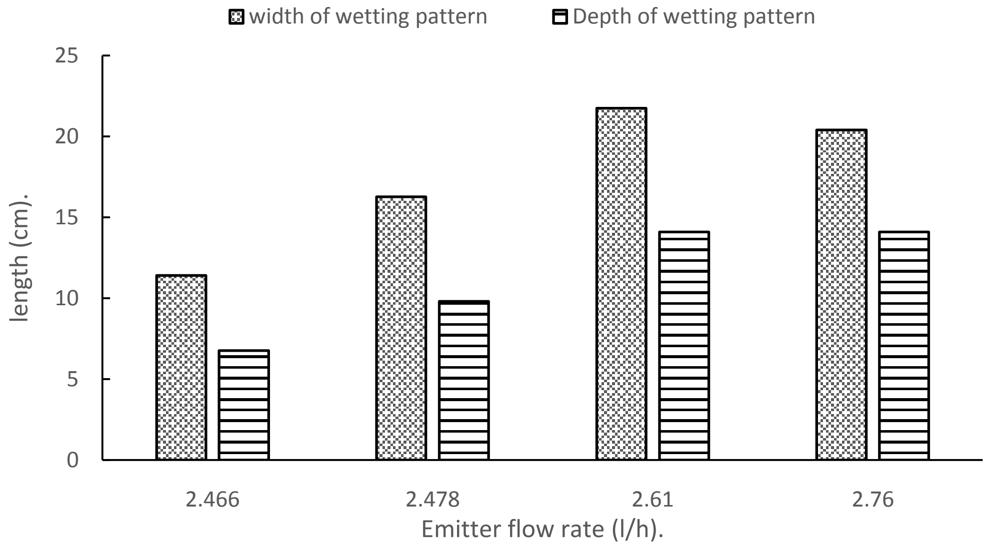

Figure 4: Width and depth of wetting pattern for dripper with 24 holes and filled with a 1 mm diameter sand

The results obtained from the second dripper with 56 holes and filled with a 2 mm diameter sand are shown in Fig. 5. The flow rates used ranged from 0.83 l/h to 1.34 l/h. At flow rate of 1.34 l/h, the longest width and depth of the wetting pattern observed were 21.37 cm and 12.57 cm, respectfully. The flow rate of 0.83 l/h produced the smallest size of wetting pattern with width of 7.6 cm and depth of 6.8 cm.

The results for both the drippers showed that higher flow rate produced larger wetting pattern. Similar results was reported by [16]. However, [17] reported that soil texture and antecedent soil water affected the wetting pattern more than the flow rate and time application. Furthermore, this study revealed that larger flow rates produced the required wetting more rapidly than smaller flow rates.[18] Observed that high frequency, short duration of application period are important factors to consider for efficient irrigation in certain conditions such as sandy soils. However, smaller flow rates enabled more tranquil application of water to the plants. The width of the wetting pattern was found to be larger than the depth because the emitters were placed at a shallow depth. It implies that with shallow subsurface irrigation the emitters and the laterals can be placed at a wider spacing.

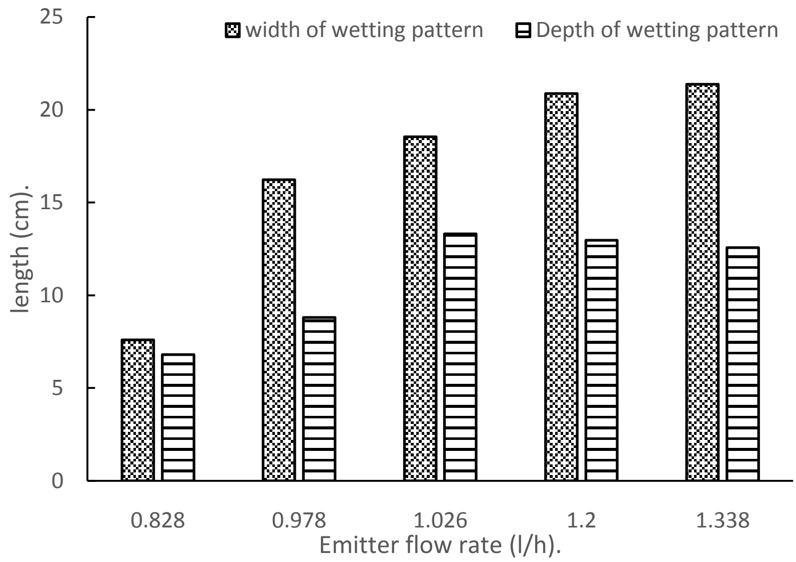

Figure 5: Width and depth of wetting pattern for emitter perforated with 56 holes and filled with a 2 mm diameter sand

Conclusion

The study evaluated the effect of dripper discharge on the wetting pattern of a subsurface drip irrigation system. From the results obtained it can be concluded that the I. V. giving set can be adapted as an emitter for a subsurface drip irrigation system. The drippers tested produced wetting patterns with larger width than the depth. This implied that field emitters can be placed at a wider spacing. It was also observed that larger flow rates produced larger sizes of soil wetting patterns. It can be recommended that the drip chamber of the I. V. giving set can used as a sand tube emitter for shallow subsurface drip irrigation system.

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