Short Research Article

EVALUATION OF SOIL WETTING PATTERNS IN CLAY LOAM SOIL UNDER DRIP IRRIGATION

ABSTRACT

Maximum agricultural water use efficiency is important owing to decrease of availability of water for agricultural field. Drip irrigation is considered so far as the most efficient irrigation systems. Knowledge of dimension of the soil wetted volume is one of the main factors in determining the spacing of drippers. It is important in the design and management of the irrigation system. The present study was conducted at the Instructional Farm, Faculty of Agricultural Engineering, Bidhan Chandra Krishi Viswavidyalaya, Moahanpur, Nadia, West Bengal to examine the vertical (Z) and horizontal (W) water front advance within the soil profile at the dripper in a clay loam soil. Same volume of water (50 litre) was applied at the rate of 2.3 and 4.9 l/h at each irrigation. By observing the soil on the tips of the auger, the depth of wetting was determined and noted it down for different points on the line of the wetted area. It was found that there is little variation in the theoretical width and depth with the actual width and depth of wetting of the soil in case of 4.9 lph discharge rate. For the given discharge rate, the inaccuracy was less for the wetted depth than the wetted diameter. In the instance of the 2.3 lph discharge rate, however, there was a lot more fluctuation. This variation might be resulted from some experimental errors due to surrounding disturbances and climatic variation.

Keywords: drip irrigation, wetted volume, spacing, drippers, clay loam soil, wetted width and depth

1. Introduction

Irrigation is the artificial application of water needed to the crop. It is the single most important input in agriculture. It is said that green revolution in India was possible largely due to availability of irrigation water. The agricultural production particularly the cereals have increased over the years almost in proportional to irrigation facility created and utilized. Over the last twelve five year plans during 1950-51 to 2017-18 the irrigation potential has been increased at the rate of about 342.30% (CWC, 2017& Jain *et* *al.,* 2019) against the production of cereals about 500%(Acharya, 2010).The groundwater has contributed about 60% of increased irrigation potential by the enormous number of tube well in irrigated area (Gandhi & Vaibhav, 2011). Groundwater in some area is the readily available water and the farmers prefer to use it as because the sources of water in most of the cases is in their field and at the same time get the opportunity of absolute command on the use of it. This opportunity has led to overexploitation of groundwater. The farmers are in general habituated to cultivate the crops of good return without much consideration to amount of water use or even not much concerned to minimization of water losses in their irrigation system. Irrigation water has become more and precious. Now a day the popular slogan is 'every drop more crop'. Agriculture sector alone uses about 80% of our usable water resources. The judicious use of irrigation water may save use us from thwart of agricultural production as well as may provide the scope to meet up the increasing demand from the domestic and industrial sectors. Drip irrigation is one of the irrigation systems that helps maintain the optimum soil moisture in the soil root zone while increasing productivity and water efficiency. Water efficiency is crucial to sustaining agricultural productivity, especially in light of falling per capita land and water supply. Drip irrigation is a precision irrigation technology that allows you to meet crop water requirements in the most efficient way possible. In order to examine the dynamics of wetting front advance in the soil and crop root zone, a hydraulic analysis of the drip irrigation system is required. Some research on the hydraulics of surface and subsurface drip irrigation has been done in India, although the results differ depending on the soil type. To improve crop yield and water use efficiency by limiting deep percolation and evaporation losses, a quantitative understanding of soil water distribution during drip irrigation is required. Drip irrigation helps to minimise water stress while also providing appropriate aeration in the soil, boosting yield and conserving water. A mix of air and water makes up the wetted volume of water in the soil beneath a dripper, with a greater concentration of water happening directly beneath the dripper in a horizontal plane. The concentration of air and water in the vertical plane fluctuates as well, but it changes over time owing to water redistribution caused by gravity or capillary action. The larger the wetted volume of soil, the more water is applied, as more soil pores are filled with water (Acar *et al*.,2009).The shape of the distribution of water when applied from a point source in soil depends mainly on soil characteristics and gravity force. The soil texture, the soil horizontal and vertical permeability, capillary suction, presence or absence of impervious layers, the the amount of water applied every irrigation, and the rate at which it is applied and the initial moisture content influence the wetting pattern of soil. The fine textured soil such as clay and clay loam, the capillary forces are strong and gravity force can be considered negligible. The horizontal movement may be faster than the downward. The wetting pattern usually takes the shape of a bulb. In light soil the capillary forces are small and the gravity force has some influence on movement of water. The downward movement is faster than horizontal, which causes a wetting pattern of more elongation to downward. The soils in between the fine and light soils the influence of capillary suction and gravity are almost equal. Therefore, the wetting pattern will have more or less equal horizontal and vertical elongation leads to pear shape. However, the soils are very complicated in nature. Soil characteristics are seldom homogeneous. Therefore, it is very difficult to predict the exact shape of the wetting pattern (Biswas, 2015).

In order to design contemporary and ecologically acceptable drip irrigation techniques, a thorough understanding of soil water distribution and patterns has become more necessary (Singh *et al.*, 2013). In terms of the effect of emitter discharge on lateral water distribution, as well as the effect of dripper discharge on the breadth of the wetting pattern, local and international studies have produced inconsistent results. It has been observed that the lower discharge drippers produce better lateral water distribution on more sandy soils, such as those found in the Cape. Water distribution in the irrigation systems design factors (drip lateral spacing, system pressure, flow rate, trickle emitter type), climatic conditions, root dispersion, soil type, water application rates, and vegetation all have an impact on the soil. Plant spacing and canopy cover, as well as soil texture, potential evaporation, water quality, and terrain, are all elements to consider when designing a drip irrigation system for improving water consumption and maximizing crop output (quality and quantity). As a result, drip irrigation systems must be meticulously planned and installed to ensure that they function properly and that nutrients and chemicals are administered uniformly and efficiently (Cetin and Uygan, 2008).

For effective design of drip irrigation systems, the water dynamics in the soil needs to be predicted using all above mentioned variables. Information about temporal evolution of the wetted volume in specific soil can help in establishing the optimal spacing between the emitters and the irrigation duration as a function of the soil volume where the crop roots are located (Provenzano, 2007). With this in mind, the current study's goals were to identify the depth and width of soil soaking, as well as to establish a link between the depth and width of wetting, as well as the rate and volume of application.

2. Methodology

The experiment was conducted at the Instructional Farm of Faculty of Agricultural Engineering, BCKV, Mohanpur, Nadia West Bengal. The place is located on latitude of 23.5^{o}N, longitude of 89^{o}E at an elevation of 6.0m above sea level. This is in New Alluvial Agro-Climatic zone (NAZ) of West Bengal, India. The physical characteristics of the soil were determined by using the Keen Raczkowski box. The soil was collected from the depth of 0-30cm from different points of the experimental plot, dried and processed for laboratory analysis. The soil physical characteristics were analyzed for the soil's bulk density, porosity, water holding capacity and textural class. A sample of the soil was placed in the Keen Raczkowski box and there after kept at about 0 tension (in water) for approximately 12 hours in order to make the soil fully saturated. The wet and oven dry weights of the residual soil which was left in the box were computed. From these known data, the maximum water holding capacity and other single value soil constants (bulk density and porosity) were calculated. The soil textural class was determined by the Bouyoucous Hydrometer method of particle size distribution. The constant head technique was used to determine the saturated hydraulic conductivity of the soil.

2.1 Determination of width and depth of wetting under drip irrigation

In this experiment, same volume of irrigation water was applied for two different discharge rates of 2.3 lph and 4.9 lph to determine the soil wetting pattern. The volume of water applied in both the cases was 50 litres. The drip irrigation set up consisted of the emitter on a lateral connected to the laboratory tap .The pressure at the emitter was maintained constant by keeping the knob of the bip-kock fixed in a position over the period of experimentation and there was a fixed pressure head in the water supply as it was connected to the constant head overhead reservoir. Thus, constant discharge from the emitters could be maintained. The time required for applying 50 litres of water through the emitters of capacity 2.3 lph and 4.9 lph were 21.7 and 10 hours respectively.

2.2 Measurement of Width of wetting

After the prescribed irrigation intervals for each discharge rates, the width of wetting for each discharge rate was measured as follows:

- The whole area of wetting was divided into four parts by two intersecting line meet each other at right angle at the point of application of irrigation water i.e. almost at the centre of wetting zone.
- The width of wetting was measured at every point at 15 cm apart on the two intersecting line starting from the centre and continued to the front of wetting.

2.3 Measurement of depth of wetting

The depth of wetting was measured for the two discharge rates using the soil auger as follows:

- The depth was measured on different points which are 15 cm apart from each other on the two intersecting lines drawn on the wetted area.
- The measurement was started from the centre of the wetted area which is the point of application of water from the emitter.

- The auger was inserted at different points of measurement at 15 cm apart from each other on the line.
- By observing the soil on the tips of the auger, the depth of wetting was determined and noted it down for different points on the line of the wetted area.

The depths of penetration of water at different points from the centre of wetting for both the x-sections are represented in graph paper to determine the average depth of penetration (**Fig.1**). Similarly the widths of wetting from the centre were drawn on the graph paper to determine the area of wetting (**Fig.2**). The volume of the wetted soil was calculated for both the emitters by using these average depths and areas of wetting. For each point on the two intersecting lines of the wetted area which are 15 cm apart from each other measured from the centre or point of application of water until the last point of wetting, the corresponding width and depth of wetting were measured.

2.4 Calculation of Average Depth and Width (or diameter) of Wetting from the Graph

2.4.1 The average depth of wetting was calculated as follows:

$$d_{av} = \frac{d_1 + d_2 + \ldots + d_n}{n} \qquad \text{………….. Eq.1}$$

Where, d_1, $d_{2\ldots}$ d_n = depth of wetting at different points, n = total number of depth

Width (diameter) of wetting was calculated as:

$$A = \frac{\Pi D^2}{4} \qquad \text{………….. Eq.2}$$

Where, A= area obtained from the graph, D = Equivalent Diameter of wetting which represents area of wetting.

2.4.2 Schwartzman and Zur (1986) equation for determination of width and depth of wetting under drip Irrigation (Gispert *et al.*, 2015)

The equation is given as:

$$Z_f = K_1 (V_w)^{0.63} \left(\frac{K_{sat}}{q}\right)^{0.45} \qquad \text{………….. Eq.3}$$

$$W_f = K_2 (V_w)^{0.22} \left(\frac{K_{sat}}{q}\right)^{-0.17} \qquad \text{………….. Eq.4}$$

Where, Z_f = vertical distance to wetting front, m, W_f = Wetted width or dia. of wetting front, K_1 = empirical coefficient = 29.2, V_w = Volume of water applied, litre, K_{sat} = Saturated hydraulic conductivity, m/s, q = Emitter discharge, lph, K_2 = Empirical coefficient = 0.031.

3. Results

The values of bulk density, saturated hydraulic conductivity and porosity were found out as 1.3 g/cc, 1.112×10^{-6} m/s and 51.2% respectively. The experimental soil consisted of 35.10% clay, 27.90% silt and 37.00% sand. The soil of these percentages of sand, silt and clay was classified as clay-loam soil with reference to Soil Texture Triangle.

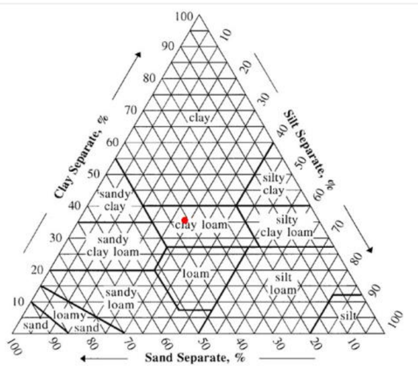

Figure.1 Soil Texture Triangle

3.1 Width and depth of wetting of soil

Average depth of wetting for 2.3 lph and 4.9 lph discharge rate as determined graphically by plotting the field data was found out as 33.17 cm and 36.43 cm respectively by using the Eq.1. Similarly, diameter of wetting (or width) for 2.3 lph and 4.9 lph was found out as 97 cm and 99.6 cm respectively. From this data, the area and volume of wetting of soil for 2.3 lph discharge rate were found out as 0.74 m^2 by using the Eq.2 and 0.27 m^3 respectively. For 4.9 lph discharge rates, the area and volume of wetting of soil were found out as 0.78 m^2 by using the Eq.2 and 0.26 m^3 respectively.

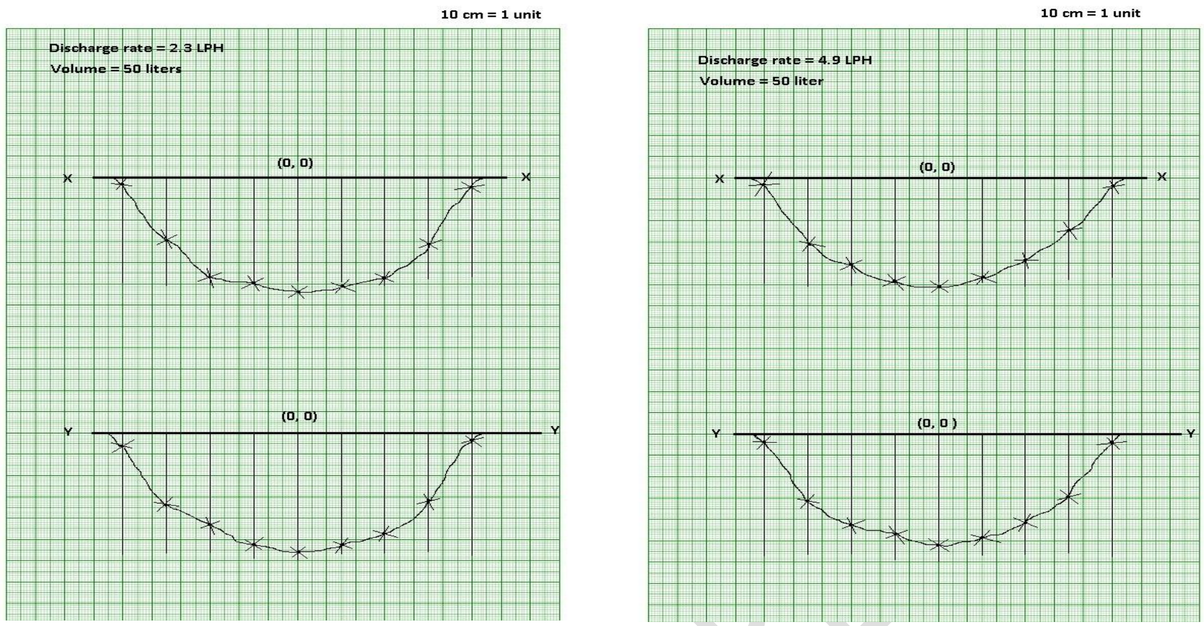

Figure.2 The depth of penetration of water at different points from the centre of wetting for both the x-sections

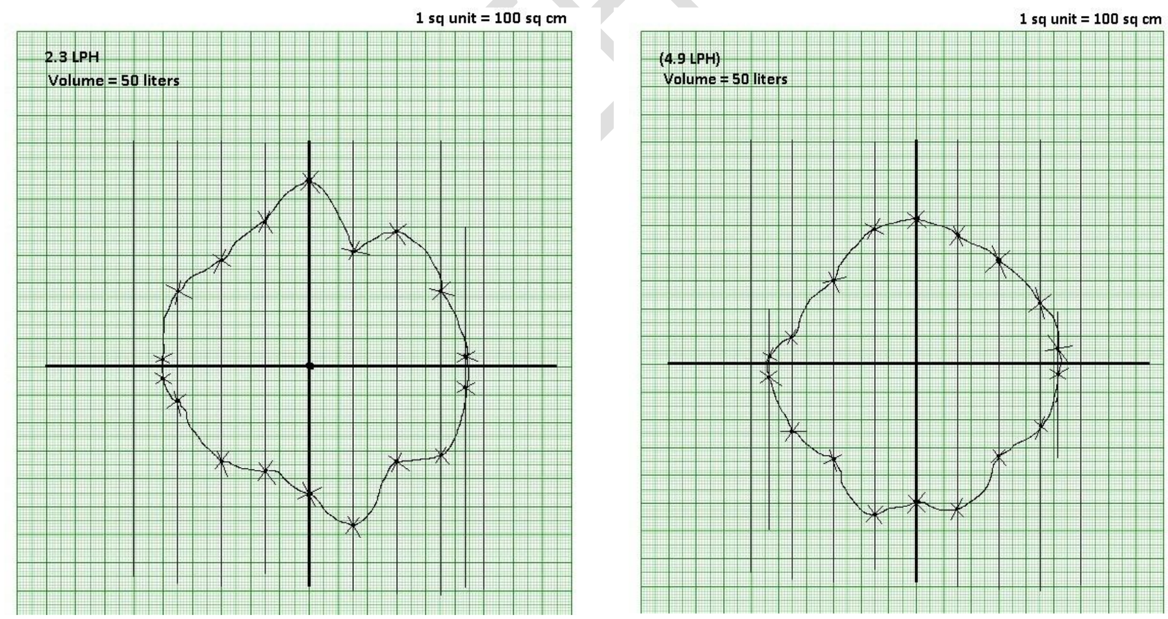

Figure.3 Width of wetting of water from the centre

3.2 Width (or diameter) and Depth of wetting of soil following Schwartzman and Zur, 1986

By using the Eq.3 & Eq.4, the following results were obtained

For 2.3 lph discharge rate, depth = 49 cm and width = 88 cm

For 4.9 lph discharge rate, depth = 35 cm and width = 98.7 cm

4. Discussion

For 4.9 lph discharge rate, there was little variation between the actual depth and width of wetting and the estimated width and depth as calculated from Schwartzman and Zur equation. The percentage of variation is only about 5% for depth and 1% for width of wetting. For 2.3 lph, there was comparatively more variation between the actual and the estimated results. The reason behind this variation might be resulted from some experimental errors caused by disturbance of experimental setup, surrounding disturbances and climatic variation.

5. Conclusion and Recommendations

The results from the field experiment were used to assess the basic empirical model of Schwartzman and Zur (1986). In the instance of a 4.9 lph discharge rate, it was discovered that there is minimal difference between the theoretical breadth and depth of soaking of the soil and the actual width and depth of wetting of the soil. For the given discharge rate, the inaccuracy was lower for the wetted depth than the wetted diameter. In the instance of the 2.3 lph discharge rate, however, there was a lot more variance. This fluctuation might be the consequence of some experimental mistakes caused by environmental disturbances and climate change. Schwartzman and Zur's current model is based on soils and two distinct emitter discharge rates; therefore it may not be the greatest match for soils of all textural classes. However, the experimental data may be inferred to match this model adequately. The optimum spacing between laterals is affected by the depth of pipe installation, while lower installations can result in larger evaporative losses. The geometry of the wetted region was only slightly changed by the projected rate of surface evaporation for a particular water application. Because of its connection to soil hydraulic conductivity and water retention, soil texture has a greater influence on wetting geometry. In general, horizontal spreading is greater in fine texture soils, or in the finer textured layers of layered soils. This study may be improved further by practical incorporation into field work, as well as more modelling and irrigation scenario research.

6. References

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