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Kashyap Partap Singh
Students, Department of Soil Science and Agriculture Chemistry, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Nitin Changade
Associate Professor, Soil Science and Agriculture Chemistry, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author
Nitin Changade
Associate Professor, Soil Science and Agriculture Chemistry, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Soil moisture distribution under drip irrigation and emitter clogging problems: A review

Kashyap Partap Singh and Nitin Changade

Abstract
Drip irrigation is an essential tool for addressing the world's water scarcity. Systems that control water flow to the plants from the lateral are termed emitters or drippers. Row crops may benefit from more closely placed emitters for watering. The quantity of water in the soil is referred to as soil moisture. Vertical soil moisture transport was stronger in loamy soil at a higher velocity, but the wetted radius was bigger at lower leakage currents. Soil moisture distribution for various emitter discharge rates, emitter spacing, better irrigation design, drip irrigation depths is varied as per the soil properties. Soil moisture distribution also depends of uniformity coefficient, emission uniformity of emitters and this hydraulics could be affect due to emitter clogging, discharge variation and types of emitters. Emitter clogging is a serious issue in micro-irrigation systems which is caused by a variety of chemical, physical, and biological factors acting alone or in combination. The problem of drip irrigation emitter clogging, on the other hand, has a direct impact on the regularity and effectiveness of system. In this review paper, soil moisture distribution were studied at different drip irrigation parameter i.e lateral spacing, depth, emitter spacing, discharge and observed that the good soil moisture distribution was observed at closely lateral spacing, emitter spacing as well as it is depend on textural classification of soil. The emitter clogging is the key factor of system efficiency and could be reduced by using good quality of water.

Keywords: Drip irrigation, emitter, soil, moisture, emitter clogging

Introduction

Drip irrigation is the artificially distribution of water near to the root zone aiming to better crop growth and to save the water. Since the last decades, drip irrigation systems (DIS) which was firstly developed by Israel engineer Symcha Blass in 1964, have gained popularity across the globe. Today India has covered around 2,87,500 hectares area under Drip irrigation and standing on 7 th rank across the globe [1]. However, given the state of water supply and farmer circumstances, precise water application provides more value to farmers. Drip irrigation, on the other hand, is becoming more popular among the people. Drip irrigation normally maintain adequate air water proportion near the root system of the plants [2]. The constant watering rather than micro irrigation, the macrospores and microspores are filled by water which prevent oxygen passing from the plant root to plant and affecting plant development. Water distribution pattern depends upon the discharge rate of the emitters. As the discharge rate from the emitters increases the wetting pattern is more in the horizontal direction which mean the horizontal movement of water is more, while when the discharge rate from the emitters is less the wetting pattern is more in the vertical direction which mean downward movement of water is more [3]. During irrigation, changes in the wetted surface radius and vertical wetted depth were measured, and the findings revealed that when the volume applied increased, the rise in the wetted surface radius and vertical wetted depth could be represented by a power function [4]. In drip irrigation, emitters play an important role in wetting the soil profile. Drippers, or emitters, control the stream of fluid from the reservoir to the crops. For a single plant, such as a tree, one or more emitters are used, and they are typically spaced more than one meter apart. More closely spaced emitters might be used to irrigate a strip area of soil in row crops and large spaced emitter are used for tree or plant [5]. Several emitter designs have been created in recent years. One of the most critical variables affecting the effectiveness of drip irrigation systems is emitter blockage [6]. The effectiveness of water distribution through emitter is based on the water quality and emitter type. The selection of emitter to avoid the blockage is based on water quality and pressure of applied water. The pressure compensated and non-compensated drippers are available in market with various spacing 30, 45, 60 and more. This selection of emitter is based on crop type and crop spacing.

Emitter blockage, which occurs quickly due to irrigation systems operating under insufficient pressure or due to poor water quality, affects water distribution uniformity and results in insufficient irrigation [7]. Looking the advantages of drip irrigation and maintenance issue, various review were collected and discussed as below to study the soil moisture distribution with respect to drip line spacing, depth of installation, embitter discharge, spacing and blockage of drip system.

Literature Reviewed

Consequences of soil texture on soil distribution

The texture of the soil is determined by its amount of clay, sand, and silt. Soil characteristics are a recurring character that influences soil biophysical properties, soil fertility and quality over a lengthy period. Soil texture affects water holding capacity, gaseous diffusion, and water movement, all of which are indicators of soil quality. Thus, Microbial propagules can survive in clay loam soil because of gaseous diffusion and water penetration and the availability of moisture to support microbial development. The matric potential plays vital role in the uniformity of water distribution in the form of soil moisture at different depth and three direction because hydraulic potential of soil varies as per the soil depth and water movement direction [8]. Soil water distribution is also depend on the organic matter content and sand proportion within the soil texture. Vertical water movement is more in sandy soil. Mostafa (2014) studied the water movement in vertical tube filled with compost and sand and observed that significant water storage available at depth 20-60 cm [9]. More soil moisture content was observed in vertical column filled with compost than column filled with sand. Aineeche *et al*. (2009) analyzed soil wetting patterns under trickle irrigation that the wetted breadth and depth rise as the water supply increases. For all volumes of irrigation water delivered, sandy soil had the greatest wetted breadth and depth, followed by loam soil, sand, and silt clay loam [10].

Dripline spacing's impact on soil moisture distribution

The emitter used in drip irrigation is critical for ensuring equal water distribution and application in the crop root zone. Capra and Scicolone (2004) performed a field experiment with several kinds of emitters and filters for utilization of wastewater in drip irrigation and discovered that in-line emitters and gravel filters were a better match than vortex emitters and screen filters [11]. Pei *et al*., (2014) studied online pressure compensating and online non-pressure compensating emitters and suggested online pressure compensating emitters for practical use [12].

Galvez and Simmonds (2006) measured lettuce drip irrigation in sandy loam soil: the three- dimensional flow of water analysis with 40 cm drippers and 65 cm laterals. The findings revealed that the compact soil layer reduced the penetration of the leak front to a deepness of 25 cm; after 24 hours, the radial effect had grown to 25 cm, whereas the radial effect had grown to 30 cm, indicating a homogenous spread [13]. According to Grabow, *et al.* (2006), SDI drip lines in sandy loam soil were buried 0.25 m below ground level, with drippers spaced at 0.30 m and laterals spaced at 0.91 and 1.82 m. According to the studies, water moved across to the intermediate of both lateral spacing's and vertically to 0.53 m. Cotton production and irrigation water usage efficiency for lateral spacing [14]. Chauhan *et al.* (2015) conducted the study on soil moisture distribution at different lateral spacing and observed that the soil moisture at depth 0-60 decreases as the lateral spacing increases. He also observed the higher moisture content at closely spacing lateral i.e 60 cm distance and lower moisture content at lateral distance 100 cm [15].

Significance of drip line depth on soil moisture distribution

According to Singh *et al.* (2006), the depth of wetness increased as the depth of lateral implantation increased [16]. Cabrera *et al.* (2016) examined the distribution of soil moisture beneath drip-irrigated potatoes in sandy soil in Florida [17]. The drip tape installation depths used in the research were 0.05 m on the surface and 0.15 m on the bottom. When compared to the 0.15 m depth of irrigation (9.7 kg/m^3, 26.3 Mg/ha,), the production and water use efficiency of the crop dropped (19.9 Mg/ha, 7.4 kg/m^3). Surface drip irrigation, which had the drip line higher in the soil profile than SDI, was used to boost the variation in soil hydration in the top section of the soil profile, where 61–77% of the roots were observed. The SDI's lower drip line lowered soil moisture in the topsoil layer, resulting in a considerable decrease in commercial output. This research found that irrigating the root zone using a shallow drip tape (0.05 m) was the most effective way to address weak permeability and porosity. Rafie and EL-Boraie (2017) suggested that drip lateral placed at surface showed more soil moisture content compared to subsurface lateral. They also added that horizontal water movement was more in 4lph emitter discharge and vertical water movement was more in 2 lph emitter discharge [18].

The function of dripper discharge rate on the dispersion of soil moisture

Water penetration and redistribution under drip irrigation on sandy loam soil were studied by Skaggs *et al.* (2004) in California. Various water application rates, including 20, 40, and 60 lpm, were utilized [19]. The water font advance towards lateral and vertical direction varies as per the soil texture as well as the discharge rate and time. More the emitter discharge induced more lateral movement of water on clay or clay loam soil**.** Srivastava *et al.* (2011) conducted the study on different irrigation levels and pair row planting methods and observed that the lateral water moment was more when the more amount of water applied by dripper for more duration [20]. According to Molavi *et al.*, (2012), wetted bulb coordinates were calculated using water application time, saturated hydraulic conductivity of the soil, average volumetric water content variation, and emitter [21]. In Samasthipur (Bihar, India), Shekhar *et al.* (2017) used various dripper discharge rates to perform a soil moisture profile analysis. When the release amount was raised from 2 to 6.0 lph and 2 to 4.4 lph, the vertical spread was reduced by 18% and 32% [22]. Saxena *et al.* (2018) resulted that an increase in emitter discharge rate increased the maximum wetted radius at the soil surface and under the soil surface, while the wetted depth for vertisols remained unchanged. In various agro-ecological situations, pulsed movement may be employed with three times the continuous flow with less clogging and a significant rise in emitter size [23].

The role of emitter spacing on soil moisture variability

The emitter spacing plays the vital role in water movement in vertically and horizontally which depend upon soil texture and emitter discharge. The scientist studied the water font at various emitter spacing and discharge rate. Shan *et al.* (2011) evaluated moisture patterns in the overlap between zones when drip irrigation was delivered from two sites. Shorter emitter spacing's resulted in a greater wetting front according to the research. the emitter spacing of 30cm with discharge rate of 1.8, 2.2, 3 lph irrigation volume was recorded 8L, 10L, 12 L. whereas in emitter spacing 40 cm with discharge rate 2.2 Lh^{-1} the irrigation volume was 10 L. Hence it result that to increase the wetted surface and hence increase water content and efficiency, the authors suggested utilizing a shorter emitter spacing [24]. In Egypt, Badr and Abuarab (2013) [3] studied the patterns of soil moisture redistribution in sandy soil utilizing surface and subsurface drip irrigation systems. The adjustment in lateral line distance from 100 to 75 cm did not influence soil moisture distribution. According to the findings, an SDI system at a depth of 30 cm is suggested since it reflects numerous vegetable plants with a dynamic root zone, which collects water in sandy soils. Under 30-cm dripper spacing, the soil moisture distribution was better than under 50 cm. Chauhan *et al* (2015) [15] observed that the maximum moisture content soil moisture when the emitter were placed at 30 cm apart as well as the lateral were closely spaced i.e 60 cm whereas less moisture content were observed at emitter spacing 50 cm. Huang *et al.* (2015) investigated the influence of emitter spacing on sugarcane crop. He observed that the good wetted depth (33.5 cm) was observed at closer emitter spacing i.e cm as compared to the emitter spacing at 40 cm. In latosols for sugarcane, studies suggest emitter spacing of 30 cm with a 1.38 lph emitter discharge rate [25].

Clogging of emitters lowers the efficiency of Drip irrigation

The degree of turbulence in the flow channel determines which emitters are more likely to clog. A wide cross-section enables the flow to keep flowing without clogging, and a very turbulent channel permits dirt particles to pass past the emitter in suspended form. Liu and Huang (2009) reported that the more discharge variation and smaller emission uniformity was observed when the water pass in laminar flow than the turbulent flow and online pressure compensated dripper [26]. Drip irrigation guarantees that water is distributed evenly throughout the whole cycle. Clogging of emitter is related to the water quality may include suspended sediment load, chemical element, and biological activity [27]. According to Al-Amoud and Saeed (1988), the system should be run in pulses rather than constantly maintaining the application rate [28]. With a modest adjustment in the wetting pattern, Jackson and Kay (1987) suggested that to reduced emitter clogging, the pulsed flow might be used three times the continuous flow and a significant increase in emitter size, [29]. Abdelraouf *et al.* (2012) studied the clogging ratio of emitter and concluded that clogging emitter ratio decreases with increases with the frequency of irrigation in pulses [30]. Emitter clogging is a severe issue that micro-irrigation systems face. Water quality and emitter shape both influences the clogging process. Clogging caused by suspended solid particles is the most common agent received form polluted surface water sources, since particles that are too small to be retained by the filter aggregate downstream from the filtering system [31]. Individual or combined effects of physical, chemical, and biological agents on distribution of water, emission uniformity and coefficient of variation of drip system described below

Presence of physical Clogging

Solid particles are considered as the most common clogging agent which leads to emitter clogging [32]. Even if the irrigation water has been filtered using a mixture of sedimentation, grit filtration, and mesh screen, residual solid particles with a diameter smaller than 0.075 mm can still enter the emitter channel [33]. Inorganic materials are sand particles ranging from 50-250 micrometers, silt particles ranging from 2-50 micrometers, and clay particles ranging from less than 2 micrometers. Organic materials are phytoplankton and algae (aquatic plants), zooplankton and snail (aquatic animals), bacteria ranging from 0.4-2 micrometer, plastic cutting etc. [32]. The physical clogging reduces the distribution uniformity of emitters, coefficient variation and reduces the efficiency of drip system.

Presence of chemical clogging

Chemical clogging occurs due to the deposition of $CaCO_3$, higher pH, variation in temperature, and the fertigation results in the reduction of emitter discharge and an uneven irrigation water distribution across the cultural land [34, 35]. Hard water is the primary source of chemical clogging. Solubility of carbonates reduced as the temperature rises. Maintain the pH of alkaline water by adding acid to the water which is widely recommended for maintaining $CaCO_3$ precipitation in drip systems [35]. Sahin *et al.* (2012) evaluated the clogging of emitter by passing the magnetized saline water through emitter and observed discharge of emitter was more in magnetized saline water compared to non-magnetized saline water [36]. Many factors that cause clogging in emitter's i.e Heavy metals, anions such as carbonate, hydroxide, silicate, sulfide, cations such as calcium, magnesium, iron, manganese and many fertilizers sources use for fertigation i.e aqueous ammonia, iron, copper, zinc, phosphorous, manganese, etc, may be reduces or discarded by using acid treatment [32].

Presence of biological clogging

Biological clogging is mostly common in drip irrigation because of the presence of microorganism and organic matter in water source. Major factors for the biological clogging are microorganisms and suspended particles, protozoa and bacteria etc. [37]. Biological clogging occur due to growing of algae, bacteria and zooplanktons and other organisms and they reproduce easily which result in slime formation. When the slime water mix with minerals particles and cause biological emitters clogging [38]. This clogging of emitter due to microorganism could be reduce by chlorination treatment and using anit-clogging agent mixed with water [39]. The fungi and bacterial stains were isolated form the water and performance of emitter were studied by Sahin *et al* (2005) [40]. It was observed that the antagonistic bacterial strains have the potential to be used as anti-clogging agents which may reduces the emitter clogging.

Conclusion

The soil moisture distribution is affected by placement of drip line, soil texture, emitter spacing, depth of drip line installation, and emitter discharge rate under and beneath the surface under trickle irrigation. From the above review literature, it has been concluded that the good soil moisture distribution could be observed if the lateral are closely spaced maximum up to 60-80 m distance and emitter spacing up to 30 cm. In clayey and loam soils, a greater emitter flow rate favors vertical and lateral water flow under drip irrigation.

The clogging of emitter occurred due the poor quality of water, pressure variation and type of emitter.

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