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Soil Wetting Pattern under Point and Line Source of Trickle Irrigation

P.H. Rank*, Y.B. Unjia and A.N. Kunapara

Department of Soil and Water Engineering, College of Agricultural Engineering and Technology, Anand Agricultural University, Godhra - 389001, India

**Corresponding author*

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Horizontal wetted distance, Vertical wetted depth, Antecedent moisture content, Point source, Line source

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A B S T R A C T

A field experiment was conducted to study the horizontal and vertical movement of moisture front under point and line source of trickle irrigation system by operating system up to three hours. Emitter of 2, 4, 8 lph discharge were used for studying the moisture movement under point source and 4, 5, 8 and 10 l/m/hr discharging emitter for the wetting pattern under line source. The effect of antecedent moisture content on Radial as well as Vertical movement was also considered in this field Experiment. The relationship between Radial movement and Vertical movement with respect to irrigation time, both can be described by a power function. Result revealed that vertical movement was found more in line source as compare to point source while more horizontal movement was observed in point source than line source irrigation.

Introduction

India is country based on agriculture as two third of its population depends on agriculture. Due to population growth in India and increasing living standards, water usage increased and application of water in field has become very essential.The need for water conservation and improvement in water-use efficiency to achieve more crop per drop is necessary. One of the most challenging issues is how to choose emitter flow rate, dripper's space corresponding to water requirement of crop (Zhang *et al.*, 2012). Thus the scarcity of water and more water requirement can be overcome by trickle irrigation system. Trickle irrigation is more effective and less expensive if an adequate amount of soil can be wetted matching with root zone with each emitter without losing water or nutrients below the root zone (Skaggs *et al.*, 2010).

Information on moisture distribution patterns under point source trickle emitters is a pre-requisite for the design and operation of trickle irrigation systems compared to all subsequent operations in the field (Ainechee, 2009). Point source allows for more fine-tuned control over how much water each plant receives and is most effective when plants are spaced far apart. When emitters are placed at prefixed uniform interval as per crop spacing, then line source infiltration takes place. When wetted bulbs under each dripper in line touches, it switches to line source. Elmaloglou *et al.,* (2009) concluded that the validity of the assumption that an irrigation event from point sources can be approximated as an infinite line source. During the initial growth stage, the point source of irrigation can be adequate to wet the roo tzone but during the subsequent growth stages, the continuous wetted strip is required to be wetted to match the root zone of the crop.

Therefore, it is required to have technical knowledge on horizontal and vertical spreading of wetted bulb for the various dripper discharge and operating time under different soil texture. Therefore, the present field experiment was designed to study the soil water movement under point source and line source. The objectives of this study were to measure differences in the extent of wetting patterns between point source and line source.

Materials and Methods

The experiment was conducted at College of Agricultural Engineering & Technology, Godhra, located at 22°46’ N latitude and 73°39’ E longitude with an altitude of 143 meter above mean sea level. The climate of area is subtropical and semi-arid type with an average rainfall of 900 mm and average pan evaporation of 6.8 mm/day. May is hottest month with the mean temperature varying between 35 °C to 45 °C and December is coolest month with mean monthly minimum temperature varying between 5 °C to 10 °C. The physiochemical properties of soil of the experimental field are depicted in Table 1. The Table 1 shows that soil of the experiment field is clay. The soil is rich in phosphorus but poor in Nitrogen and Potash. The EC of the soil indicates healthy soil. The available water in the soil can be as high as 17%. Prior to installation of the trickle irrigation system, the field was deep cultivated in two directions. A further passes were performed with a vertically tined rotary cultivator to break up some of the larger clods. The present field experimental layout is shown in Figure 1. The source of water was tube well and pump required for experiment was 5 hp. The screen filter was used for filtering the water. The Pressure gauge was fitted at inlet and outlet of filter to know the head loss through filter so that the requirement of cleaning of filter can be known. The bypass assembly was fitted between Pump and Head Unit to regulate excess flow.

The PVC Pipe of 63 mm × 4 $kg/cm^2$was used as Sub Main. The total 9 LLDPE laterals of 16 mm were fitted with sub main through grommet takeoff at 2 m apart. The 16 mm cock was fitted on each lateral after sub main connection. Total 9 laterals were run parallel at right angle to the sub main. The 5 drippers of 2 lph, 4 lph and 8 lph of discharge were fitted each of lateral number 1, 4 and 7, 2, 5 and 8, and 3, 6 and 9 respectively.

The trickle system was run for 1 hour, 2 hour and 3 hours for the laterals sets of 1-2-3, 4-5-6 and 7-8-9 respectively for point source, similarly for same setup 4, 5, 8 and 10 l/m/h discharging emitter were used for line source. The wetted bulb was allowed for moisture redistribution until field capacity has been attained after 24 hours of irrigation termination. The vertical section was cut for each wetted bulb and horizontal/ vertical distance was measured.

Results and Discussion

The spread of wetted bulb under point source and line source of irrigation were assessed and analyzed. The results are discussed in the subsequent subheads (Fig. 1–3).

Dynamic of wetting front under Point Source

Horizontal movement

A correlative analysis is applied to horizontal movement of wetted front on surface with application rate as well as applied time. The horizontal movement of wetting front on surface at 1, 2 and 3 hours of irrigation water application was obtained as 38 cm, 73 cm and 90 cm under 2 lph emitter discharge capacity, 47 cm, 82.5 cm and 100 cm under 4 lph emitter and 72 cm, 107.5 cm and 125 cm under 8 lph emitter, respectively.

The horizontal movement of wetting front was increased with water application time and with emitting rate. The horizontal wetting front movement was more faster under higher emitting rate as compared to lower emitting rate due higher excess water on surface under higher emitting rate of point source to spread horizontally. The wetting front advances at diminishing rate with time of application (Trout *et al.,* 2005). The reason is that with increase in the wetting front, the area of water infiltration on surface also increases which leads to reducing excess water to flow horizontally. The movement occurs more due to soil suction rather than due to hydraulic forces. The similar results were found for most of the types of soil texture as reported by Zhang *et al.,* (2012).

The observed data on horizontal distances at various time of water application under various emitting rate were attempted to fit in various mathematical frames and the following power form of mathematical model was found best.

$D_h = 38.988(t)^{0.8014}$, $R^2 = 0.98$ for 2 lph emitter

$D_h = 47.987(t)^{0.7007}$, $R^2 = 0.98$ for 4 lph emitter,

$D_h = 72.921(t)^{0.5103}$, $R^2 = 0.99$ for 8 lph emitter

Where, D_h is the diameter of the wetted bulb on surface at time-t(hour).

The above models shows that the multiplying coefficient increases while power exponents of time decreases with increase in discharge rate. The above models also shows that the advancement rate decrease with time more rapidly under 8 lph followed by 4 lph and 2 lph emitting rate.

This is due to higher infiltrating area under higher emitting rate at any time.

Vertical movement

The maximum vertical movement of wetting front was found as11.5 cm, 17 cm and 20 cm. Under 2lph emitter, 15.1 cm, 20.4 cm and 23 cm under 4 lph emitter and 18 cm, 28 cm and 33 cm under 8 lph emitter at 1,2 and 3 hours of water application. The vertical advancement rate was highest during 1st hour, followed by that of during 2nd and 3rd hour respectively. The vertical advancement rate of the wetting front diminishes with time but increases with emitting rate. The vertical movement of water wetting front depends on the infiltration rate if the adequate water is available on surface to infiltrate at its potential rate and if this is not so, soil suction and gravity forces controls the wetting front advancement in downward direction. The observed data on Vertical distances at various time of water application under various emitting rate were attempted to fit in various mathematical frames and the following power form of mathematical model was found best.

$D_h= 11.648(t)^{0.512}$, $R^2 = 0.99$ for 2 lph emitter

$D_h = 15.228(t)^{0.3885}$, $R^2 = 0.99$for 4 lph emitter,

$D_h = 18.267(t)^{0.5612}$, $R^2 = 0.99$for 8 lph emitter

Where, D_h is the diameter of the wetted bulb on surface at time-t(hour).

Dynamic of wetting front under Line Source

Horizontal movement

The horizontal movement of water under 2 lph x40cm line source was such that two wetting circles touches at 57 minute. However, the wetting circle at surface of adjacent emitter touched at 116 minutes in the case of 2 lph x50cm line source. The similar phenomena was found at 49 minutes under 4 lph x 40cm line source. The wetting patterns of two adjacent emitters started overlapping just at 68minutes under 4lph × 50cm line source. Adjacent drippers wetting pattern overlapped, thus resulted in the increase of vertical movement radially than the horizontal movement. The results shows that the point source having lower discharge per unit length would not serve better to wet the root zone of the crops having wider root spread. Therefore, the emitter rate and spacing of line should be designed based on soil texture such that it can give enough width of wetted strips to cover the root spread of the crops.

Vertical movement

The maximum wetted bulb depth below the emitting point under 2 lph was observed as 10 cm, 19.3 cm and 24 cm for 40 cm spacing and 10 cm, 20.7 cm and 26 cm for 50 cm spacing and the maximum wetted bulb depth below the emitting point was under 4 lph as 11 cm, 33 cm and 44 cm for 40 cm spacing and 11 cm, 29 cm and 38 cm for 50 cm spacing for 1, 2 and 3 hours duration of application respectively.

As the results of present field experiment the Radial movement of water under point source is more than line source for first 2 hours and then it increases radially after 2 hours and the Vertical movement of water under line source is more than point source for first 2 hours and then it increases radially after 2 hours at same discharge and time.

Maximum radial movement goes 125 cm at surface for 8 lph at 3 hour under point source. As maximum vertical movement goes 44 cm at surface for 4 lph at 40 spacing for 3 hour under line source.

The radial water spread increases rapidly with time initially but then increases at a decreasing rate to limit the radius to a constant value.

The depth of wetting front was found to be invariant with emitter flow rate provided the emitter discharge is less than the infiltration capacity of the soil. Similar results were found by Skaggs *et al.,* (2010) reported that increasing the antecedent water content increases water spreading in radial distances as compared to vertical distance, which is undesirable where root zones are shallow, water is scarce, and groundwater contamination is a concern.

Present study was undertaken to know the geometry of the wetted bulb for different emitter discharge rates and volume of applications under point source and line source. The following conclusions were drawn from the present study

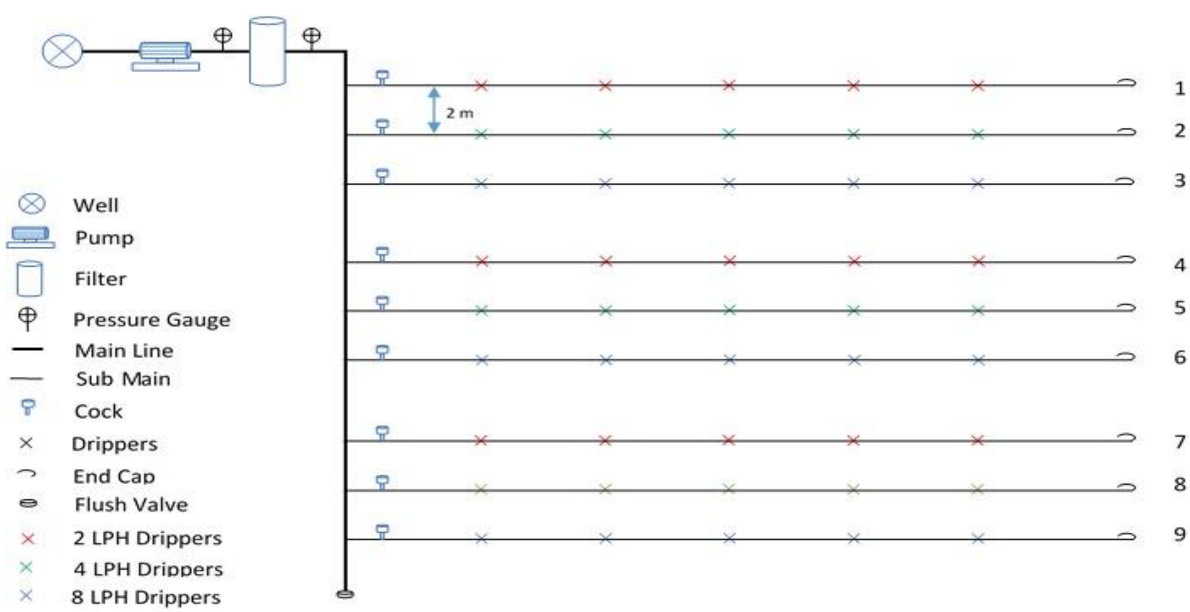
The antecedent moisture content measured at the top surface, 15 cm, 30 cm, 35 cm depths were found 4.6 %, 8.3 %, 24.2 %, 27.9 %.

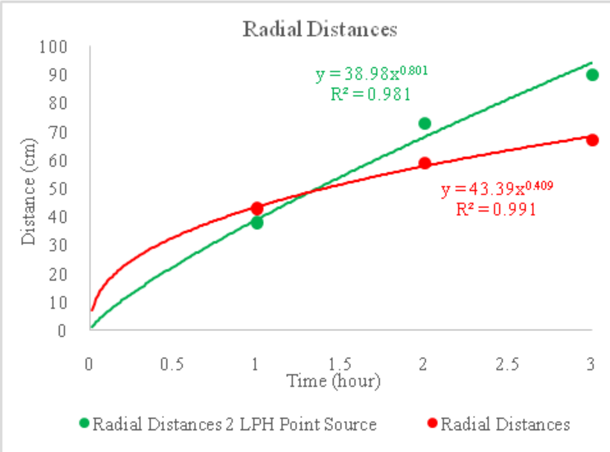
The maximum radial movement under point source for 2 lph emitter were 38 cm, 73 cm and 90 cm in 1, 2 and 3 hours duration of irrigation water application. The maximum vertical movement under point source for 2 lph emitter were 11.5 cm, 17 cm and 20 cm for 1, 2 and 3 hours duration of application.

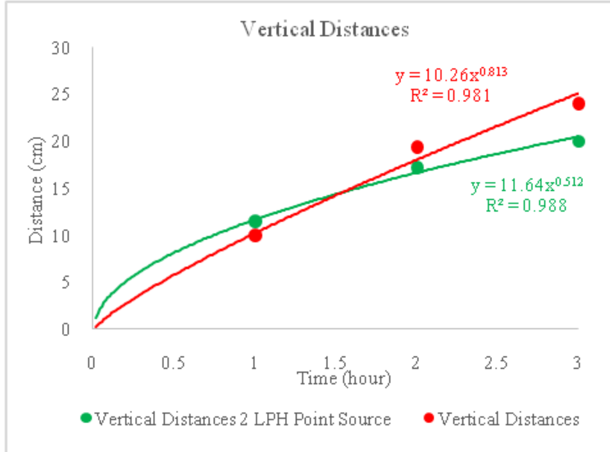
Table.1 Physiochemical properties of the soil of experimental field

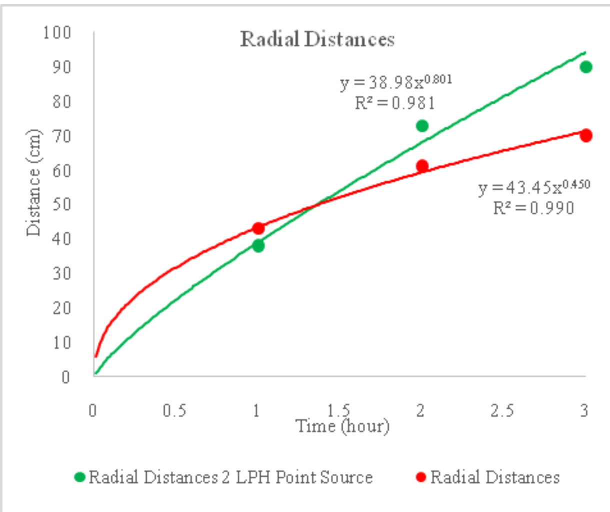
Sr. No.	Particular	Units	Values
1	Sand	%	11.11
2	Silt	%	25.80
3	Clay	%	63.11
4	Bulk Density (% wb)	g/cc	02.02
5	Moisture Content	%	10.09
6	Specific Gravity	%	02.55
7	Porosity	%	43.56
8	Field Capacity	%	32.00
9	Saturation Percentage	%	33.33
10	Wilting Point	%	15.00
11	Hydraulic Conductivity	cm/h	02.83
12	Infiltration Rate	mm/h	58.45
13	Phosphate	kg/ha	520.00
14	Nitrogen	kg/ha	21.83
15	Potash	kg/ha	94.00
16	pH (1:2.5)	-	07.67
17	EC	ds/m	00.11

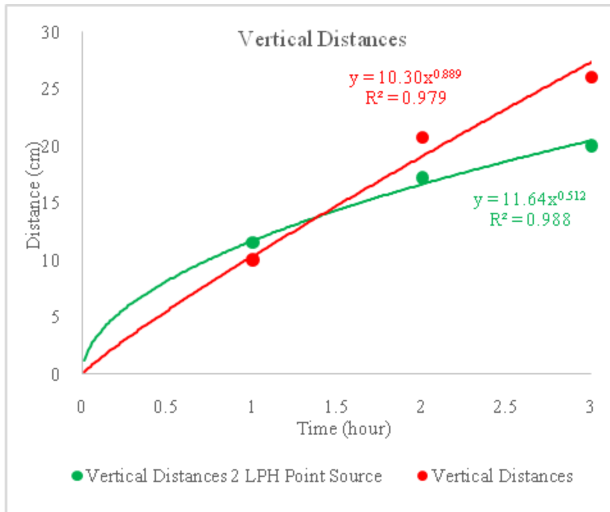
Fig.1 Experimental Layout

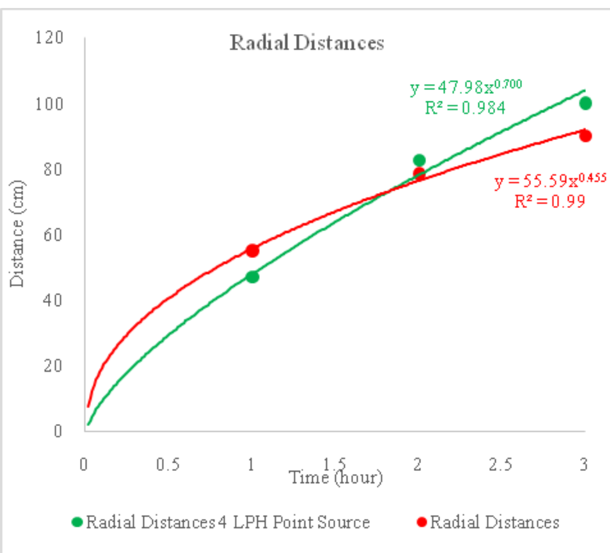


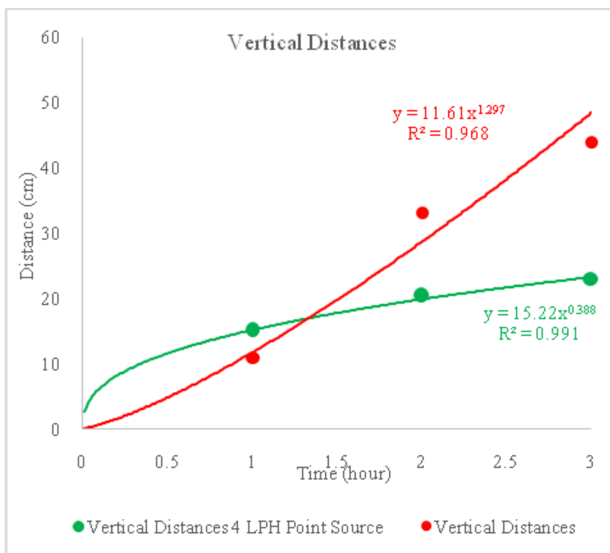

Radial Distances
y = 38.98x^0.801
R² = 0.981
y = 43.39x^0.409
R² = 0.991
Distance (cm)
Time (hour)
Radial Distances 2 LPH Point Source
Radial Distances


Vertical Distances
y = 10.26x^0.813
R² = 0.981
y = 11.64x^0.512
R² = 0.988
Distance (cm)
Time (hour)
Vertical Distances 2 LPH Point Source
Vertical Distances


Radial Distances
y = 38.98x^0.801
R² = 0.981
y = 43.45x^0.450
R² = 0.990
Distance (cm)
Time (hour)
Radial Distances 2 LPH Point Source
Radial Distances


Vertical Distances
y = 10.30x^0.889
R² = 0.979
y = 11.64x^0.512
R² = 0.988
Distance (cm)
Time (hour)
Vertical Distances 2 LPH Point Source
Vertical Distances


Radial Distances
y = 47.98x^0.700
R² = 0.984
y = 55.59x^0.455
R² = 0.99
Distance (cm)
Time (hour)
Radial Distances 4 LPH Point Source
Radial Distances


Vertical Distances
y = 11.61x^1.297
R² = 0.968
y = 15.22x^0.388
R² = 0.991
Distance (cm)
Time (hour)
Vertical Distances 4 LPH Point Source
Vertical Distances

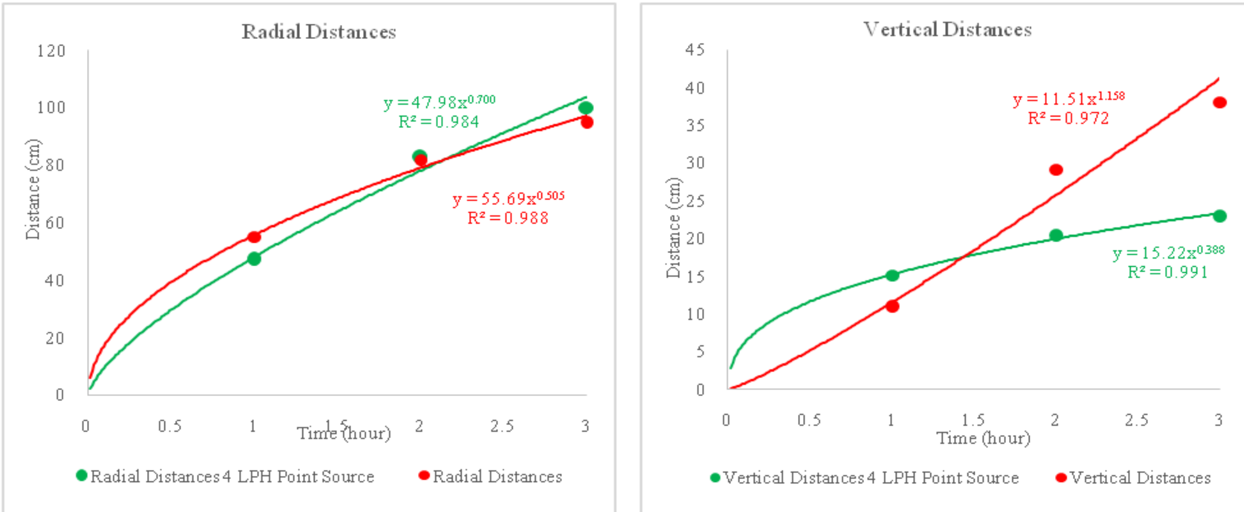


Fig.2 Comparision of Point Source & Line Source

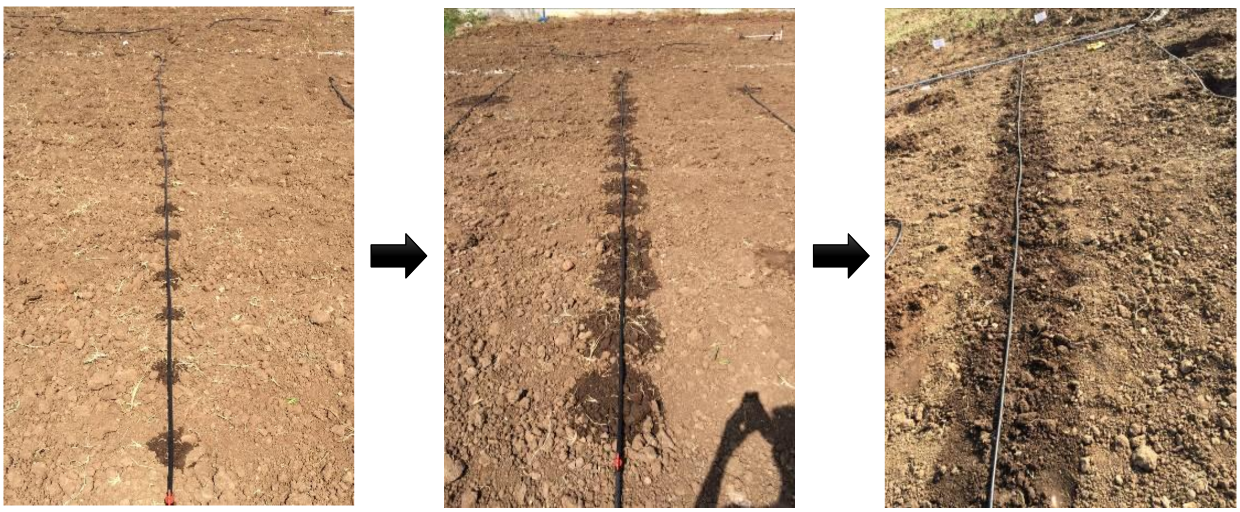


Fig.3 Conversion of Point Source into Line Source at Certain Period

The maximum radial movement under point source for 4 lph emitter were 47 cm, 82.5 cm and 100 cm in 1, 2 and 3 hours duration of irrigation water application. The maximum vertical movement under point source for 4 lph emitter were 15.1 cm, 20.4 cm and 23 cm for 1, 2 and 3 hours duration of application.

The maximum radial movement under point source for 8 lph emitter were 72 cm, 107.5 cm and 125 cm in 1, 2 and 3 hours duration of irrigation water application. The maximum vertical movement under point source for 8 lph emitter were 18 cm, 28 cm and 33 cm for 1, 2 and 3 hours duration of application.

The maximum radial movement under line source for 2 lph having emitter spacing 40 cm were 43 cm, 59 cm, 67 cm in 1, 2 and 3 hours duration of irrigation water application. The maximum vertical movement under line source for 2 lph having emitter spacing 40 cm were 10 cm, 19.3 cm and 24 cm for 1, 2 and 3 hours duration of application. The time of overlapping for 2 lph having emitter spacing 40 cm was 57 minutes.

The maximum radial movement under line source for 2 lph having emitter spacing 50 cm were 43 cm, 61 cm, 70 cm in 1, 2 and 3 hours duration of irrigation water application. The maximum vertical movement under line source for 2 lph having emitter spacing 50 cm were 10 cm, 20.7 cm and 26 cm for 1, 2 and 3 hours duration of application. The time of overlapping for 2 lph having emitter spacing 50 cm was 1 hour 57 minutes.

The maximum radial movement under line source for 4 lph having emitter spacing 40 cm were 55 cm, 78 cm, 90 cm in 1, 2 and 3 hours duration of irrigation water application. The maximum vertical movement under line source for 4 lph having emitter spacing 40 cm were 11 cm, 33 cm and 44 cm for 1, 2 and 3 hours duration of application. The time of overlapping for 4 lph having emitter spacing 40 cm was 49 minutes.

The maximum radial movement under line source for 4 lph having emitter spacing 50 cm were 55 cm, 82 cm, 95 cm in 1, 2 and 3 hours duration of irrigation water application. The maximum vertical movement under line source for 4 lph having emitter spacing 50 cm were 11 cm, 29 cm and 38 cm for 1, 2 and 3 hours duration of application. The time of overlapping for 4 lph having emitter spacing 50 cm was 1 hour 8 minutes.

Maximum radial movement goes 125 cm at surface for 8 lph at 3 hour under point source. As maximum vertical movement goes 44 cm at surface for 4 lph at 40 spacing for 3 hour under line source.

From Present field experiment it was concluded that the Point Source having lower discharge per unit length would not serve better to wet the root zone of the crops having wider root spread. Therefore, the emitter rate and spacing of line should be designed based on soil texture such that it can give enough width of wetted strips to cover the root spread of the crops.

Increasing the antecedent moisture content increases water spreading in radial distances as compared to vertical distance, which is undesirable where root zones are shallow, water is scarce, and groundwater contamination is a concern.

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