HORIZONTAL AND VERTICAL MOISTURE DISTRIBUTION PATTERN UNDER SPRINKLER IRRIGATION SYSTEM IN SANDY LOAM SOIL

T.M.V. Suryanarayana, H.J. Parmar & N.R. Patel
Water Resources Engineering and Management Institute, The M.S. University of Baroda, Vadodara, India
tmvkiran@yahoo.com

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ABSTRACT:
The improvement of irrigation water management is becoming critical to increase the efficiency of irrigation water use and to reduce irrigation water demands. The field evaluation of sprinkler irrigation systems is essentially required for studying the efficiency and performance of the system during and after the operation. There is a need to study and understand the distribution of moisture pattern, within the soil, where irrigation is applied. The area selected for the present study is the Training Cum Demonstration (TCD) farm of Water Resources Engineering and Management Institute (WREMI), which is located in Samiala, Vadodara District, Gujarat. The sprinkler system is run for Six various durations, i.e. Ten minutes, Twenty minutes, Thirty minutes, One hour, One and a Half hour and Two hours .The Experimental Details and Specifications are as follows: The Area of Field size under study is 50m x 25m having each Plot, i.e Plot-X and Plot-Y as 25m x 25m, Four Horizontals with 6 m length & 63 mm diameter in each plot, One Manifold with 18 m length & 63 mm diameter in each plot, Main having 12 m length & 63 mm diameter. Sprinkler grid size is 12m x 12m with 4 Sprinklers in each plot. The Source of the water is at middle top of the field. The Grid size for sample collection is 4m x 4m. The soil samples are collected at four various depths, i.e. 15cms, 40cms, 60 cms and 90 cms, at uniform intervals using core cutter. The objective of the study is to determine the horizontal and vertical moisture distribution pattern in soil strata at various depths and also to determine the effect of overlapping of Moisture of one plot on another plot.

1. INTRODUCTION

In the sprinkler method of irrigation, water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. The spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping. With careful selection of nozzle sizes, operating pressure and sprinkler spacing the amount of irrigation water required to refill the crop root zone can be applied nearly uniform at the rate to suit the infiltration rate of soil. Every sprinkler system is composed of a pipe network and of sprinklers. The pipes convey the water and supply it to all the operating sprinklers at the correct pressure head. At the nozzle of the sprinklers the pressure head of the water is converted to the velocity head. The water flows out of the nozzle in the form of a jet, and breaks down into drops of water which wet the area within a certain range. The range of the wetted area depends on the magnitude of velocity head given to the water; it is also influenced by the angle of flow of the jet, the type of sprinkler and its moving mechanism, and by wind conditions during the irrigation period. The provision of the proper pressure head to each sprinkler in the irrigated field, the correct spacing of the sprinklers according to their type and wind condition, and the design of the sprinkler system according to the nature of the soil and crops in the area are the factors which ensure the efficient spreading of water in the correct quantities and at the proper times.
The study analyzing the factors affecting deep percolation was carried out by Ben-Asher and Ayars (1990). The relationship between applied water and a point water balance is studied by Ben-Asher and Ayars (1990) using a linear move sprinkler, irrigating a field of sugar beets (Beta vulgaris L. Var. HC11). The effect of pressure heads (H), stake heights (h) of micro sprinkler, types of micro sprinkler and length of Horizontal (L) on the wetted diameter of soil (D) were studied by Firake et-al (1992). Chang and Hills (1993) has developed, a numerical simulation model that employs full three-dimensional Navier-stokes equations and the finite difference procedure is utilized for studying pressure and shear distribution on a soil surface following sprinkler droplet impact. Sprinkler droplet impact angle and surface water layer depth were studied by Chang and Hills (1993) in relation to a soil's infiltration rate. The program was developed by Dingre (2007) for computation of overlapped

pattern and uniformity coefficients from multiple sprinklers test data by considering the fact that the depth of water from different sprinklers contributing to overlapped area is a function of sprinkler spacing. The study was carried out by Bharti et al. (2008) to investigate the soil moisture movement and irrigation water distribution pattern under pressurized irrigation system in sandy clay loam soil for summer bitter gourd. It was observed that H and h have greater influence on D.
The improvement of irrigation water management is becoming critical to increase the efficiency of irrigation water use and to reduce irrigation water demands. The field evaluation of sprinkler irrigation systems is essentially required for studying the efficiency and performance of the system during and after the operation. There is a need to study and understand the distribution of moisture pattern, within the soil, where irrigation is applied.

2. STUDY AREA

The area selected for the present study is the Training Cum Demonstration (TCD) farm of Water Resources Engineering and Management Institute (WREMI), which is located in Samiala, Vadodara District, Gujarat.

3. METHODOLOGY

The sprinkler system is run for Six various durations, i.e. Ten minutes, Twenty minutes, Thirty minutes, One hour, One and a Half hour and Two hours .The Experimental Details and Specifications are as follows: The Area of Field size under study is 50m x 25m having each Plot, i.e Plot-X and Plot-Y as 25m x 25m, Four Horizontals with 6 m length & 63 mm diameter in each plot, One Manifold with 18 m length & 63 mm diameter in each plot, Main having 12 m length & 63 mm diameter. Sprinkler grid size is 12m x 12m with 4 Sprinklers in each plot. The Source of the water is at middle top of the field. The Grid size for sample collection is 4m x 4m. The soil samples are collected at four various depths, i.e. 15cms, 40cms, 60 cms and 90 cms, at uniform intervals using core cutter and the moisture content is determined by gravimetric method. The objective of the study is to determine the horizontal and vertical moisture distribution pattern in soil strata at various depths and also to determine the effect of overlapping of Moisture of one plot on another plot.

4. RESULTS AND ANALYSIS

The moisture content before and after operating the system for 10 min. is considered as pre and post moisture content. Thus moisture content for 10 min. operation time is the difference between post and pre moisture content. Similarly, moisture content for other time durations is determined.

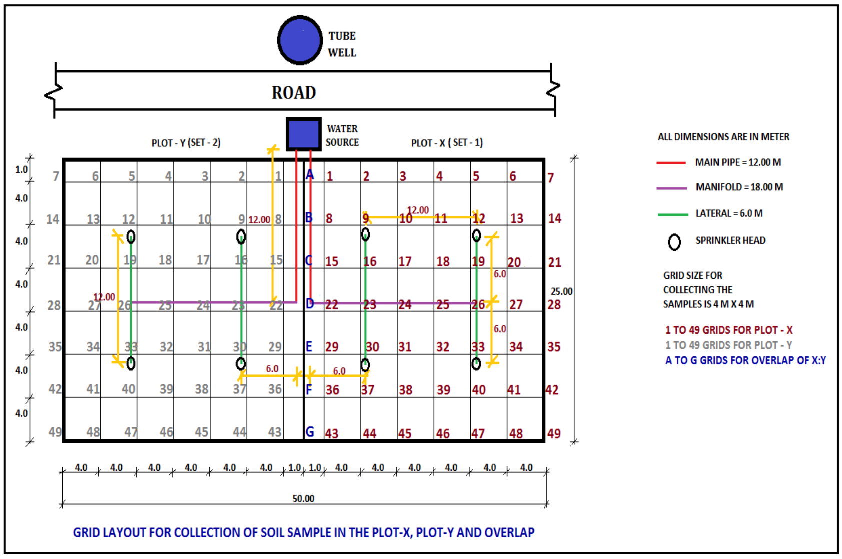

Figure 1 Grid Layout for Collection of Soil Samples in Plot – X, Plot – Y and X:Y Overlap

Vertical Distribution of Moisture Content

Tables 1, 2, 3 and 4 presents the ranges of moisture content concentration in soil profile at Grids 1 through 49 for depths of 15 cm, 40 cm, 60 cm and 90 cm respectively.

Table 1 Ranges of Moisture Content Concentration in Soil Profile for Different Time duration at 15 cm Depth

Time Duration	M.C. Range, %		
	Plot - X	X:Y Overlap	Plot – Y
Pre 10 min	0.71 – 6.88	1.93 – 6.49	0.85 – 3.81
Post 10 min	1.21 – 6.72	2.66 – 9.66	1.02 – 9.49
Post 20 min	1.17 – 20.10	2.59 – 18.10	0.8 – 16.98
Post 30 min	0.63 – 25.70	1.31 – 14.22	0.57 – 16.40
Post 1 hr	1.19 – 21.43	5.57 – 19.36	1.57 – 17.91
Post 1 hr 30 min	1.52 – 24.02	5.73 – 23.75	3.23 – 21.56
Post 2 hr	2.79 – 24.84	12.14 – 19.89	5.60 – 20.73

Table 2 Ranges of Moisture Content Concentration in Soil Profile for Different Time duration at 40 cm Depth

Time Duration	M.C. Range, %		
	Plot - X	X:Y Overlap	Plot – Y
Pre 10 min	7.53 – 12.77	-	6.92
Post 10 min	2.99 – 11.01	8.12 – 10.79	-
Post 20 min	2.02 – 26.30	4.67 – 9.74	4.57 – 18.46
Post 30 min	1.12 – 12.60	1.62 – 14.54	2.06 – 20.82
Post 1 hr	1.41 – 18.99	3.91 – 16.16	3.63 – 10.71
Post 1 hr 30 min	1.76 – 19.68	6.29 – 16.89	2.39 – 12.51
Post 2 hr	8.44 – 27.41	7.77 – 28.55	5.39 – 17.77

Table 3 Ranges of Moisture Content Concentration in Soil Profile for Different Time duration at 60 cm Depth

Time Duration	M.C. Range, %		
	Plot - X	X:Y Overlap	Plot – Y
Pre 10 min	8.26 – 13.72	-	9.42
Post 10 min	12.94	-	-
Post 20 min	-	-	-
Post 30 min	2.54 – 9.44	7.00 – 10.02	-
Post 1 hr	2.61 – 19.30	6.78 – 9.73	3.63 – 12.90
Post 1 hr 30 min	5.08 – 22.06	2.15 – 12.41	3.27 – 16.36
Post 2 hr	4.41 – 24.41	9.12 – 31.50	5.41 – 17.53

Table 4 Ranges of Moisture Content Concentration in Soil Profile for Different Time duration at 90 cm Depth

Time Duration	M.C. Range, %		
	Plot - X	X:Y Overlap	Plot – Y
Pre 10 min	2.65 – 11.39	-	12.12
Post 10 min	12.90	-	-
Post 20 min	-	-	-
Post 30 min	6.78 – 8.24	9.27 – 9.84	-
Post 1 hr	3.89 – 17.36	7.45 – 11.72	7.07 – 14.05
Post 1 hr 30 min	5.39 – 17.49	8.41 – 12.75	6.73 – 12.96
Post 2 hr	8.29 – 25.99	9.23 – 32.46	7.40 – 16.60

The Vertical and Horizontal moisture distribution are plotted for grids 1 through 49 for all combinations of 4 depths and 6 Time durations. The Vertical Distribution of Moisture Content at 15 cm, 40 cm, 60 cm and 90 cm Depth for Different Time Durations for 1 - 7 Grids is given in Fig. 2 and the same for Grids 1 to 7 and also 8 to 49 are analyzed and discussed herewith.

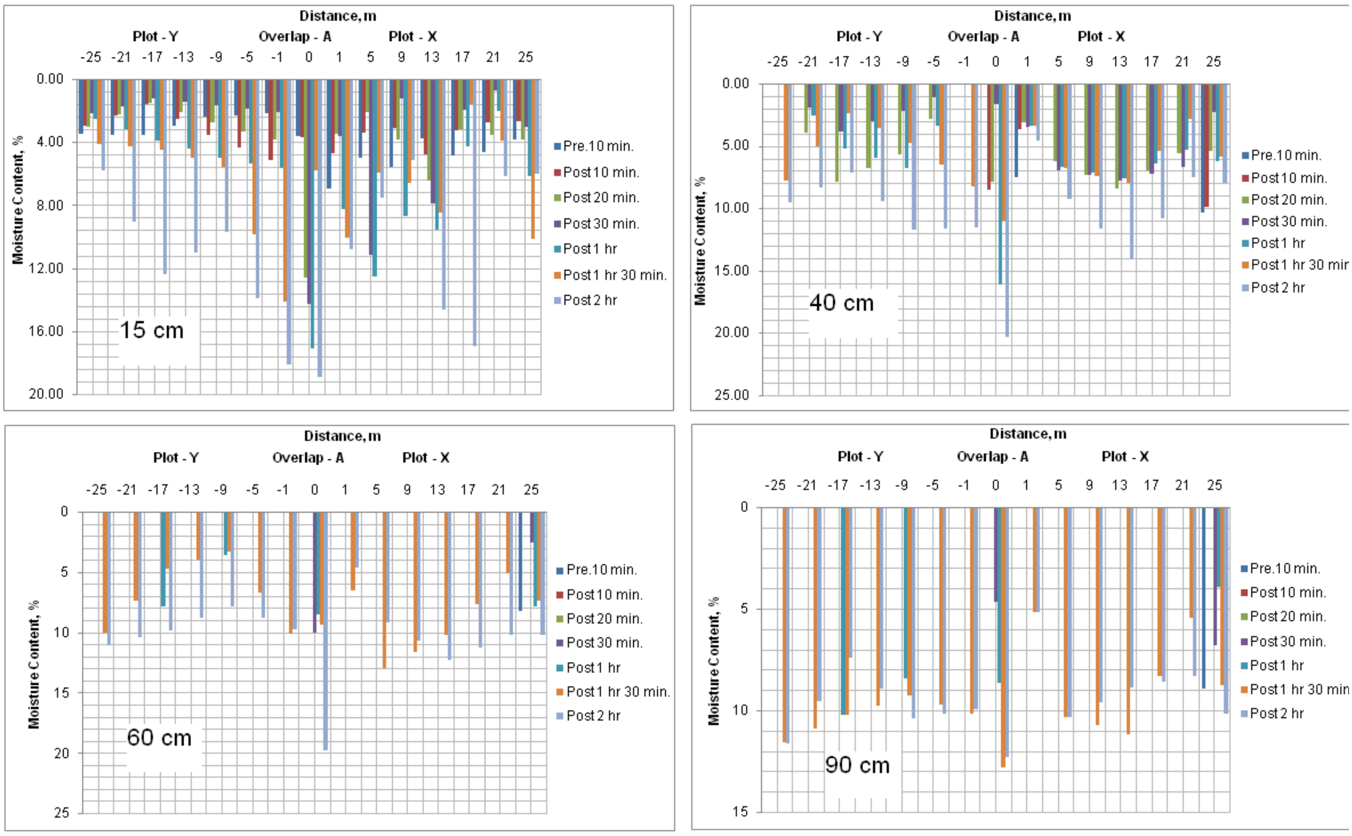

Figure 2 Vertical Distribution of Moisture Content at 15 cm, 40 cm, 60 cm and 90 cm Depth for Different Time Durations for 1 - 7 Grids

Vertical distribution of moisture for 1-7 grids

From fig. 2, one can clearly see that for 15 cm depth, the moisture content for longer time duration, i.e. for 2 hours, is maximum except for 5 m and 9 m distance of plot – X. The overlap-A shows maximum moisture content. Similarly, for 40 cm depth, the 2 hours moisture content is having maximum. The moisture content near the overlap – A and near the sprinklers is maximum compared to the other distances. For 60 cm and 90 cm depth, the moisture content is not observed for the time periods before 1 hour. For all the depths, it is observed that the overlap- A has the maximum moisture content.

Vertical distribution of moisture at 15 cm for 8-14 grids

In plot – X & Y, the moisture content is more than the moisture available after operating the system for 10 min. Then decrease in the moisture content after operating the system for 20 min is observed, then moisture content increase for 30 min., 1 hr, 1 hr 30 min. and 2 hr time duration in plot – X at 1 m and in plot – Y at 9 to 25 m. In plot – Y, at 1 m and 5 m & point B, the moisture content increases after 20 min. In plot – X, for the distance of 13 m, 21 m and 25 m, there is rise in the moisture content after the 30 min time duration.

Vertical distribution of moisture at 40 cm for 8-14 grids

At point B, moisture content increases after 1 hr. In Plot – X, at 5 m, moisture pattern increases after 30 min. At 21 m and 25 m, increase in the moisture pattern after 1 hr time duration is observed. At 17 m, the moisture pattern after 30 min. is found to be decreasing and again increases for 2 hours operation time. In Plot – Y, at distance of 1 m, 5 m, 9 m and 13 m, the moisture pattern increases after the 1 hr time duration. At distance of 17 m, 21 m and 25 m, increase in moisture content is observed after 30 min.

Vertical distribution of moisture at 60 cm for 8-14 grids

In both plots and Point B, the moisture content of 1 hr 30 min. is less than the moisture content of 2 hr except for some time durations.

Vertical distribution of moisture at 90 cm for 8-14 grids

Moisture pattern increases after 1 hr and 1 hr 30 min. but at some distances 2 hr moisture is less than the 1hr 30 min. and the moisture content for 1 hr 30 min. is less than the 1 hr operation time.

Vertical distribution of moisture at 15 cm for 15-21 grids

At point C, there is rise in moisture content with time. In Plot – X and Y, moisture content increases after 1 hr. In Plot – Y, for 9 m & 13 m, moisture content increases with time.

Vertical distribution of moisture at 40 cm for 15-21 grids

At point C, moisture content decreases from 10 min. to 1 hr 30 min. time duration but increases for 2 hr operating time. In Plot – X, at distances of 1 m, 9 m and 13 m, moisture pattern increases after 1 hr time duration. At distance of 5 m, moisture pattern increases after 30 min. time duration. At 17 m and 21 m, moisture content decreases from 30 min. to 1 hr time duration. At 25 m distance, the moisture content increases with time duration. In Plot – Y, at distance of 1 m, 5 m, 9 m, 13 m, 17 m and 21 m, moisture content increases after 20 min. time duration.

Vertical distribution of moisture at 60 cm for 15-21 grids

At point C, 9 m to 25 m in plot – X and in plot - Y moisture content increases after the 1 hr but in plot – Y at 1 m, 9 m, 13 m and 25 m, the moisture content of 1 hr is more than the moisture content of 1 hr 30 min.

Vertical distribution of moisture at 90 cm for 15-21 grids

In both plots and overlap, moisture content increases after 1 hr except for some distances.

Vertical distribution of moisture at 15 cm for 22-28 grids

In Plot – Y, for distance of 21 m & 25 m and at point D, there is increase in moisture pattern for all time durations except for 20 min. and 2 hr. In Plot – Y, at the distance of 1m & 5 m, rise in the moisture content beyond 10 min. up to 2 hr time duration is observed. At distance of 13 m & 17 m, moisture pattern decreases for 1 hr and 2 hr. In Plot – X, for distance of 17 m & 21 m, there is increase in moisture pattern. For distance of 9 m, there is increase in moisture content for all time durations, but for 30 min. & 20 min., moisture content is found to be decreasing.

Vertical distribution of moisture at 40 cm for 22-28 grids

At point D, increase in moisture content with time except for 10 min. is observed. In Plot – X, at 1 m, 5 m, 13 m, 17 m, 21 m and 25 m, moisture pattern increases after the 30 min. operating time. In Plot – Y, at 1 m, 5 m, 9 m and 13 m distance, it is observed as same as in plot-X operation. At 21 m, 17 m and 25 m, moisture pattern is found to be highly varied.

Vertical distribution of moisture at 60 cm for 22-28 grids

At point D, in plot – X and plot – Y, the moisture content increases after 1 hr operation time.

Vertical distribution of moisture at 90 cm for 22-28 grids

In both plots and overlap, the moisture content rises after 1 hr 30 min. time duration and 1 hr time duration but at some distance & at point D moisture content of 1 hr is more than the 1 hr 30 min.

Vertical distribution of moisture at 15 cm for 29-35 grids

In Plot – X at distance of 5 m, 13 m & 17 m the moisture content is found to be in increasing pattern except for 10 min. In Plot – Y, at 1 m distance, rise in moisture content is observed, except for 20 min. At 5 m and 9 m, increase in the moisture pattern is observed up to the 2 hr operating time. At 17 m, 21 m & 25 m, there is increase in moisture content after 30 min. At 13 m, the moisture pattern increases after 20 min.

Vertical distribution of moisture at 40 cm for 29-35 grids

At point E, moisture content decreases from 10 min. to 1 hr and then increases up to 2 hr time. In Plot – X, at 1 m, 5 m, 9 m, 13 m, 17 m, 21 m and 25 m distance, moisture content increases after 30 min., but at 13 m, 17 m and 21 m, the 1 hr moisture content is more than the 1 hr 30 min. moisture content. In both Plots the moisture content of 20 min. is more than the 30 min. time duration.

Vertical distribution of moisture at 15 cm for 36-42 grids

In Plot – Y, at 1 m and 5 m, the moisture content increases except for 10 min. and 2 hr. At 17 m distance, increase in moisture content after the 20 min. is observed. In Plot – X, at 1 m, increase in the moisture content after 10 min. is observed. At 17 m, increase in the moisture pattern with time is observed, but 1 hr moisture content is more than the 1 hr 30 min. moisture content. At 25 m, rise in the moisture content is observed. At point F, the moisture pattern is found to beincreasing.

Vertical distribution of moisture at 40 cm for 36-42 grids

At point F, moisture content increases after 1 hr time duration. In Plot – X, for all distances, the moisture content increases with time durations. In both Plots the moisture content of 20 min. time duration is more than the 30 min. time duration.

Vertical distribution of moisture at 15 cm for 43-49 grids

In Plot – X, at 9 m, 17 m, 21 m and 25 m distance, increase in the moisture content after 30 min. is observed, whereas at 1 m and 5 m distance, increase in the moisture content is observed after 20 min. In Plot – Y, at 1 m and 17 m, increase in the moisture content after 20 min. is observed. At 5 m, 13 m, 21 m and 25 m, the moisture pattern is found to be increasing after 30 min. operating time.

Vertical distribution of moisture at 40 cm for 43-49 grids

In both Plots, the moisture content of 20 min. is more than the 30 min. In Plot – X, at 1 m, 5 m and 13 m distance, the moisture pattern increases with time after 30 min. operating time. At 17 m, 21 m and 25 m distance, there is increase in moisture pattern after 20 min. but, 30 min. moisture content is more than the 1 hr moisture content. At 9 m, the moisture content decreases from 20 min. to 1 hr and thereafter it is found to be increasing with respect to time.

It is observed that the distribution of water near to the sprinkler is more than the distribution of water away from the sprinkler. It is also observed that the moisture content decreases with increase in distance from the sprinkler because the spray nozzle effect is more near to the sprinkler and for the spray nozzle area of spreading is also less compared to the impact nozzle except for the overlapping of two impact nozzles.

Horizontal Distribution of Moisture Content

The Horizontal distribution of moisture content was plotted by considering the difference of pre moisture content and post moisture content for the Plot – X, Plot – Y and Overlap Zone at depths of 15, 40, 60 and 90 cm respectively.

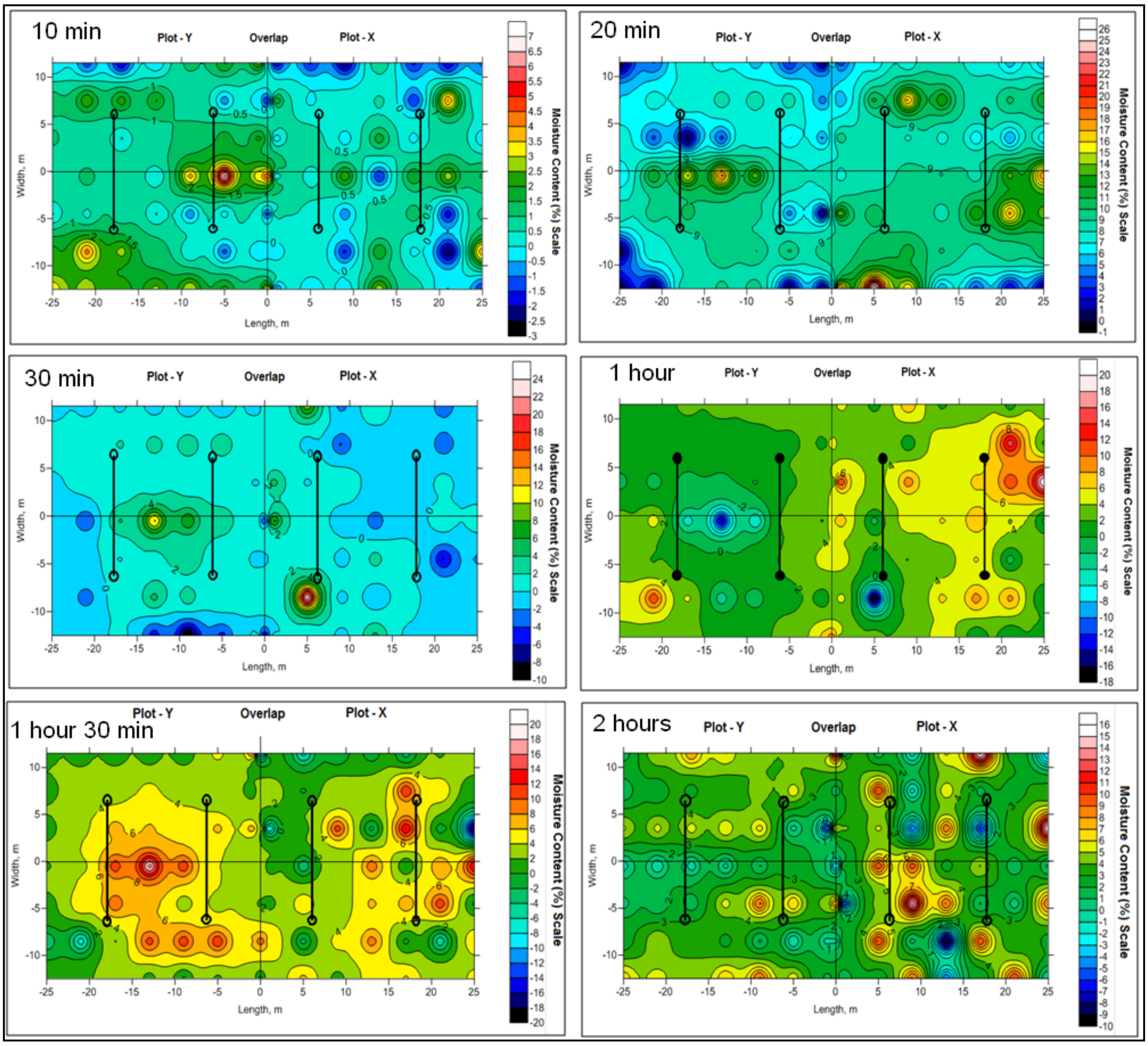

Figure 3 Horizontal Distribution of Moisture Content at 15 cm Depth

From Figure 3, it is clear that the moisture distribution nearer to the sprinklers is more compared to the other areas. Also, the Horizontal distribution is influenced by the time duration of the operation of the sprinklers. Figure 4 represents the horizontal distribution of moisture for 40 cm depth. Beyond 10 min. operating time, increase in moisture content is observed with increase in the time intervals.

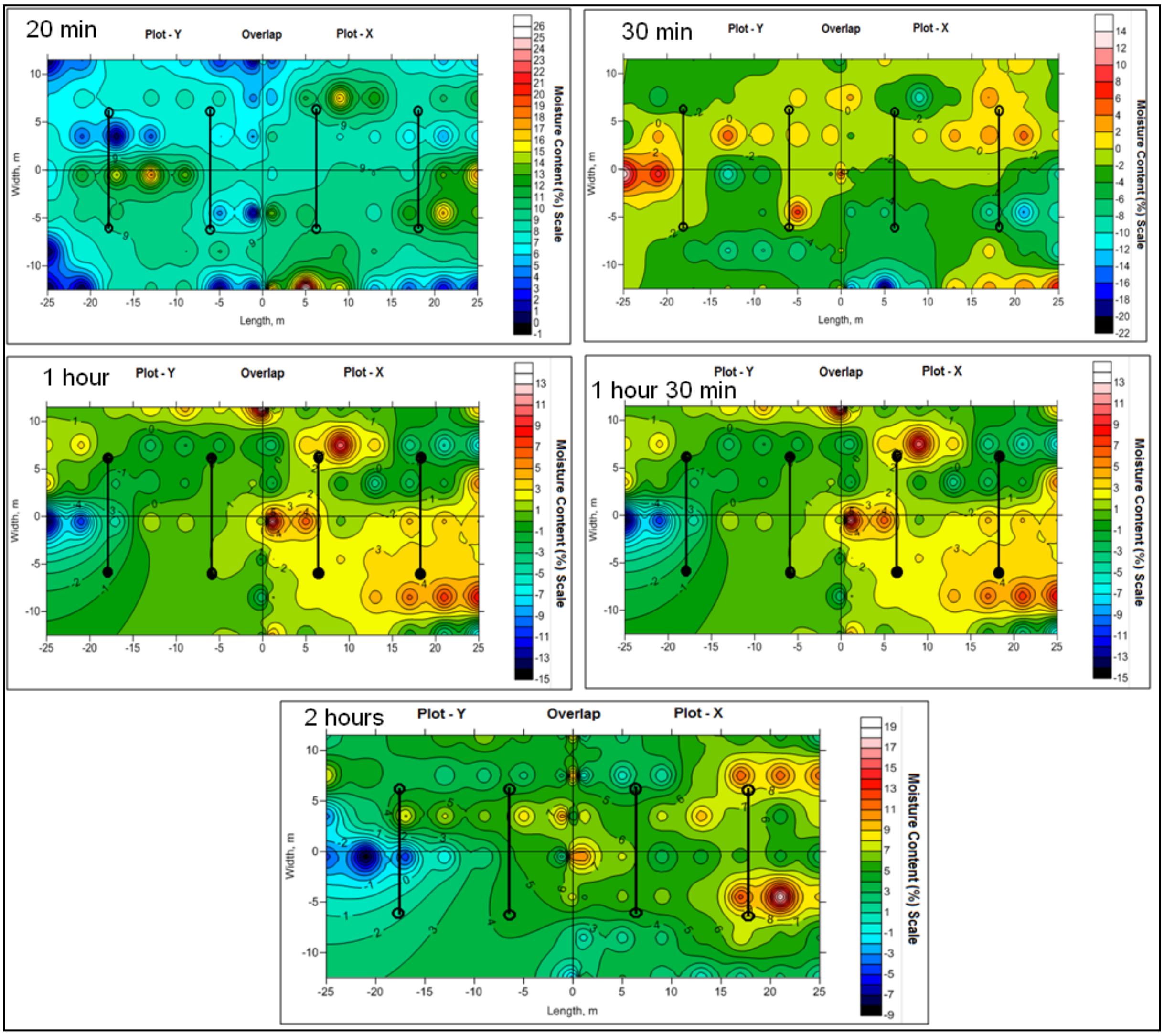

Figure 4 Horizontal Distribution of Moisture Content at 40 cm Depth

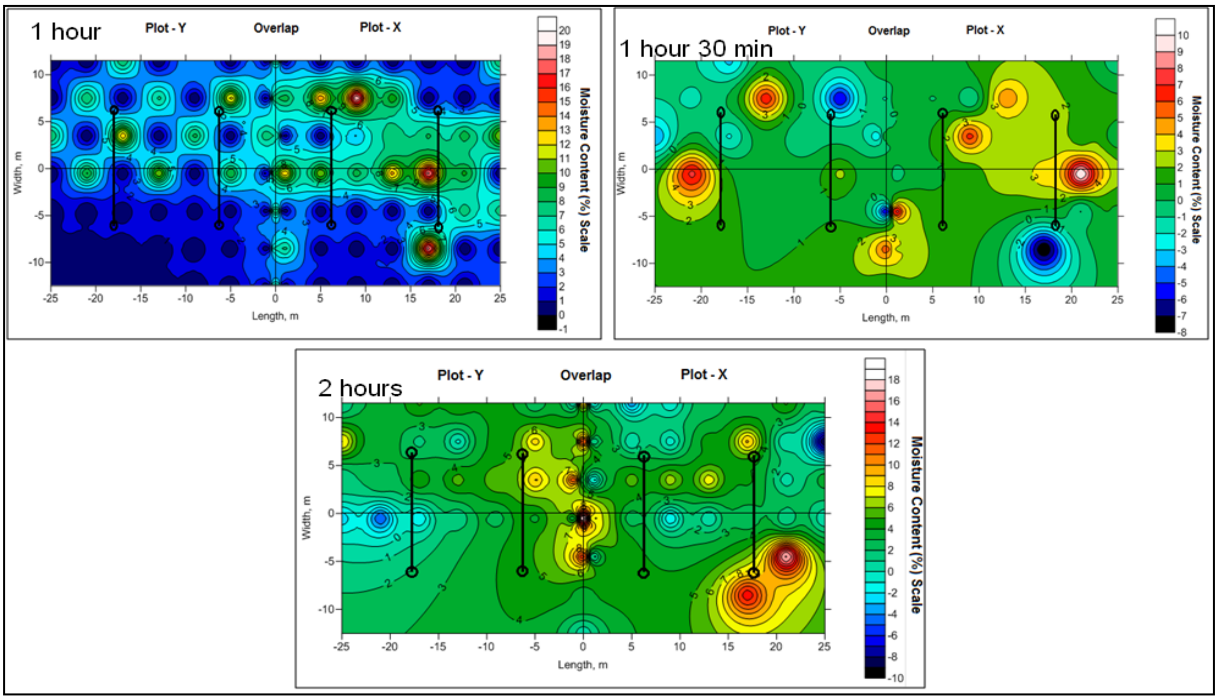

Figure 5 Horizontal Distribution of Moisture Content at 60 cm Depth

Fig. 5 depicts the horizontal distribution of moisture content for 60 cm depth. After 1 hour operation time, the moisture content is observed to be increasing with increase in time intervals. Similar results are observed for 90 cm depth, as shown in Fig. 6.

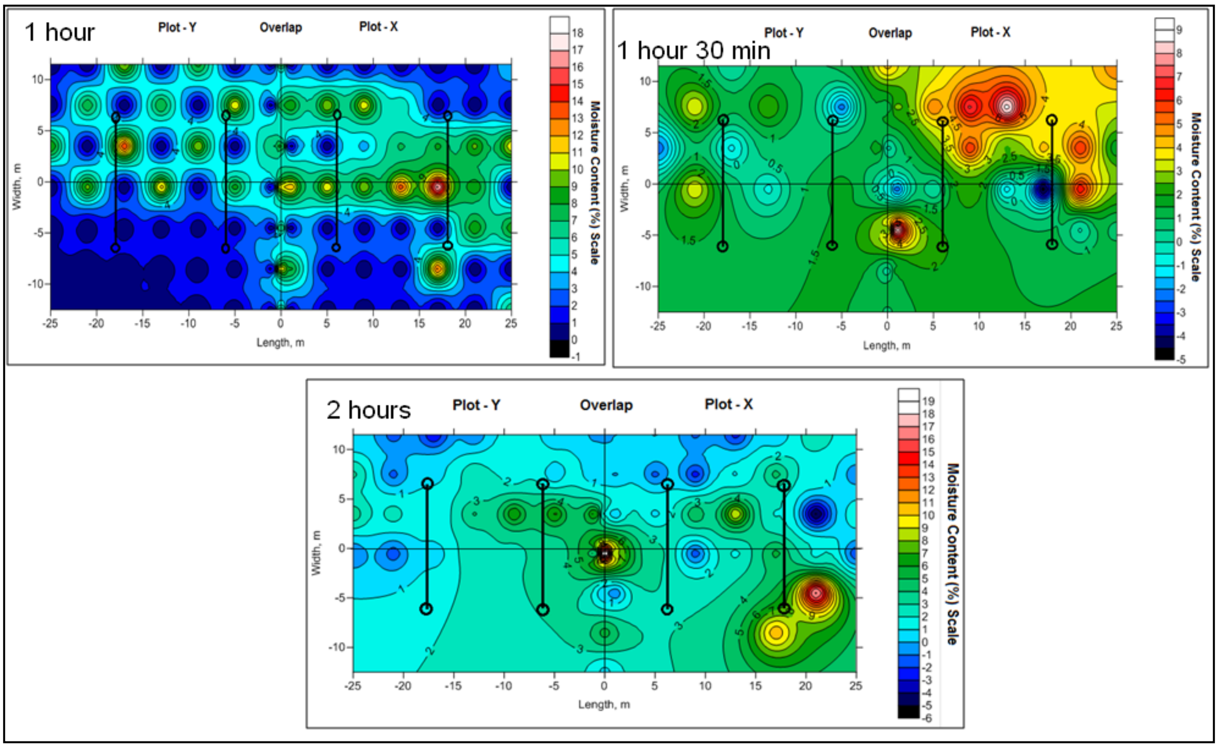

Figure 6 Horizontal Distribution of Moisture Content at 90 cm Depth

5. CONCLUSIONS

For the experimental plot, it is observed that from the horizontal distribution, the moisture content decreases with increase in the distance from the sprinkler because the spray nozzle effect is more nearer to the sprinkler and the spray nozzle area of spreading is also less compared to the impact nozzle. It is also seen that the overlapping zones of two or more sprinklers contains the more moisture content than the other zones.

From the study of vertical distribution, the accumulation of maximum moisture content in the soil profile are found to be 12.94 % for 10 min. duration at depth of 60 cm, 26.30 % for 20 min. duration at depth of 40 cm, 25.70 % for 30 min. duration at depth of 15 cm, 21.43 % for 1 hr duration at depth of 15 cm, 24.02 % for 1 hr 30 min. duration at depth of 15 cm and 27.42 % for 2 hr duration at depth of 40 cm. From this it may be concluded that the maximum soil moisture concentration is found at the upper most layer of the soil.

6. REFERENCES

Ben-Asher, J. and Ayars, J. E. – "Deep Seepage Under Nonuniform Sprinkler Irrigation. i: Theory", Journal of Irrigation and Drainage Engineering, Vol. 116, No. 3, May/June, 1990.

Ben-Asher, J. and Ayars, J. E. – "Deep Seepage Under Nonuniform Sprinkler Irrigation. ii: Field Data", Journal of Irrigation and Drainage Engineering, Vol. 116, No. 3, May/June, 1990.

Bharti, J. P., Pandey, V. K. and Bagde, H. D. – "Moisture Distribution Pattern Under Pressurized Irrigation Systems In Sandy Clay Loam Soil", Journal of Indian Water Resources Society, Vol. 28, No. 1, January, 2008.

Chang, W. and Hills, D. J. – "Sprinkler Droplet Effects on Infiltration. 1: Impact Simulation", Journal of Irrigation and Drainage Engineering, Vol. 119, No. 1, January/February, 1993.

Chang, W. and Hills, D. J. – "Sprinkler Droplet Effects on Infiltration. 2: Laboratory Study", Journal of Irrigation and Drainage Engineering, Vol. 119, No. 1, January/February, 1993.

Dingre, S. – “Computation of Overlapping from Generated Multiple Sprinkler Observation Patterns”, Agricultural Engineering Today, Vol 31(3&4):34-38, 2007.

Firake, N. N., Salunkhe, D.S. and Pampattiwar, P. S. – “Effect of System Variables on Wetted Area of Soil in Micro-Sprinkler Irrigation”, Journal of Indian Water Resources Society, Vol. 12, No. 1&2, January/April, 1992.