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Soil moisture distribution under different lateral and dripper spacing of surface drip irrigation system in clay loam soil

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Abstract

The status, availability and distribution of moisture distribution within a crop's root zone affect the yield and growth of crops. To increase the efficiency of the water use while reducing water losses due to evaporation, the precise distribution of water around the emitters must be known. For this purpose a field experiments were carried out in clay loam soil at the farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), during the successive *rabi* season of 2012-13 and 2013-14 to determine and evaluate the effect of the different lateral and dripper spacing on the soil moisture distribution, distribution pattern and distribution efficiency. To achieve the objectives of this study, a surface drip irrigation system was installed with three lateral spacing i.e. T_1 – 60 cm, T_2 – 80 cm, T_3 – 100 cm and three dripper spacing are S_1 – 30 cm, S_2 – 40 cm and S_3 – 50 cm in three replication under a split plot design. The presented data indicated that the soil moisture distribution and its uniformity within the soil profile under surface drip was to great extent affected by the lateral and drippers spacing. The soil moisture uniformity under dense dripper geometry is better rather than wider. Installing the system at 60 cm lateral with 30 cm dripper spacing is the one to be recommended as it provide a uniform moisture distribution with high water storage efficiency of 85.73 % in the active root zone for most vegetable and cereals crops and leads to better water saving in clay loam soils.

Highlights

- The surface drip irrigation system installed at 60 cm lateral with 30 cm dripper spacing provide a uniform moisture distribution with high water storage efficiency of 85.73 % in the active root zone for most vegetable and cereals crops and leads to better water saving in clay loam soils.

Keywords: Soil moisture, moisture distribution, drip irrigated wheat, water storage efficiency

The sustainability of agricultural production depends on conservation and appropriate use and management of scarce water resources especially in arid and semi-arid areas where irrigation is required for the production of food and cash crops (Chouhan *et al.* 2014). Irrigation system, irrigating amount and timing are the objectives for reducing run off, decreasing percolation of water beneath the root zone and reducing water evaporation after irrigation and maintaining the root zone at field capacity (El-Gindy *et al.* 2001).

Drip irrigation is a recent concept which allows accurate control of water supplied in small quantities directly to the root zone and forming partially wetted soil (Kumar *et al.* 2015). Frequent irrigation helps in maintaining favorable water content near field capacity in the soil for root proliferation within the partially wetted soil volume (Abdallah and Mohamed, 2013). Uniform moisture is an important factor for the growth of microorganisms and in controlling the rate of organic matter decomposition. Although presence of moisture above a certain level is not congenial for plant growth (Das *et al.* 2015). Moreover, matching application rates with crop water requirement ensure efficient water utilization while reducing deep percolation losses of water and nutrients (Souza *et al.* 2009).

Application of uniform and sufficient water to each and every crop plant throughout the growing period is one of the most challenging issues of surface drip irrigation (SDI). Water availability for crop in SDI is depending on water movement from the emitting source to the plant (Douh and Boujelben, 2013). The process is therefore affected by distance from emitting source to plant, evaporation demand and hydraulic conductivity, which dependent on soil texture, structure and antecedent water content (Burt and Styles 1994).

A good understanding of soil water distribution and its patterns has become increasingly important in order to develop modern and environmentally friendly practices involving drip irrigation (Singh *et al.* 2013). In planning and managing of a SDI system, selection of appropriate lateral and dripper spacing is a important aspect (Chouhan *et al.* 2015). The purposes of this study were to determine and evaluate the effect of the different lateral and dripper spacing on the soil moisture distribution, distribution pattern and distribution efficiency. The findings from this research may be useful in selection of appropriate lateral and dripper spacing at which irrigation is best carried out in most vegetable and cereals crop for optimum yield.

Material and Methods

Site Description

Field experiment conducted at the research farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh, India, for two consecutive *rabi* season of years 2012-13 and 2013-14. Research site lies between latitude 23°13′05″N and 79°57′39″E longitude and at an altitude of 411.78 m. The climate of the study area was semi tropical and annual temperature was 25.7°C and average annual rainfall of the area was 1350 mm which is mostly received from south-west monsoon between mid June to end of September with little occasional rainfall of 67.9 mm during other months. The soil of the study area was clay loam soil in texture contain clay 28.7%, silt 23.7% and sand 47.6%. It is low in organic carbon and phosphorus, where as Nitrogen and Potash is at medium level and ph of soil is around normal level of 7.7. The average bulk density of the soil is 2.65 g/cm^3, soil depth is 120 cm. Field capacity is 27% and permanent wilting point is 15%.

Experimental Details

Surface drip irrigation system was installed with three lateral spacing i.e. T_1 – 60 cm, T_2 –80 cm and T_3 – 100 cm with three dripper spacing S_1 – 30 cm, S_2 – 40 cm and S_3 – 50 cm in three replication under a split plot design on the same site.

The crop was irrigated as per crop water requirement in alternate third day through a surface drip irrigation system. The control valve of a particular treatment was opened for a calculated time so that required depth of irrigation will supply to each treatment plot equally.

A overhead tank at height of 13 m was used as a pressurized water source for drip irrigation system. Main line of size 75 mm and submain line of size 50 mm both made of Poly vinyl chloride (PVC) delivered irrigation water through laterals of 16 mm outer diameter made of Linear Low Density Polyethylene (LLDPE) with built-in drippers of discharge of 4 lph with three different dripper spacing (30 cm, 40 cm and 50 cm). After the installation of drip irrigation system, it was tested for design discharge, uniformity of emitters and for clogging problem. All other agronomic practices were adapted as per normal recommendations.

Soil moisture distribution

Soil moisture before and after irrigation were taken periodically from locations 0, 10, 20, 30, 40, 50 cm away from the emitter and at 0, 15, 30, 45 and 60 cm soil depths, to characterize the soil water distribution pattern. Samples were oven dried to determine the moisture content. Soil moisture distribution pattern for all the treatments were recorded and contour map of moisture between two lateral was prepared using *surfer* software and analyzed statistically.

Water storage efficiency

The concept of water storage efficiency gives an insight as to how completely the required water has been stored in the crop root zone during irrigation. It is the ratio of water stored in the root zone during irrigation to water needed in the root zone priors to irrigation (field capacity- available moisture).

Where,

E_s Is water storage efficiency

W_s water stored in the root zone during irrigation

W_n water needed in the root zone priors to irrigation

Statically analysis

Results were analyzed statistically as per the procedure prescribed for split plot design by method of analysis of variance (ANOVA). F-Tests were considered significant at the 0.05 level of probability and Fisher's protected least significant difference (LSD) was used to compare treatment means for significant ($p \leq 0.05$) effects.

Results and Discussion

The data obtained from this study will be presented and discussed as fallows:

Soil moisture distribution

It is important to wet a relatively large part of the potential root system and have a large enough volume of moisture soil to promote root initiative and water uptake. To study how much water that soil maintains in root zone post irrigation, the soil moisture content was measured within soil depth and around the dripper 6 hours after irrigation experiment started.

Table 1. Statistical parameters of soil moisture content

Parameters	Treatment								
	$T_1 S_1$	$T_1 S_2$	$T_1 S_3$	$T_2 S_1$	$T_2 S_2$	$T_2 S_3$	$T_3 S_1$	$T_3 S_2$	$T_3 S_3$
Max. Moisture content (%)	26.34	24.31	23.8	26.0	25.08	25.0	26.30	26.24	26.47
Min. Moisture content (%)	17.85	17.5	17.2	15.68	15.10	14.2	13.08	12.17	12.08
Mean	21.14	21.0	20.83	19.21	18.74	18.16	19.20	18.24	17.85
Median	21.3	21.12	21.1	18.70	17.31	18.04	18.85	17.63	17.23
Standard Error	0.286	.299	0.28	0.354	0.30	0.36	0.352	0.455	0.41
Standard Deviation	1.69	1.77	1.65	2.62	2.26	2.67	2.61	3.37	3.06
Coff. of Variance	0.08	0.08	0.07	0.14	0.11	0.14	0.13	0.18	0.16
Kurtosis	2..90	1.90	2.45	2.93	2.62	2.34	4.34	3.51	3.16
Skewness	0.58	-0.10	-0.31	0.91	0.717	0.27	0.17	0.71	0.55
Water storage efficiency (%)	85.73	84.06	81.98	81.67	80.02	77.95	77.84	76.17	74.09

The statistical parameters in Table 1 indicated soil moisture distribution pattern varied with the different lateral and dripper spacing, although the same amount of irrigation was applied in each plot. The mean and median of soil moisture content in 0-60 cm depth of soil gradually decreases with increase of both lateral spacing and dripper spacing and recorded highest mean value of 21.14% in T_1S_1 and lowest 17.85% in T_3S_3. The maximum (26.47%) and minimum (12.08%) value of moisture content was recorded in T_3S_3 indicated high moisture variation whereas low moisture variation (5.6%) is recorded in T_1S_3. The soil moisture content under 60 cm lateral spacing with all three dripper spacing was more uniform in comparison with 80 cm and 100 cm lateral spacing because dense dripper geometry allow uniform soil moisture distribution, minimize the evaporative loss.

The low value of coefficient of variance, in 60 cm lateral spacing with combination of all three dripper spacing i.e. 0.08, 0.08, and 0.07 in T_1S_1, T_1S_2 and T_1S_3 respectively as compared to 80 cm and 100 cm lateral spacing, indicate that moisture variation is more homogeneous in 60 cm lateral spacing. Whereas, moisture variation in 80 cm lateral spacing is more homogeneous as compared to 100 cm lateral spacing but more variable as compared to 60 cm lateral spacing. Similarly, the standard deviation followed the same trend.

The kurtosis of the 100 cm lateral spacing with all three dripper spacing i.e. T_3S_1, T_3S_2 and T_3S_3 was recorded more than three (4.34, 3.51 and 3.16 respectively) indicate that the moisture distribution curve is *lepokurtic*. It means that curve follow normal distribution but have high peak or in other words moisture just below the lateral is much higher as compared to moisture content of both side of lateral. In other combination of different lateral and dripper spacing, the value of kurtosis was less than three indicate that moisture distribution curve is *platykutic* and variation is low.

It was also observed from Table 1 that the value of skewness in all lateral spacing and dripper spacing is between ±3 indicate that moisture distribution is evenly distributed to both side of lateral (i.e. towards left and right side of lateral). The contour maps for different treatments are plotted using *surfer's* universal point kriging technique to assess the spatiotemporal distribution of soil moisture and shown in Figure 1 to Figure 9.

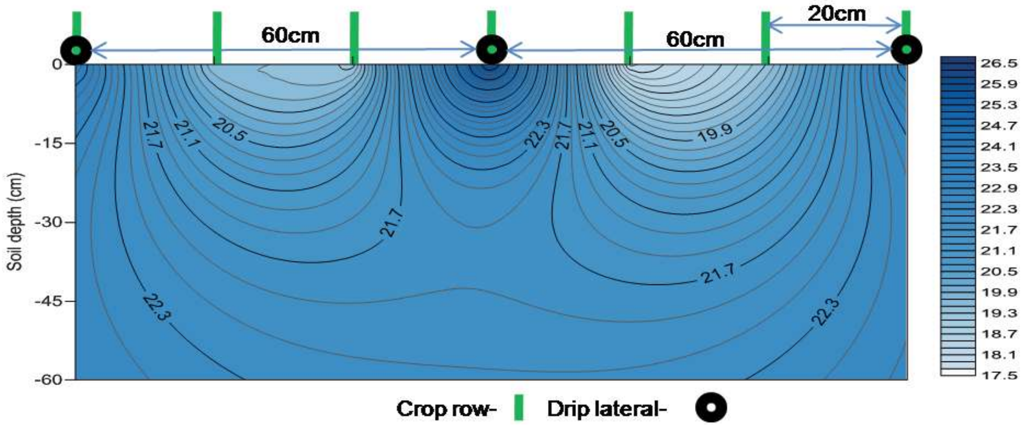

Fig. 1. Soil moisture contour map for T_1S_1 treatment

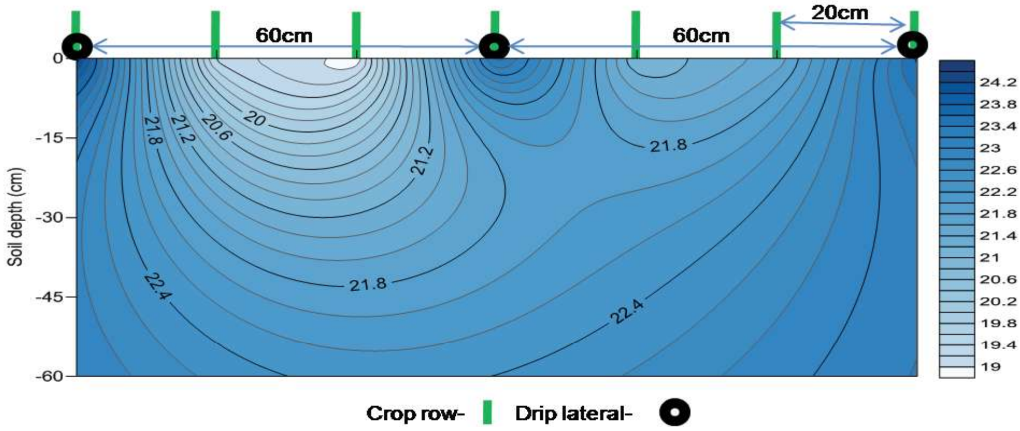

Fig. 2. Soil moisture contour map for T_1S_2 treatment

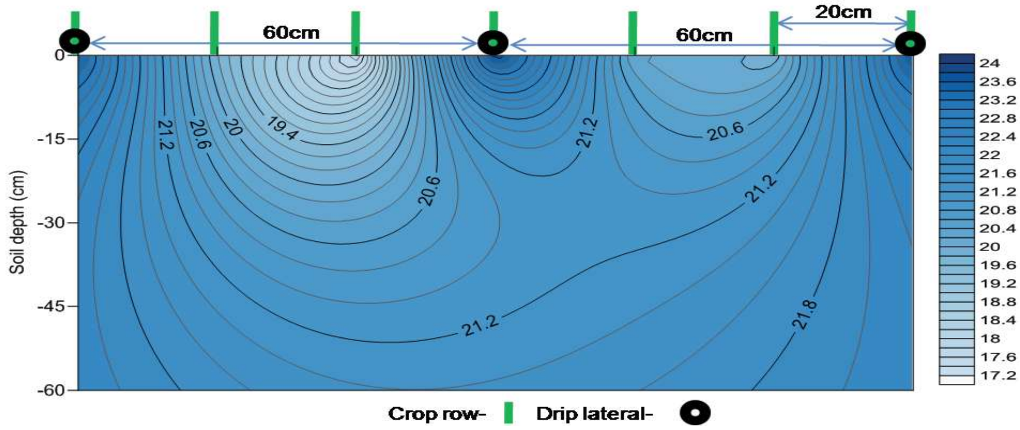

Fig. 3. Soil moisture contour map for T_1S_3 treatment

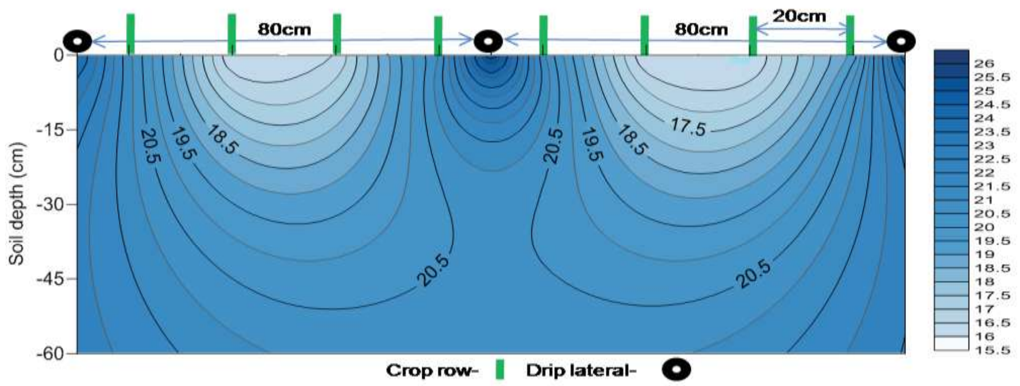

Fig. 4. Soil moisture contour map for T_2S_1 treatment

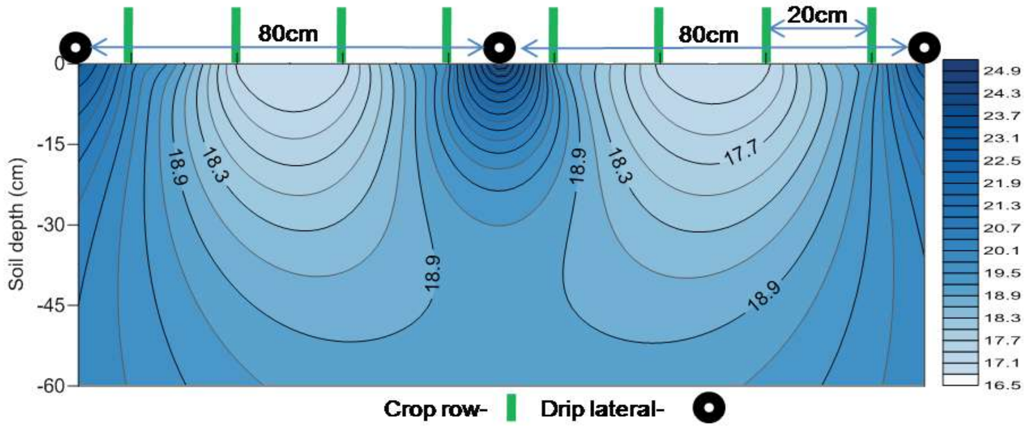

Fig. 5 Soil moisture contour map for T_2S_2 treatment

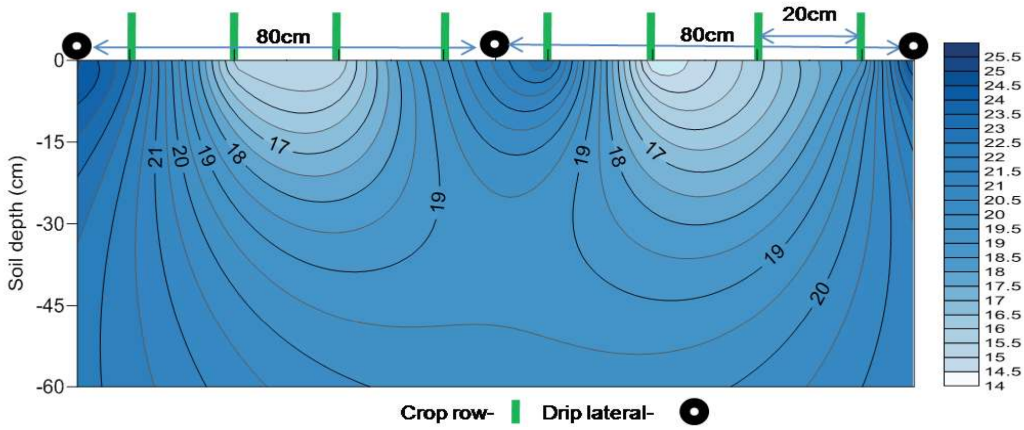

Fig. 6. Soil moisture contour map for T_2S_3 treatment

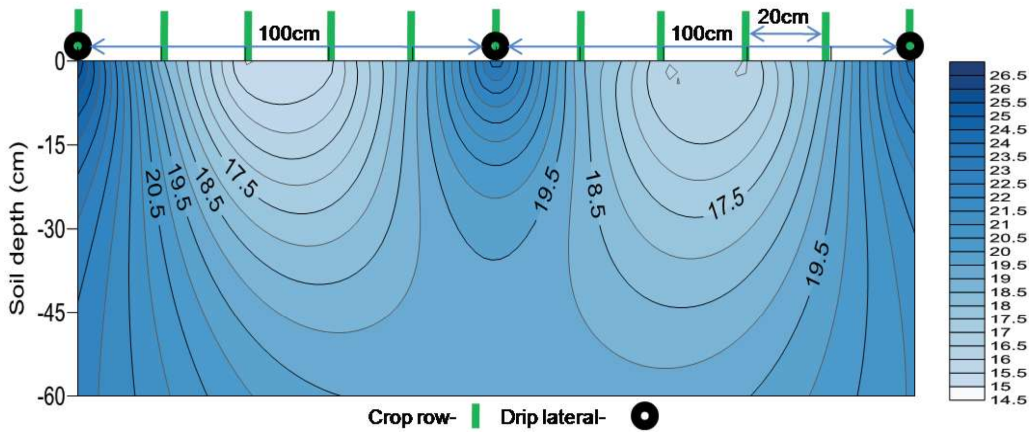

Fig. 7. Soil moisture contour map for T_3S_1 treatment

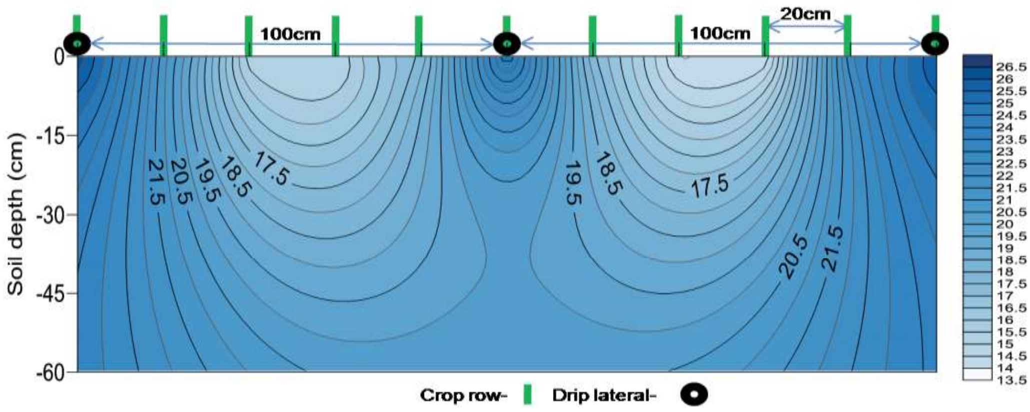

Fig. 8. Soil moisture contour map for T_3S_2 treatment

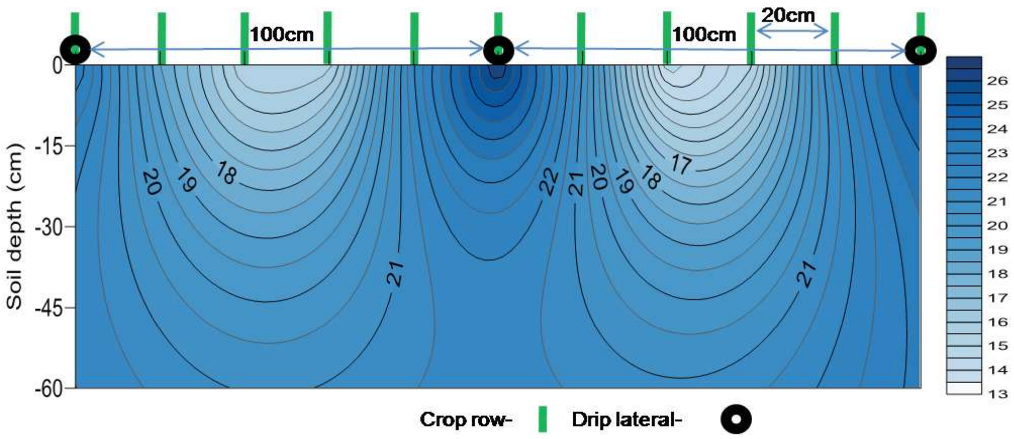

Fig. 9. Soil moisture contour map for T_3S_3 treatment

Water storage efficiency

Different lateral spacing and dripper spacing showed significant effect on water storage efficiency (Figure 10). 60 cm lateral spacing recorded significantly higher water storage efficiency as compared to 80 cm and 100 cm lateral spacing. 80 cm lateral spacing also recorded significantly higher water storage efficiency as compared to 100 cm lateral spacing. This may be due to uniform coverage of moisture in whole cropped area under closer lateral spacing as compare to wider lateral spacing. Among all dripper spacing, 30 cm dripper spacing recorded significantly higher water storage efficiency as compared to 40 cm dripper spacing and 50 cm dripper spacing. Further, 40 cm dripper spacing also recorded significantly higher water storage efficiency as compared to 50 cm dripper spacing which may justified by the explanation given above.

The data pertaining to second order interaction (Table 1) clearly indicated that water storage efficiency decreases with increase in lateral and dripper spacing. It found maximum (85.73 %) under 60 cm lateral spacing with 30 cm dripper spacing (T_1S_1) among all combination of treatments and found minimum (74.09 %) under 100 cm lateral spacing with 50 cm dripper spacing i.e. T_3S_3.

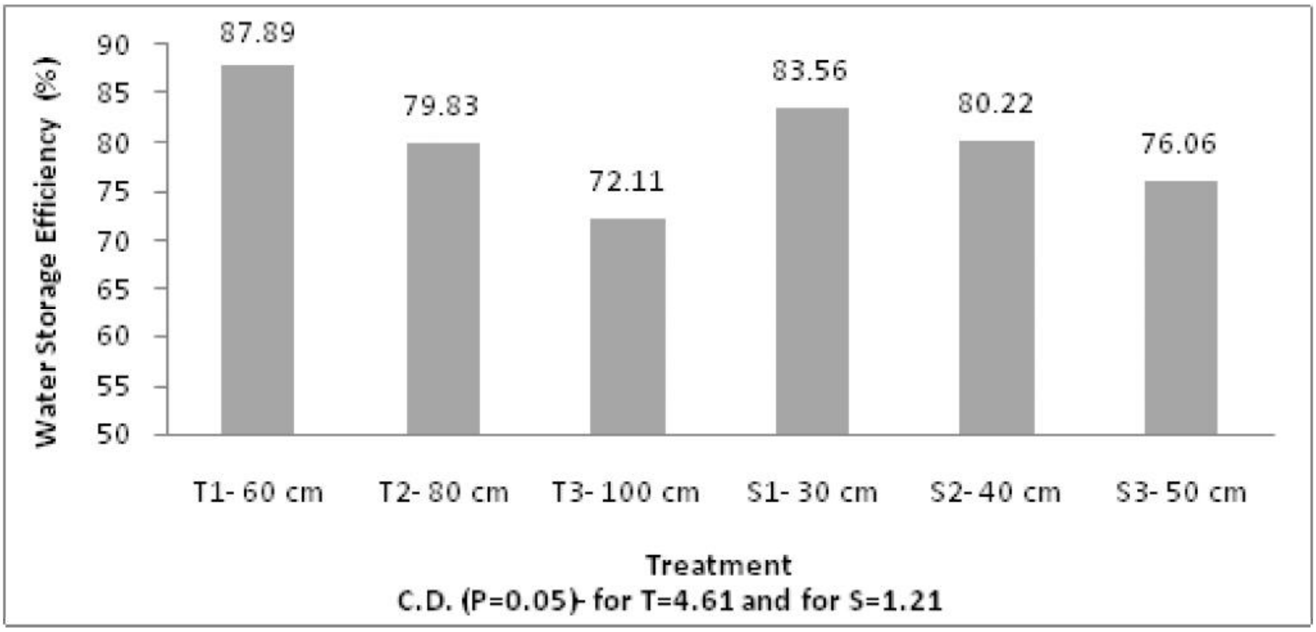

Fig. 10. Effect of different lateral and dripper spacing on water storage efficiency

Conclusion

The presented data indicated that the soil moisture distribution and its uniformity within the soil profile under surface drip was to great extent affected by the lateral and drippers spacing. The soil moisture uniformity under dense dripper geometry is bet er rather than wider. Installing the system at 60 cm lateral with 30 cm dripper spacing is the one to be recommended as it provide a uniform moisture distribution with high water storage efficiency of 85.73 % in the active root zone for most vegetable and cereals crops and leads to bet er water saving in clay loam soils.

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