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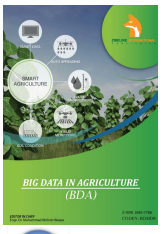


RESEARCH ARTICLE

# DRIP LATERAL PLACEMENT RESPONSE ON WETTING PATTERN AND WATER AVAILABILITY IN RAISED BED

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**ABSTRACT**

Adoption of high efficiency irrigation system for water management is the key component to ensure the food security in the world. The research was carried out at the experimental area of Water Management Research Center (WMRC) located at Post-Graduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad. The drip irrigation system was installed on an area of about 5 hectares to evaluate uniformity of water application and wetting pattern of 60cm wide bed through three different treatments (T-1, T-II and T-III) Surface, Channel and Subsurface placement of drip laterals. Soil moisture content was recorded at start, middle and end of 67m long bed. Results shows that placement of drip in the channel gave better response of moisture content distribution than that the buried one and when placed openly on the bed. All three drip pipe placements (T1, T2, T3) differ significantly for location, positions, depths and their different interaction within the variables reported. Although, it was tried to put lateral in the center but analysis indicate that it was significant in case of open placed drip pipe whereas it was non-significant in the case of buried pipes or placed in channel. It is also important to mention that pipe placed in the channel was easy to handle, replace and to fold back than the buried one.

**KEYWORDS**

Drip Irrigation, Lateral Placement, Raised Bed, Moister Distribution and Availability.

## 1. INTRODUCTION

The Indus plains of the Pakistan are situated in arid and semi-arid climate where monsoon rains are erratic and mostly fall in the months of July and August, which are quite insufficient to grow even a single crop without artificial irrigation. To make the agriculture a success under the ambient agro-environment, a network of gravity flow surface irrigation canals is handling 129 BCM water and about 60 BCM groundwater from 0.750 million tube wells. The estimated losses from the network are 90 BCM from canals to field and 15 BCM within the field due to low application irrigation efficiency. In Pakistan, out of 20.90 million hectors of cultivable land, about 15.76 million hectors is under irrigation. Under the increase of population pressure, agriculture intensity has increasing trend with already limited resources of water. In order to coop with this situation, it is imperative to make use of available water resources efficiently.

A group researchers conducted a study on using of subsurface drip irrigation for alfalfa (Alam et al., 2002). The treatments included drip tape spacing of 60, 40, and 30 inches placed at depths of 18 and 12 inches. Seedling emergence and yield were adversely affected at 60 inches spacing, while the depth of placement of drip tapes (18 and 12 inches) showed no effect on yield. A group scientist conducted a study on micro-irrigation: for the analysis of soil wetting and solute transport in subsurface trickle irrigation (Cote et al., 2003). The results demonstrate the need to account for differences in soil hydraulic properties and solute transport when designing irrigation and fertigation management strategies. A studied micro-irrigation advances in system design and management subsurface drip irrigation for corn production: a review of 10 years of research in Kansas (Lamm and Todd, 2003). Irrigation water use for corn could be reduced by 35–55% when using SDI compared with more traditional forms of irrigation.

A drip line spacing of 1.5 m was found to be the most economical for corn grown in 0.76 m spaced rows. A group researchers conducted a study on tomato root distribution, yield and fruit quality under subsurface drip irrigation for a 2year field trial with subsurface drip irrigation at 20 cm (RI) and 40 cm (RII) depths (Rui et al., 2003). It was conducted that commercial yields were 87.6 and 114.2 (R0), 107.5 and 128.1 (RI), 105.0 and 124.8 (RII), for 1997 and 1998, respectively. Although no significant differences were found among treatments, slightly higher values were observed with irrigation tubes at 20 cm depth. A study conducted using SDI and a range of time thresholds with cotton for the purpose of estimating the time threshold values that best match the range of available water supplies produced from irrigation wells (Wanjiru et al., 2003). Irrigation applied was 15.7, 12.3, and 7.9 inches for 2.5 hr, 5.5 hr, and 7.5 hr time thresholds, respectively. The 5.5 hr time threshold produced the most optimum water level of the three-time thresholds by producing 98 % of maximum yield with 21 % less irrigation.

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A studied yield responses for over 30 crops were included, either in comparisons between subsurface drip and other types of irrigation or in comparisons of lateral depth, lateral spacing, or irrigation management methods (Camp, 1998). In most cases, crop yield was greater than or equal to that for other irrigation methods, including surface drip, and required less water in many cases. A study conducted a field experiment for three years (2009-2011) to evaluate the response of cucumber (Cucumis sativus L.) under 0 (surface) (D00), 5(D05), 10 (D10) and 15 (D15) cm depth of lateral placement (Mali et al., 2016). Soil moisture content in root zone, germination percentage, vine length and yield per plot were recorded and irrigation water use efficiency (IWUE) was estimated. It was observed that soil moisture content was higher and moisture profile was more uniform under SDI. Shallower depths of lateral, D00 and D05, resulted in higher seed germination percentage (92.8 and 90.2 %). Increased moisture and nutrient availability under D10 and D15 resulted in higher vine length (2.49 and 2.36m).

Some researchers conducted an experiment was conducted on potato (var. Kufri Anand) for 3 years (2002–2005) to study the effect of depth of placement of drip tape and different levels of irrigation application on potato yield (Patel and Rajput, 2007). Three different irrigation levels of 60, 80 and 100% of the crop evapotranspiration and five depths of placement of drip tape namely, 0.0, 5.0, 10.0, 15.0 and 20.0 cm were maintained in the study. Maximum yield was obtained by applying the 100% of the crop evapotranspiration (23.6 cm of irrigation water) and by placing the drip tape at 10.0 cm depth in the sandy loam soil**.** In other hand, some researchers conducted a study on evaluation of no-tillage crop production with subsurface drip irrigation on soils with compacted layers Subsurface drip irrigation offers many advantages for management of water and nutrients (Camp et al., 1999). From the results, it appeared that strategies were developed to reduce soil strength to obtain optimum no-tillage crop production with subsurface drip irrigation on these soils. This study was conducted to find out wetting pattern, water distribution and moister availability in a 60 cm wide bed.

## 2. Material and Methods

### 2.1 Drip Irrigation System

The research was carried out at the experimental area of Water Management Research Center (WMRC) located at Post-Graduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad. The soil of the study area is sandy loam with average hydraulic conductivity 25mm/hr. The drip irrigation system was installed on an area of about 5 hectors (12 acres).

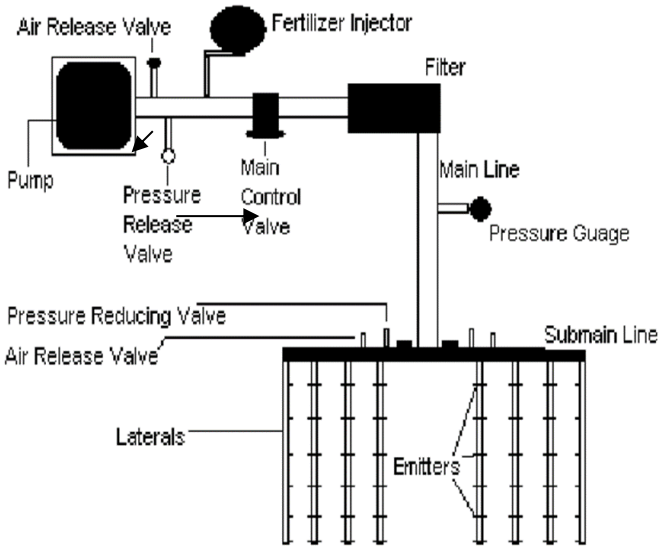


**Figure 1:** Components of the drip irrigation system

### 2.2 Area to be irrigated

$$Pf = \frac{L_L \times L \times N_L}{K \times A_f} = 2.28\%$$

Where, $L_L$ (spacing between laterals) = 3ft, L (Length of lateral) =220 ft, $N_L$ (Numbers of laterals) =18, Af (Total area) = 12 Acres, K (Constant) = 435.6

### 2.3 Time of operation

$$H = \frac{0.24 \times P_f \times D}{DDIR} = 5.47 \text{ hrs}$$

Where, D (Desire depth of irrigation) = 2inches, DDIR (Design daily irrigation requirement) = 0.20 inches/day,

### 2.4 Depth to be applied

$$D_a = \frac{H \times DDIR}{0.24 \times P_f} = 1.46 \approx 1.5 \text{ inches (4cm)}$$

### 2.5 Discharge for the system

$$Q = \frac{D_a \times L \times S}{H \times E_i} = 7.64 \text{ ft}^3\text{/h} = 11 \text{ m}^3\text{/h}$$

S (Spacing between emitters on the laterals) = 1 ft

In the market size of pump available was 8 $m^3$/ h, so that pump was used. These equations were taken from (Principle of Farm Irrigation System Design, 1988).

### 2.6 System Components

The total head required for the system is 33 m so 37 m head of pump was selected. Primary Filter which consisted of internal and external filter was used. The diameter of Internal Filter was 20cm and the mesh No. was 120. A fertilizer/chemical injector tank of 75cm diameter and 135cm length was mounted on the mobile trolley. Three pressure gauges were used in this system one gauge was installed on delivery pipe, second gauge after secondary filter and third gauge at the end of the lateral. The backflow valve, pressure regulator valve and block valves were installed also. Main line of 7.62cm diameter and 107m length, sub-mains of 5cm diameter and 15.24m length with 18 laterals and seven risers were mounted on main line at a spacing of 15.24m. The emitter used in this system was built in type emitter, with discharge capacity of 2 lph.

### 2.7 Installation of the Field Unit

The bed length and width were 67m and 60cm respectively with 23cm furrow width.

The following treatments were used in the field.

- $T_1$. Bed with open drip pipe
- $T_2$. Bed with channel (7 × 5cm) drip pipe
- $T_3$. Bed with buried drip pipe (at a depth of 5cm)

The laterals were placed in the center of the beds. layout of the field is given in the fig. 3.8

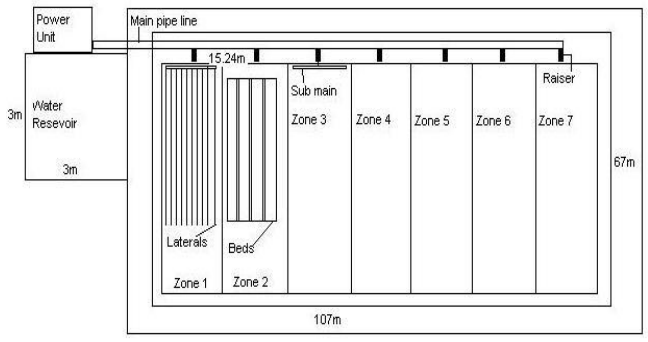


**Figure 2:** Layout of the Field Unit

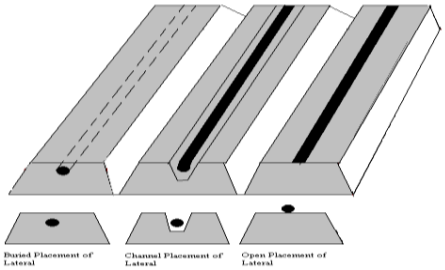


**Figure 3:** Different Placements of the Laterals on the Beds.

### 2.8 Determination of the soil moisture content percentage

The soil moisture content was determined by gravimetric method. The bed width was 60cm and sampling was done at 3cm, 30cm and 57cm depth, right, center and left respectively. The first sampling was done before and after 48 hours of 1st irrigation, second sampling was done before and after 48 hours of 2nd irrigation. To determine water distribution uniformity and water availability, sampling was done at the three different locations of the beds i.e. head, middle, and tail, 10, 110 and 210 feet respectively. The sampling locations on the bed are given in the figure.

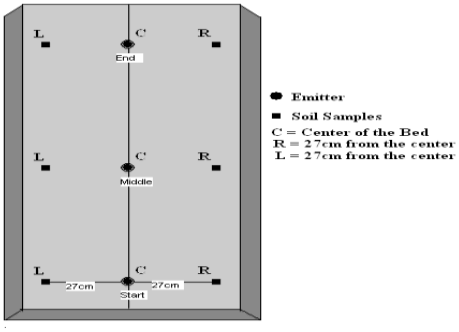


**Figure 4:** Location of the Sampling on the Bed

## 3. Result and Discussion

### 3.1 Soil Moisture Content of Bed with Openly Placed Drip Lateral (Treatment-I)

#### *3.1.1 Difference in moisture content before and after 48 hours of 1st irrigation*

The moisture content increase in the start of bed ranged from 6.52 to 7.22%. On the average there was an increase of 6.82% in moisture content in the start. Similarly, the moisture content increase at the middle of the bed ranged from 6.11 to 6.85%, whereas, the average increase in moisture content was 6.56%. The increase in moisture content at the end of bed ranged from 5.59 to 6.55%, with on average moisture content of 6.23%.

**Table 1:** Difference in moisture content before and after 1st irrigation with drip pipe placed on the bed.

| Location | | Moisture content (%) (before irrigation) | Moisture content (%) (after irrigation) | Difference (%) |
|---|---|---|---|---|
| **Start** | Right | 12.49 | 19.00 | 6.52 |
| | Center | 12.43 | 19.64 | 7.22 |
| | Left | 11.82 | 18.53 | 6.71 |
| **Average** | | | | **6.82** |
| **Middle** | Right | 12.33 | 18.44 | 6.11 |
| | Center | 12.22 | 18.94 | 6.72 |
| | Left | 11.48 | 18.33 | 6.85 |
| **Average** | | | | **6.56** |
| **End** | Right | 12.30 | 18.26 | 5.96 |
| | Center | 12.41 | 18.96 | 6.55 |
| | Left | 12.10 | 18.29 | 6.18 |
| **Average** | | | | **6.23** |

These results revealed that there was higher moisture content in the start of bed, which decreased with respect to length of the bed probably due to discharge variation at the beginning and end of the drip pipe. Results further showed that there was little higher variation in moisture content distribution at the tail end of the lateral than at the start of the lateral. The increase in moisture contents percentage in the bed in first 45cm depth with respect to the location of bed have been shown in Figure 5.

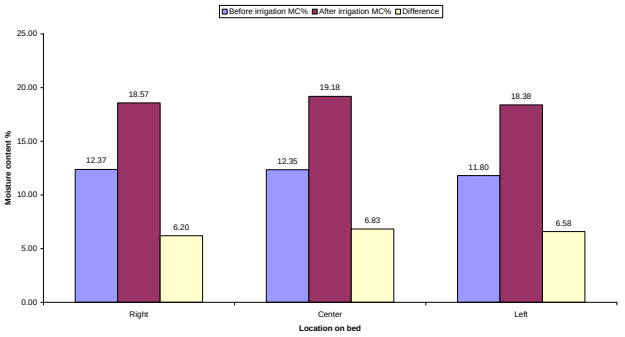


**Figure 5:** Distribution of moisture content (%) in the bed irrigated with drip pipe placed on the bed

The figure shows that there was little higher moisture content in the center of the bed than the right and left of the bed. However, the left side of the bed showed higher moisture content than the right side of the bed. Although, effort was made to put the lateral in the center of the bed, however, this moisture content difference could be due to the placement of the lateral or orientation of the inbuilt emitters of the lateral pipe. Moreover, the higher moisture content in the center was due to the placement of lateral and high infiltration rate of the sandy loam soil.

#### *3.1.2 Difference in moisture content before and after 48 hours of 2nd irrigation*

The moisture content increase in the start of bed were from 4.28 to 5.04% after irrigation there was an average increase of 4.60% in moisture content in the start. Similarly, the moisture content increase at the middle of the bed ranged from 4.33 to 4.54%, with the average increase in moisture content of 4.38%. The increase in moisture content at the end of bed ranged from 4.37 to 4.67%, with on average moisture content increase of 6.24%.

**Table 2:** Difference in moisture content before and after 2nd irrigation with drip pipe placed on the bed.

| Location | | Moisture content (%) (before irrigation) | Moisture content (%) (after irrigation) | Difference |
|---|---|---|---|---|
| **Start** | Right | 14.41 | 18.69 | 4.28 |
| | Center | 13.71 | 18.74 | 5.04 |
| | Left | 13.85 | 18.33 | 4.47 |
| **Average** | | | | **4.60** |
| **Middle** | Right | 13.87 | 18.21 | 4.33 |
| | Center | 13.85 | 18.11 | 4.26 |
| | Left | 13.33 | 17.87 | 4.54 |
| **Average** | | | | **4.38** |
| **End** | Right | 13.49 | 18.15 | 4.67 |
| | Center | 13.75 | 18.18 | 4.43 |
| | Left | 13.48 | 17.85 | 4.37 |
| **Average** | | | | **4.49** |

These results revealed that there was higher moisture content in the start of bed. The reason could be same as mentioned earlier in the last section. Results further showed that there was little higher variation in moisture content distribution at the tail end of the lateral than at the start of the lateral. The distribution of the moisture contents percentage within the bed upto a depth of 45cm is given in Figure.

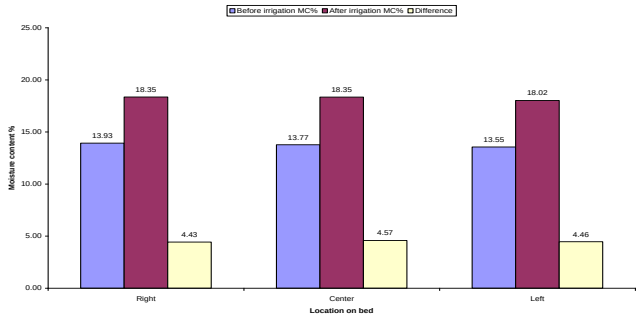


**Figure 6:** Distribution of moisture content (%) in the bed irrigated with drip pipe placed on the bed.

The Figure shows that there was little higher moisture content in the center of the bed than the right and left of the bed. However, the left side of the bed showed higher moisture content than the right side of the bed.

## 3.2 Soil Moisture Content of Bed with Drip Pipe Placed in Channel (Treatment-II)

### *3.2.1 Difference in moisture content before and after 48 hours of 1st irrigation*

The moisture content increase in the start of bed were from 7.57 to 8.79% after irrigation there was an increase of 8.06% in moisture content in the start. Similarly, the moisture content increase at the middle of the bed ranged from 7.21 to 7.72%, with the average increase in moisture content of 7.40%. The increase in moisture content at the end of bed ranged from 6.71 to 7.40%, with on average moisture content of 7.00%.

**Table 3:** Difference in moisture content before and after 48 hours of 1st irrigation with drip pipe placed in a channel.

| Location | | Moisture content (%) (before irrigation) | Moisture content (%) (after irrigation) | Difference |
|---|---|---|---|---|
| **Start** | Right | 11.43 | 19.24 | 7.82 |
| | Center | 11.19 | 19.98 | 8.79 |
| | Left | 11.62 | 19.19 | 7.57 |
| **Average** | | | | **8.06** |
| **Middle** | Right | 11.98 | 19.25 | 7.27 |
| | Center | 12.11 | 19.83 | 7.72 |
| | Left | 12.09 | 19.30 | 7.21 |
| **Average** | | | | **7.40** |
| **End** | Right | 12.00 | 18.71 | 6.71 |
| | Center | 12.70 | 19.59 | 6.89 |
| | Left | 11.43 | 18.83 | 7.40 |
| **Average** | | | | **7.00** |

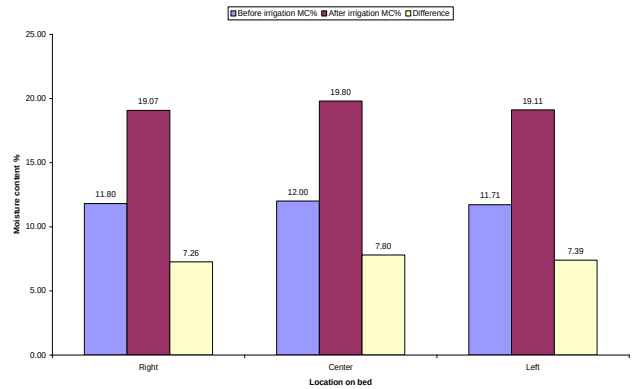


**Figure 6:** Distribution of moisture content (%) in the bed irrigated with drip pipe placed in the channel

The Figure shows that there was little higher moisture content in the center of the bed than the right and left of the bed.

### *3.2.2 Difference in moisture content before and after 48 hours of 2nd irrigation*

The moisture content increase in the start of bed were from 5.17% to 6.34% after irrigation there was an increase of 5.59% in moisture content in the start. Similarly, the moisture content increase at the middle of the bed ranged from 5.30 to 5.59%, with the average increase in moisture content of 5.43%. The increase in moisture content at the end of bed ranged from 5.12 to 5.47%, with on average moisture content of 5.24%.

**Table 4:** Difference in moisture content before and after 2nd irrigation with drip pipe placed in the channel

| Location | | Moisture content (%) (before irrigation) | Moisture content (%) (after irrigation) | Difference |
|---|---|---|---|---|
| **Start** | Right | 14.08 | 19.34 | 5.26 |
| | Center | 13.61 | 19.95 | 6.34 |
| | Left | 14.06 | 19.23 | 5.17 |
| **Average** | | | | **5.59** |
| **Middle** | Right | 13.70 | 19.11 | 5.41 |
| | Center | 14.15 | 19.75 | 5.59 |
| | Left | 13.75 | 19.05 | 5.30 |
| **Average** | | | | **5.43** |
| **End** | Right | 13.69 | 18.82 | 5.12 |
| | Center | 14.24 | 19.71 | 5.47 |
| | Left | 13.76 | 18.91 | 5.14 |
| **Average** | | | | **5.24** |

These results revealed that there was higher moisture content in the start of bed. The reason could be same as mentioned earlier in the last section. Results further showed that there was little higher variation in moisture content distribution at the tail end of the lateral than at the start of the lateral.

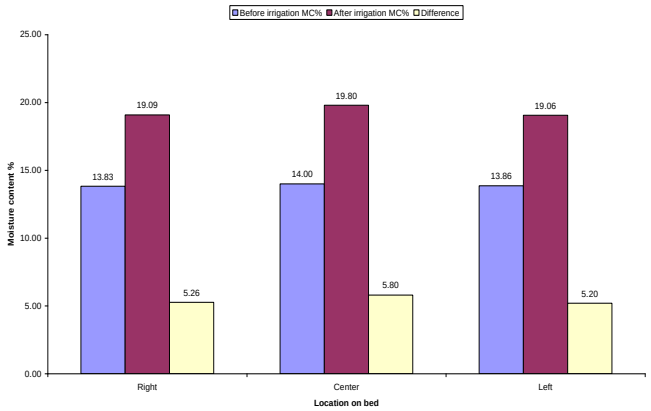


**Figure 7:** Distribution of moisture content (%) in the bed irrigated before and after 2nd irrigation with drip pipe placed in the channel

There was little higher moisture content in the center of the bed than the right and left of the bed. The left side showed lower moisture content than the right side of bed.

## 3.3 Soil Moisture Content of the Bed with Buried Placement of Drip (Treatment-III)

### *3.3.1 Difference in Soil Moisture Content before and after 48 hours of 1st Irrigation*

The moisture content increase in the start of bed were from 7.35 to 8.32% after irrigation with an average increase of 7.73% in the start. Similarly, the moisture content increase at the middle of the bed ranged from 7.21 to 7.49%, with the average increase in moisture content of 7.38%. The increase in moisture content at the end of bed ranged from 6.74 to 7.0%, with on average moisture content of 6.94%.

| **Table 5:** Difference in moisture content before and after irrigation with buried placement of drip pipe | | | | |
|---|---|---|---|---|
| **Location** | | **Moisture content (%) (before irrigation)** | **Moisture content (%) (after irrigation)** | **Difference** |
| **Start** | Right | 11.70 | 19.04 | 7.35 |
| | Center | 10.96 | 19.28 | 8.32 |
| | Left | 11.43 | 18.97 | 7.53 |
| **Average** | | | | **7.73** |
| **Middle** | Right | 11.36 | 18.80 | 7.44 |
| | Center | 11.68 | 19.16 | 7.49 |
| | Left | 11.60 | 18.81 | 7.21 |
| **Average** | | | | **7.38** |
| **End** | Right | 12.28 | 19.03 | 6.74 |
| | Center | 12.18 | 19.28 | 7.10 |
| | Left | 12.07 | 19.04 | 6.98 |
| **Average** | | | | **6.94** |

These results revealed that there was higher moisture content in the start of bed. The reason could be same as mentioned earlier in the last section. Results further showed that there was little higher variation in moisture content distribution at the tail end of the lateral than at the start of the lateral.

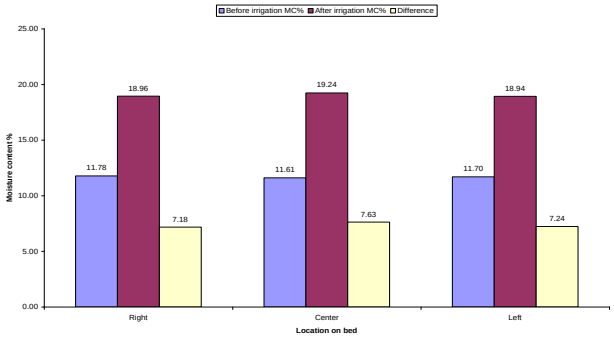


**Figure 8:** Distribution of moisture content (%) in the bed irrigated with buried placement of drip pipe.

The Figure shows that there was little higher moisture content in the center of the bed than the right and left of the bed. The left side of the bed showed higher moisture content than the right side of the bed.

### *3.3.2 Difference in Soil Moisture Content before and after 48 hours of 2nd Irrigation*

The moisture content increase in the start of bed were from 5.09 to 5.19% after 2nd irrigation with an average increase of 5.14%. Similarly, the moisture content increase at the middle of the bed ranged from 4.41 to 5.33%, with the average increase in moisture content of 4.96%. The increase in moisture content at the end of bed ranged from 4.15 to 5.30%, with on average moisture content of 4.62%.

| **Table 6:** Difference in moisture content before and after 2nd irrigation with buried placement of drip pipe. | | | | |
|---|---|---|---|---|
| **Location** | | **Moisture content (%) (before irrigation)** | **Moisture content (%) (after irrigation)** | **Difference** |
| **Start** | Right | 14.24 | 19.39 | 5.14 |
| | Center | 14.66 | 19.85 | 5.19 |
| | Left | 14.23 | 19.32 | 5.09 |
| **Average** | | | | **5.14** |
| **Middle** | Right | 14.62 | 19.03 | 4.41 |
| | Center | 14.50 | 19.64 | 5.14 |
| | Left | 13.78 | 19.11 | 5.33 |
| **Average** | | | | **4.96** |
| **End** | Right | 14.54 | 18.95 | 4.41 |
| | Center | 14.16 | 19.45 | 5.30 |
| | Left | 14.88 | 19.03 | 4.15 |
| **Average** | | | | **4.62** |

These results revealed that there was higher moisture content in the start of bed. Results further showed that there was little higher variation in moisture content distribution at the tail end of the lateral than at the start of the lateral.

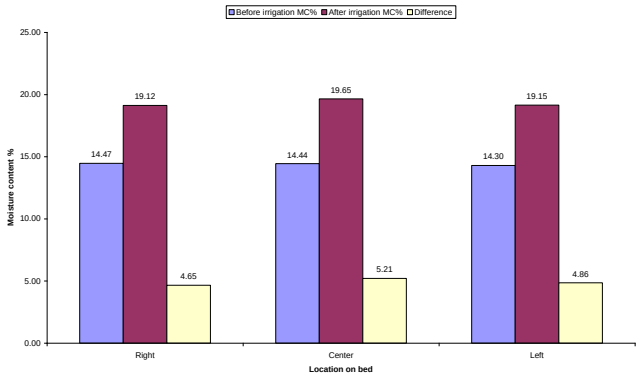


**Figure 9:** Distribution of moisture content (%) in the bed irrigated with buried placement of drip pipe.

The Figure shows that there was little higher moisture content in the center of the bed than the right and left of the bed. The left side of the bed showed lower moisture content than the right side of the bed

### 3.4 Comparison of moisture content distribution in the bed under different placement of drip laterals

As explained earlier in the procedure drip pipe having in-built emitters at 30cm, respectively, were compared for their soil moisture content distribution in the bed. Table 7 shows average moisture content of the bed irrigated with lateral drip with different placements. Result showed that on an average, there was 6.13% moisture content where lateral was buried in the bed. In case where the drip pipe was placed in channel moisture content was 6.45%. The lowest moisture content in the bed was observed where drip pipe placed on the top center of the bed and it was 5.50%. The above-mentioned data shows that highest moisture content was obtained when drip pipe was placed in channel in comparison with drip pipe placed on the surface of the bed or buried in the bed. However, it is important that to report that experiment was conducted during the months of October and November when evaporation is not high as it can be during the summer. These results revealed also that the placement of the lateral in the channel resulted in better distribution of moister content with respect to depth but buried drip pipe gave better distribution of moisture content with respect to lateral movement of moisture contents. The results have been presented in the Figure 10.

| **Table 7:** Average moisture content (%) of the bed irrigated with drip pipe with different placements. | | | |
|---|---|---|---|
| **Location** | **Open placed** | **Channel placed** | **Buried in bed** |
| **Right** | 5.31 | 6.26 | 5.92 |
| **Center** | 5.67 | 6.80 | 6.42 |
| **Left** | 5.52 | 6.30 | 6.05 |
| **Average** | **5.50** | **6.45** | **6.13** |

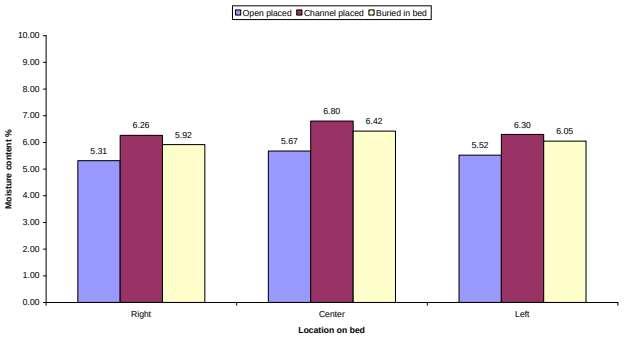


**Figure 10:** Comparison of moisture content (%) of the bed irrigated with drip pipe with different placements.

Analysis of variance Table 7 shows that all three drip pipe placements (T1, T2, T3) differ significantly for location, positions, depths and their different interaction within the variables reported above. The significant difference for the location in each treatment indicates that discharge of emitters was not uniform as desired with respect to length of the field. Although, it was tried to put the pipe in the center but results of analysis indicate that it was significant in case of open placed drip pipe whereas it was non-significant in the case of when pipe was buried or placed in channel. It is also important to mention that pipe placed in the channel was easy to handle, replace and to fold back.

## 4. Conclusion

These results revealed also that the placement of the lateral in the channel resulted in better distribution of moister content with respect to depth but buried drip pipe gave better distribution of moisture content with respect to lateral movement of moisture contents. There is need to conduct similar studies for different type of soils and for different crops (Rabi and Kharif) to find out their water use efficiency and growth response.

## References

Alam, Mahbub, Trooien, T.P., Dumler, T.J., Rogers, D.H., 2002. Journal of the American Water Resources Association.

Camp, C.R., 1998. Subsurface drip irrigation: a review. Transactions of the ASAE, 41 (5), Pp. 1353

Camp, Rand, M., Yitayew. 1990. Evaluation of Subsurface Trickle Irrigation System. Paper of ASAE. No. 90, Pp. 2531.

Cote, C.M., Keith, L.B., Philip, B.C., Freeman, J.C., Peter, J.T., 2003. Analysis of soil wetting and solute transport in subsurface trickle irrigation. Irrigation Science j., 22 (3-4), Pp. 143-156.

Lamm, F.R., Todd, P.T., 2003. Subsurface drip irrigation for corn production: a review of 10 years of research in Kansas. Irrigation Science j., 22 (3-4), Pp. 195-200.

Mali, S.S., Singh, R., Singh, A.K., Meena, M., 2016. Influence of drip lateral placement depth and fertigation level on germination, yield and water-use efficiency of cucumber (Cucumis sativus). Indian Journal of Agricultural Sciences, 86 (2).

Patel, N., Rajput, T.B.S., 2007. Effect of drip tape placement depth and irrigation level on yield of potato. Agricultural Water Management, 88 (1–3), Pp. 209–223.

Rui, M.A.M., Maria do Rosario, G., Oliveira, Carlos, A.M.P., 2003. Tomato root distribution, yield and fruit quality under subsurface drip irrigation. Plant and Soil j., 255 (1), Pp. 333-334.

Wanjura, D.F., Upchurch, D.R., Lascano, R.J., 2003. Subsurface Drip Irrigation of Cotton Using Time Thresholds. Proceedings of 2003 Beltwide Cotton Conference, Pp. 554-562.