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Soil moisture distribution as influenced by drip irrigation supply and planting pattern in heavy soils of Madhya Pradesh

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A field experiment was conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur with the aim to study the effect of drip irrigation supplies on soil moisture distribution, yield of Pusa Ruby variety of tomato (*Lycopercicum esculentum*) under different planting patterns. Four levels of irrigation i.e. irrigation at 0.6, 0.8, 1.0, and, 1.2 times crop evapotranspiration, and two planting patterns of paired-row and four-row which were selected for the study. Observations revealed that the lateral and vertical spread of water in the soil increased with the amount of irrigation. In all the treatments, the lateral spread of irrigation water was more than the vertical spread, with the magnitude of spread being more under paired-row planting than under four-row planting. Maximum yield (324.19 q ha^{-1}) was obtained in the treatment combination of four-row planting coupled with irrigation at 1.0 times crop evapotransipiration.

Key words: *Lycopercicum esculentum,* drip irrigation supplies, soil moisture distribution

Introduction

Real water savings and productivity gains in agriculture can be achieved through more reliable water supply to irrigated areas and using precision irrigation delivery technologies. For this, the drip method of irrigation is the best option available at present [Sivannapan et al. (1974), Grimes *et al*. (1976), Deshmukh *et al* (1988). However economic considerations usually limit the use of drip irrigation to orchards and vegetables. Even in vegetable production, it has been observed that the drip method of irrigation is not catching up for adoption as anticipated for want of high initial investment on system layout. The main items of expenditure in drip system are the cost of lateral lines and the number of emitters. This high cost component can possibly be reduced by

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little manipulation in crop planting pattern without any significant loss of yield Singh (1978); Satpute, *et al.,* (1989); Shinde (1996) and Pandey (1998) coupled with appropriate irrigation supply Water movement and its distribution in the soil depends upon various parameters like soil type, crop cultivars, cop planting pattern, amount of irrigation applied, and climatic factors. It was with this view that the present investigation were taken up to study the effect of irrigation level and planting pattern on soil moisture distribution pattern and its effect on yield of tomato (*L. esculentum*) under heavy soils of Madhya Pradesh.

Materials and methods

The experiment was conducted during January to April 2000, at Instructional Farm of College of Agricultural Engineering, J.N. Krishi Vishwa Vidyalaya, Jabalpur. Jabalpur is situated at 23°09' N Latitude and 79°57' E Longitude with an altitude of 393m above mean sea level. Dry summer and cold winter characterize the climate of Jabalpur. Soil of the study area is clay overlaid with a thin layer of clay-loam having an average bulk density of 1.95 g cc^{-1}; field capacity and wilting point are 40 per cent and 16 per cent respectively, on dry weight basis; infiltration capacity is 0.67cm hr^{-1} [Jain et al. (1996), Tripathi, P.N. (1998)].

Four levels of irrigation [viz. irrigation at 0.6, 0.8, 1.0, and, 1.2 times crop evapotranspiration (ET_c) designated as I_1, I_2, I_3 and, I_4 respectively] as main treatment, and two planting patterns [viz. Paired-row (P_1) and, Four–row (P_2)] as sub-treatment were selected for the study. In all, there were eight combinations of irrigation level and planting pattern.Treatments were laid with 30m long laterals (Low Density Poly Ethene pipe -∅ 16mm) under both paired-row (P_1) and four-row (P_2) planting patterns. Micro-tubes (∅ 1.2mm) of rated discharge 6 l hr^{-1} (at operating pressure of 1.0 kg cm^{-2}) were punched and coiled around the laterals at 45cm regular spacing matching plant-to-plant spacing within the rows of tomato. Row-to-row distance was fixed as 40cm. The effective width of the P_1 and P_2 was fixed as 1.2m and 2.4m respectively so that the plant population remained the same i.e. 36,666 plants per hectare in both the planting patterns. In the P_1, one lateral served two rows of the plants and was placed in the middle of the two rows, whereas in the P_2, one lateral served four rows of plants and was placed in the middle of the two inner rows. Eventually, each micro-tube in the paired-row planting pattern served two plants and each micro-tube in the four-row planting pattern served four plants. Irrigation was scheduled on alternate days using daily crop coefficient values for tomato, and evaporation data measured from a Sunken-Pan evaporimeter installed on the experimental plot. An operating pressure of 1.0 kg cm^{-2} was

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maintained throughout the experimental period. Pusa Ruby variety of tomato (*L. esculentum*) was used for the study. Twenty days old tomato seedlings were transplanted on January 6th, 2000. Recommended practices for cultivation of tomato were adopted. Soil moisture distribution pattern under the different treatments, soil samples were collected 24 hours after irrigation at different distances form the micro-tube [(0, 20, 40, 60 cm for P_1), (0, 20, 40, 60, 80, 100, 120 cm for P_2)] across the laterals and, at different depths (0, 10, 20, 30, 40, 50, 60 cm for both P_1 and P_2). Three stages viz. initial, crop development stage and mid-season of tomato crop were considered for the soil sampling. Soil moisture of the samples was determined on dry weight basis using gravimetric method. Picking of ripe tomato commenced on March 20th, 2000 and continued till April 21st, 2000. Analysis of variance was carried out for the yield data.

Results and discussions

Vertical and lateral moisture distribution patterns were found to be different under different treatments and stages of crop growth (Table 1). This may be attributed to the different irrigation levels, distance between source and sink, and evaporative demands of crops during their successive phenological stages Under the paired row- planting pattern, the micro-tube served two plants. In the treatment I_1P_1 the moisture content in the soil profile (0-60 cm) beneath the source ranged between 40–19, 40-20 and 40-18 per cent during initial, crop-development and mid-season stages respectively. Lateral spread of water was found to be more than the vertical spread. In the treatment I_2P_1 moisture content vertically below the source varied between 43–19, 41-22 and 40-20 per cent during the three stages respectively. On comparing the water spreads in I_1P_1 and I_2P_1, it was noted that the magnitude of spread was more in the case of I_2P_1. Similarly, the soil moisture in I_3P_1 and I_4P_1 ranged between 43 – 23, 41-23, 40-21 per cent, and 43–20, 41-24, 42-27 per cent respectively during the three successive stages of crop growth. On observing both the vertical and lateral spread of water in the soil profile, it was found that in all the irrigation levels the lateral movement gave more than the vertical movement, and as the irrigation level increased, magnitude of lateral spread was found to be more than the vertical spread.

Table 1. Soil moisture (%) distribution in various treatments at selected crop stages

Initial stage	**planting**								**Four row planting**		
							60%				
Distance, cm	0	20	40	60	0	2	4	6	8	1	1
						0	0	0	0	0	2
										0	0
10	40	31	26	18	4	3	3	3	2	2	1
					1	5	6	0	4	3	9
20	30	28	23	16	3	3	2	2	2	2	1
					3	7	7	8	2	0	7
30	26	25	22	14	2	3	2	2	1	1	1
					7	6	5	5	6	5	5
40	24	21	20	14	2	2	2	2	1	1	1
					5	4	3	3	6	3	2
50	20	19	17	12	2	2	2	1	1	1	1
					4	2	0	9	4	4	1
60	19	18	15	12	2	1	1	1	1	1	8
					0	9	7	6	3	2	
							80%				
Distance, cm	0	20	40	60	0	2	4	6	8	1	1
						0	0	0	0	0	2
										0	0
10	43	36	34	27	4	3	3	3	2	2	2
					3	8	4	1	6	4	4
20	32	31	29	23	3	3	3	2	2	2	2
					5	3	0	8	5	1	1
30	28	27	25	20	2	3	2	2	2	2	1
					8	0	7	6	5	0	8
40	24	24	24	17	2	2	2	2	2	1	1
					6	6	4	4	2	8	7
50	21	20	20	16	2	2	2	2	1	1	1
					3	2	3	1	9	7	4
60	19	18	17	14	2	2	2	2	1	1	1
					2	4	2	0	7	5	1
							100%				
Distance, cm	0	20	40	60	0	2	4	6	8	1	1
						0	0	0	0	0	2
										0	0
10	43	36	35	30	4	3	3	3	3	2	2
					4	6	5	5	1	6	5
20	35	31	30	29	3	3	3	3	3	2	2
					8	3	2	1	0	5	4
30	29	29	25	23	3	3	2	2	2	2	2
					2	1	9	8	7	5	3

40	27	25	23	16	3	2	2	2	2	2	2
					0	8	7	7	5	3	1
50	23	23	22	14	2	2	2	2	2	2	1
					6	5	4	3	3	1	7
60	23	19	17	14	2	2	2	2	1	1	1
					2	2	2	1	9	8	6
120%											
Distance, cm	0	20	40	60	0	2	4	6	8	1	1
						0	0	0	0	0	2
										0	0
10	43	38	38	30	4	3	3	3	3	2	2
					2	7	4	6	2	7	6
20	36	33	31	30	3	3	3	3	3	2	2
					8	5	2	2	1	7	5
30	33	29	27	28	3	3	3	3	2	2	2
					2	2	1	0	9	5	4
40	28	28	25	21	3	3	2	2	2	2	2
					0	0	8	7	7	4	2
50	25	24	24	18	2	2	2	2	2	2	2
					9	8	6	5	5	1	0
60	21	23	22	16	2	2	2	2	2	2	1
					8	4	3	0	0	0	8
Crop Development stage											
60%											
Distance, cm	0	20	40	60	0	2	4	6	8	1	1
						0	0	0	0	0	2
										0	0
10	40	31	34	24	4	3	3	3	3	2	1
					3	5	3	1	3	6	8
20	33	29	28	24	3	3	3	2	2	2	1
					5	2	0	9	9	5	7
30	28	25	18	22	3	2	2	2	2	2	1
					2	9	7	6	5	5	4
40	25	23	17	20	2	2	2	2	2	2	1
					9	7	5	4	2	2	3
50	24	21	17	17	2	2	2	2	2	1	1
					5	5	3	1	0	8	1
60	20	19	15	15	2	2	2	1	1	1	1
					2	2	2	9	8	5	1
80%											
Distance, cm	0	20	40	60	0	2	4	6	8	1	1
						0	0	0	0	0	2
										0	0

10	41	32	32	26	41	36	34	33	34	33	27
20	36	29	29	24	38	33	32	30	30	29	25
30	32	27	25	22	35	30	30	28	28	25	25
40	27	25	25	21	30	28	26	25	24	22	20
50	23	25	23	18	26	26	24	23	21	19	17
60	22	21	19	17	25	24	23	20	19	17	14
100%											
Distance, cm	0	20	40	60	0	20	40	60	80	100	120
10	41	34	35	29	42	38	35	33	35	33	27
20	36	32	31	28	40	34	32	32	34	32	28
30	33	30	26	26	36	31	30	30	31	27	24
40	27	28	22	24	33	28	28	29	26	23	22
50	25	25	20	19	27	27	26	25	23	21	19
60	23	22	20	18	26	25	23	24	22	19	15
120%											
Distance, cm	0	20	40	60	0	20	40	60	80	100	120
10	41	38	36	31	43	37	35	36	34	35	29
20	38	35	31	29	41	36	34	33	34	33	25
30	34	32	28	27	37	34	32	32	32	30	24
40	28	28	24	25	34	33	31	30	29	25	23
50	26	25	22	24	30	30	29	27	25	23	21
60	24	24	20	22	28	27	25	24	22	20	18
Mid Season stage											
60%											

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Distance, cm	0	20	40	60	0	20	40	60	80	100	120
10	40	34	34	27	44	34	37	33	35	30	25
20	33	25	30	24	34	31	31	30	31	30	22
30	28	27	25	23	32	29	26	28	28	27	19
40	24	23	22	20	29	27	24	26	25	24	17
50	22	22	18	17	26	25	25	24	23	20	14
60	18	20	17	16	23	32	22	21	18	16	10
80%											
Distance, cm	0	20	40	60	0	20	40	60	80	100	120
10	40	31	38	30	45	37	36	31	36	37	22
20	33	31	32	30	36	35	32	31	33	33	25
30	29	28	27	26	33	32	29	28	30	29	24
40	27	25	24	23	30	27	27	25	26	25	21
50	22	23	19	18	28	25	25	24	22	22	18
60	20	21	19	16	27	24	24	23	18	19	16
100%											
Distance, cm	0	20	40	60	0	20	40	60	80	100	120
10	40	34	36	34	45	37	34	35	36	33	28
20	35	32	34	30	38	34	34	33	36	31	25
30	33	29	29	27	33	31	31	30	32	30	24
40	29	29	26	34	31	29	29	29	29	26	20

50	25	26	22	20	29	26	26	24	23	22	18
60	21	24	20	18	28	25	22	21	22	20	17
					120%						
Distance, cm	0	20	40	60	0	20	40	60	80	100	120
10	42	34	37	38	43	38	36	36	36	35	31
20	38	33	36	34	40	37	34	34	36	34	29
30	33	30	31	32	38	35	32	32	34	34	27
40	30	28	27	29	34	33	31	30	32	30	25
50	28	27	24	23	32	31	29	28	28	24	24
60	27	25	21	20	30	29	28	25	23	18	19

In the four-row pattern of planting, each micro-tube served four plants. Thus the time of operation of laterals in four-row planting was more than that in paired-row planting. Due to this, the soil moisture distribution pattern under the four-row planting was observed to be different than that obtained in the paired-row planting under the same irrigation level. In the treatment I_1P_2, moisture content in the soil profile beneath the source ranged between 41 – 20, 43-22 and 44-23 per cent during initial, crop-development and mid season stages respectively. Here the lateral spread of water was found to more than the vertical spread. In the treatments I_2P_2 and I_3P_2, the soil moisture ranged between 43 – 22, 41-25, 45-27 per cent and, 44 – 22, 42-26, 45-28 per cent respectively during the three stages. As the level of irrigation increased from I_1 to I_3, the soil moisture spread also increased with the lateral spread being more than the vertical spread. Similar trend was observed in the case of I_4P_2 where the soil moisture varied between 42-26, 43-28 and 43-30 per cent during the three stages respectively. Thus, like the case with paired-row planting pattern, with increase in irrigation level, lateral spread was found to be more than the vertical spread. However, on comparing the two planting patterns, it was observed that the moisture spread both vertically and laterally was more in case of four-row planting than the paired-row planting pattern with the magnitude of lateral spread being more than the vertical spread.

Overall observations on soil moisture distribution revealed that magnitude of spread of water in the soil profile was more in lateral direction than the vertical direction. As the irrigation level increased the lateral spread was more pronounced than the vertical spread. Magnitude of the lateral spread was related more in case of four-row planting than the paired-row planting. The results are in close agreement with earlier studies by Goldberg and Shimueli (1970), Yoset, et al. (1976).

Irrigation level had significant effect on the yield of tomatoes. Highest yield was recorded in I_3 level followed I_4, I_2, and minimum in case of I_1 level (Table 2). Differences in irrigation levels were found to be statistically significant to each other. Between planting patterns, P_1 gave significantly higher yield than P_2. Highest yield was obtained in the treatment I_3P_2 that was significantly superior over rest of the treatments. The minimum yield was obtained in treatment I_1P_2 that was significantly inferior to the other treatments. At lower levels of irrigation (irrigation at 0.6 times ET_c and 0.8 times ET_c), paired-row planting gave higher yields than four-row planting, whereas at higher levels of irrigation (irrigation at 1.0 times ET_c and 1.2 times ET_c and I_4), four-row planting performed better. Among different treatments, maximum yield (324.19 q ha^{-1}) was obtained in I_3P_2 that was significantly superior to other treatments. These results are in close conformation with earlier studies, Shajari (1990), Limbulkar, et al. (1998).

Table 2. Tomato yield (q ha^{-1}) under different treatments

Treatments	P1	P2	Average
I1	167.71	149.99	158.85
I2	294.58	253.16	273.87
I3	312.66	324.19	318.43
I4	276.00	309.99	293.00
Average	262.74	259.33	

Observations on soil moisture distribution in the soil profile revealed that the lateral and vertical spread of water in the soil increased with the amount of irrigation. In all the treatments, the lateral spread of irrigation water was more than the vertical spread, with the magnitude of spread being more under paired-row planting than under four-row planting. Treatments with deficit irrigation gave lower yields. The reduced rate of irrigation water application may not have been sufficient to cover all evaporative demands of crop and caused a stress condition that adversely affected tomato yield. Maximum yield was obtained in the treatment combination of four-row planting coupled with irrigation at 1.0 times crop evapotransipiration.

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