Effect of Drip Irrigation and Mulch on Soil Hydrothermal Regimes and Productivity of Apple (*Malus Domestica* Borkh cv. Oregon Spur)

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Apple, drip irrigation, mulch, hydro-thermal regimes, water use efficiency.

ABSTRACT: Studies were undertaken to investigate conjoint effects of drip irrigation and mulch on soil hydrothermal regimes and productivity of apple. Three drip irrigation levels equals to 100, 80 and 60 per cent of ET were compared with conventional surface irrigation and rainfed condition, with and without mulch. Moisture distribution under drip followed three dimensional movements covering vertical, lateral and diagonal directions. The wetting front extended up to 45 cm horizontally however, the maximum moisture content remained confined near the emitting point. Further, soil moisture under drip especially in surface 0-30 cm soil layers was markedly higher compared to surface irrigation wherein, deeper layers exhibited higher content. Application of mulch resulted in 2-3 per cent unit higher soil moisture especially in 0-30 cm soil layers. Mulch raised the minimum soil temperature by 2.5 ^{o}C, whereas, it failed to alter the maximum soil temperature appreciably. In drip, tree growth parameters (annual shoot growth, height, spread and canopy volume) were significantly higher over surface irrigation and rainfed condition. Fruit yield was about 15 and 70 per cent higher in drip compared to surface irrigation and rainfed, respectively. Studies, therefore, revealed 25 per cent water savings in drip alone and 40 per cent in drip irrigation plus mulch compared to surface irrigation besides higher productivity of apple.

INTRODUCTION

Among the various techniques of water application, the drip/trickle irrigation system has proved its superiority especially, in fruit and vegetable crops, owing to precise and direct application of water in the root zone without wetting the entire area. The technology holds great potential in water scarce areas having shallow and course textured soils especially, in the Himalayan region. (Raina 2000 and Raina et al., 1999). Availability of assured irrigation water and proper nutrients management are some of the major factors contributing to the low yield levels of apple. Though Himalayan region receives ample rains (1000-1200 mm) however, 80 per cent of the total rainfall is concentrated during monsoon (July-September) as such, pre and post monsoon water stress is of common occurrence in the region. The only viable remedy under such conditions is to harvest the rain water, store it and utilize the same through efficient irrigation systems such as drip/sprinkler. In fact, it calls for a total switch from conventional methods to the efficient techniques of irrigation and fertilization. It is well advocated by several authors that application of mulch creates their own soil hydrothermal regimes and thereby affect the plant growth and development (Ashrafuzzaman et al., 2011). The present investigation was therefore, carried out to study the combined effect of drip irrigation and mulch on soil hydro-thermal regimes and productivity of Apple in Himalayan region.

MATERIALS AND METHODS

Field experiments were executed at Krishi Vigyan Kendra, Rohru, district Shimla, Himachal Pradesh (India) on 8 years old apple plantations cv. 'Oregon Spur', planted at a distance of 3.6 x 3.6 m during 2010-11 The experimental area is located at an altitude of 1720 m above mean sea level and lies between $31^{0}45'30''$ N latitude and $77^{o}25'30''$ E longitude. Experimental soil was sandy loam, having bulk density 1.20 Mg $m^{-3,}$ organic carbon 0.63 per cent, pH 6.2 and electrical conductivity 0.31 dS m^{-1}. Volumetric soil water content at field capacity and permanent wilting point was 22.7 and 7.3 per cent, respectively. The experiment comprising following eight treatment combinations with three replications in Randomized Block Design: T_1-Drip irrigation at 100% ETc. without mulch (DI 100 M_0), T_2- Drip irrigation at 80% ETc. without mulch (DI 80 M_0), T_3-Drip irrigation at 60% ETc. without mulch (DI 60 M_0), T_4-Conventional surface irrigation without mulch (SI M_0), T_5-Drip irrigation at 100% ETc. with mulch (DI 100 M_1), T_6- Drip irrigation at 80% ETc. with mulch (DI 80 M_1), T_7-Drip irrigation at 60% ETc. with mulch (DI 60 M_1) and T_8-surface irrigation with mulch (SI M_1). Irrigations were commenced w.e.f 15 March every year and continued till end June. Amount of water applied under drip irrigation was based upon pan evaporation (0.75 class 'A' pan evaporation) and replenished weekly according to Ep recorded in the previous week using the equation $V=\sum$ (Ep x Kc x Kp x CF – Re x A) where, V is the volume of water applied in litres per plant per week which is equivalent to 100 per cent evapo-transpiration of crop (ETc.); Ep pan evaporation (mm/week); Kc crop co-efficient; Kp pan factor (0.75); CF Canopy factor; Re effective rainfall (mm) and A is the area of plant basin ($1.63m^2$). Crop factor (Kc) were considered as per FAO hand book No. 24 (Doorenbos, 1984). Amount of water applied under drip (100% ETc.) was 30.2 and 29.2 cm in 2010 and 2011, respectively. Under conventional surface irrigation, a total of 8 irrigations (5 cm depth) were applied. Each treatment received recommended dose (RD) of N, P and K which were 70, 35, 70 gm along with 10 Kg FYM g per tree per year of age, respectively. Year round mulching with black polyethylene sheet of 100 micron thickness was done. Drip systems was laid out with 12 mm diameter LLDP lateral pipes, with three emitters per plant having the discharge rate of 8 litres per hour and were placed at 30 cm distance from the tree trunk. The operating pressure of drip system was 1.6 kg cm^{-2} and emission uniformity 92-93 per cent. Soil moisture was determined at 30 cm distance from the tree trunk before and after 24 hours of next irrigation event at 0-10, 10-20, 20-30, 30-40 and 40-50 cm soil depth and also at 15, 30 and 45 cm horizontal distance from the emitter for similar depths.Soil temperature was recorded under all treatments at weekly ontervals. The data on trunk girth, tree height, annual shoot growth (ASG) and tree spread was recorded before execution and after termination of experiment and expressed as increase over initial values. Fruit yield was recorded following standard procedures.

RESULTS AND DISSCUSION

Soil Moisture distribution

Spatial distribution of soil moisture was studied developing the iso-moisture curves (Figure1).It is evident that under drip irrigation, the wetting front extended up to 45 cm horizontally however, the maximum increase in moisture content (10-12%) remained confined near the emitting point. The moisture content decreased consistently with the increasing horizontal distance up to 30 cm away from emitter and thereafter after a steep decline (0-2.0%) occurred

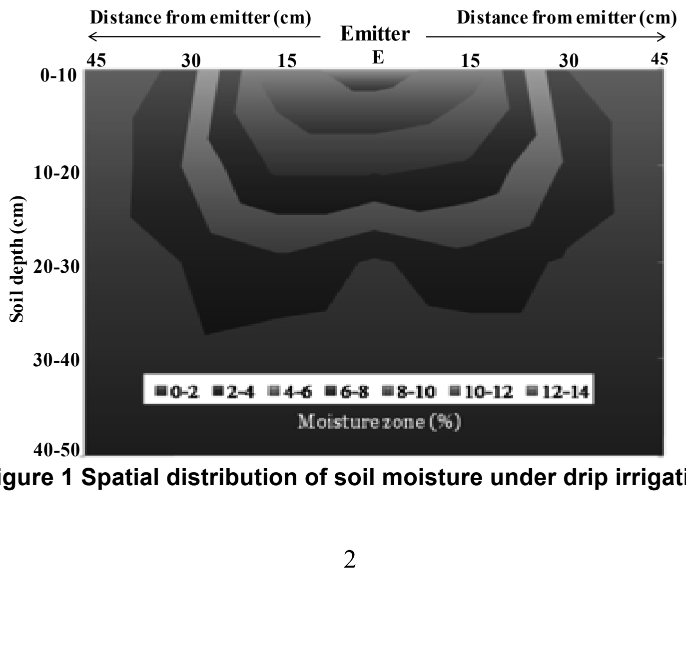

Figure 1 Spatial distribution of soil moisture under drip irrigation

It is therefore inferred that moisture distribution under drip irrigation is three dimensional function covering vertical, lateral and diagonal movements whereas, it is a unidirectional movement under surface irrigation. An almost similar lateral moisture distribution pattern under drip irrigation has been reported by Badr (2007).

The data cited in table2 reveal that soil moisture content under drip irrigation (DI 100) was markedly higher in the surface 0-10 (19.6%), 10-20 (18.1%) and 20-30 cm soil layers (15.9%) as compared to surface irrigation (SI), wherein lower soil depths 30-40 and 40-50 cm, registered higher values (16.6 and 17.0%, respectively). Under rainfed (RF), moisture content was also noted to be higher in lower soil depths. The higher soil moisture in the surface (0-30 cm) soil layers under drip irrigation may be attributed to the fact that water was applied at weekly intervals in smaller quantities, which remained confined in the upper layers only. Under surface irrigation, higher hydraulic gradient was created owing to application of bulk volume of water per irrigation with quite wider irrigation frequency, which resulted in more rapid downward movement of water. These results are in close conformity with the findings of Sharma (2007). Drip irrigation DI 80 and DI 60 exhibited a similar moisture distribution pattern as observed under DI 100.

Application of plastic mulch resulted in 2-4 per cent unit higher soil moisture especially, in 0-30 cm depth compared to unmulched condition (Figure 2). The higher moisture content under mulch treatments may be ascribed to reduced evaporation during day time which is the main reason for diurnal cycle in the bare soil. Furthermore, under the plastic mulch, the evaporated moisture condenses on the lower side of polyethylene sheet and drip down again on the soil surface, consequently eliminating the diurnal cycling process of the bare soil. These observations are in accordance with the findings of Raina *et al.* (1998) and Singh *et al.* (2004).

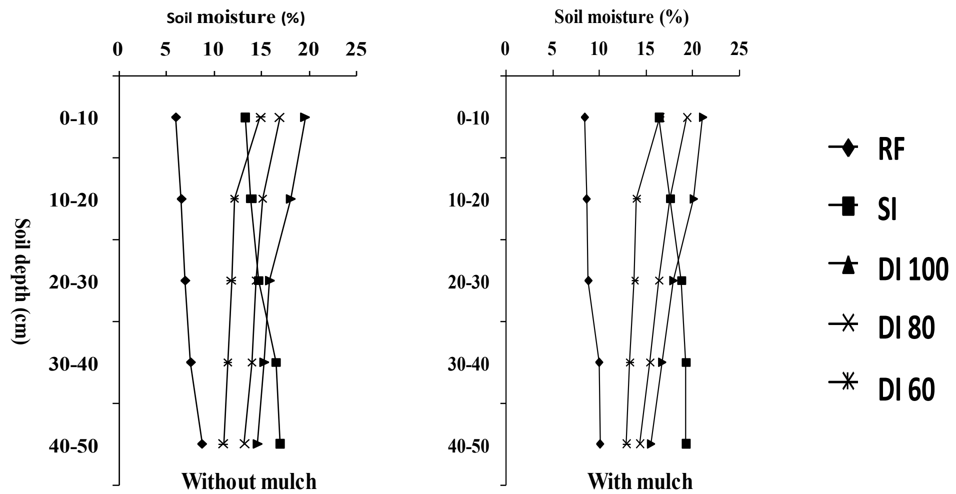

Figure 2 Soil moisture under different treatment

Soil temperature:

Minimum soil temperature increased with the increasing soil depth and remained almost same under drip and surface irrigation however, it was noted to be slightly higher (0.6-0.9 ^{o}C) compared to rainfed condition(Table1). The difference in soil temperature between irrigated and rainfed condition could be explained in light of fact that all the thermal properties of soil depend markedly on moisture content and total porosity. Water has high specific heat and low thermal conductivity as compared to dry and compact soil. Since both drip and surface irrigation maintained higher soil moisture compared to rainfed condition, consequently prevented the soil to become colder during the night and much hotter during the day time. It has also been documented that a dry soil is heated more easily than a wet soil because the specific heat of water is nearly five times than that of dry soil. The high specific heat of water prevents the sudden changes in temperature of irrigated soil during winter (Tripathi and Tomar, 2002).

Table 1: Minimum soil temperature at different growth stages of apple*

Growth stage	Depth (cm)	Soil temperature (^oC)							
		DI**		SI		RF		Avg.	
		M0	M1	M0	M1	M0	M1	M0	M1
Green tip/pink bud (20 Mar.-10 April)	10	9.4	12.5	9.5	12.6	9.3	12.4	9.4	12.5
	15	11.9	13.0	11.8	13.1	11.7	12.8	11.8	13.0
	20	13.6	13.8	13.7	13.9	13.7	13.9	13.7	13.9
Flowering/fruit set (11 April-1 May)	10	14.8	18.0	14.4	17.7	14.4	17.5	14.5	17.7
	15	17.1	18.4	16.9	18.2	16.6	17.6	16.9	18.1
	20	19.2	19.8	19.0	19.5	19.2	20.0	19.1	19.8
Walnut (2 May-22 May)	10	19.6	22.4	19.0	21.4	17.2	21.2	18.6	21.7
	15	21.1	22.3	20.8	21.8	20.3	21.5	20.7	21.9
	20	21.6	22.0	21.5	22.1	20.3	20.8	21.1	21.6
Fruit development (23 May-30 June)	10	22.2	23.7	21.6	23.2	20.9	22.8	21.6	23.2
	15	23.0	24.1	22.7	23.7	22.6	23.7	22.8	23.8
	20	23.5	24.2	23.4	24.0	23.6	24.2	23.5	24.1
Pre-harvest fruit development (1 July-20 July)	10	23.0	24.2	22.9	24.3	22.7	24.0	22.9	24.2
	15	23.5	24.4	23.5	24.5	22.8	23.7	23.3	24.2
	20	24.4	25.1	24.2	25.0	24.5	25.2	24.4	25.1

* Average values of weekly data : DI ;Drip irrigation : SI: Surface irrigation RF: Rainfed

Table 2: Maximum soil temperature at different growth stages of apple*

Growth stage	Depth (cm)	Soil temperature (^oC)							
		DI**		SI		RF		Avg.	
		M0	M1	M0	M1	M0	M1	M0	M1
Green tip/pink bud (20 Mar.-10 April)	10	12.3	13.2	12.4	13.1	12.5	13.4	12.4	13.2
	15	12.9	13.1	12.8	13.2	12.6	12.9	12.8	13.1
	20	13.2	13.1	13.4	13.2	13.4	13.1	13.3	13.1
Flowering/fruit set (11 April-1 May)	10	17.8	17.6	17.8	17.4	17.9	17.7	17.8	17.6
	15	17.6	18.0	17.4	17.8	17.1	17.2	17.4	17.7
	20	18.4	19.0	18.6	18.6	18.4	19.1	18.5	18.9
Walnut (2 May-22 May)	10	23.4	23.0	23.3	23.1	24.0	23.5	23.6	23.2
	15	22.1	22.4	21.8	21.9	21.3	21.6	21.7	22.0
	20	20.7	21.0	20.7	21.2	19.3	19.9	20.2	20.7
Fruit development (23 May-30 June)	10	25.0	23.6	25.0	23.7	25.3	24.0	25.1	23.8
	15	23.5	23.5	23.2	23.1	23.1	23.1	23.3	23.2
	20	21.7	22.5	21.7	22.2	21.9	22.5	21.8	22.4
Pre-harvest fruit development (1 July-20 July)	10	27.1	26.0	27.0	25.9	28.0	26.0	27.4	26.0
	15	25.6	25.4	25.6	25.5	24.9	24.7	25.4	25.2
	20	24.1	24.8	24	24.8	24.3	25.0	24.1	24.9

* Average values of weekly data : DI ;Drip irrigation : SI: Surface irrigation RF: Rainfed

At different soil depths maximum soil temperature exhibited a variable trend during the growing season however, was observed to be low by 0.3-0.4 ^{o}C under drip and surface irrigation compared to rainfed condition.(Table2) Application of black polyethylene mulch raised the minimum soil temperature by 2.5 ^{o}C however, it failed to alter the maximum soil temperature appreciably The effect of mulch on soil temperature could be attributed to low thermal conductivity of plastic mulch. Black polythene absorbs much of the incident radiation but transmit less energy because of presence of bad conducting air in between black polyethylene and the soil surface, consequently decreased the heat flux in the soil, due to which soil was cooler during the day time and warmer during the night. Similar findings have also earlier been reported by Jiang *et al.* (1997) and Aggarwal *et al.* (2005). These results get further support from the findings of Raina *et al.* (2004). They documented that black polyethylene mulch markedly increased the minimum soil temperature but could not alter the maximum soil temperature appreciably.

An appreciable increase in minimum and maximum soil temperature was noted under mulch especially during early growing season *i.e.* 'Green tip-flowering to fruit set' stage (March-April). Towards the end of growing season *i.e.* 'fruit development stage' (June-July), mulch application appreciably lowered the maximum soil temperature compared to unmulched condition.

GROWTH AND FRUIT YIELD

The data presented in Table 3 suggest that applications of irrigations through drip system (DI 100) resulted in about 35 per cent higher growth parameters (ASG, Tree height and spread) compared to SI and much higher over rainfed conditions. Fruit yield was also significantly high under DI 100 (12.1 t ha^{-1}) which was about 17 per cent higher compared to SI (10.3 q ha^{-1}):

Table 3 Effect of different treatments on growth and yield of apple*

Treatment	Increase over initial status				Fruit yield (t/ha)
	Girth (%)	Height (cm)	ASG (cm)	Spread (cm)	
T_1	2.79	35.7	35.9	36.0	12.1
T_2	2.53	31.9	31.7	32.3	9.4
T_3	2.31	27.4	28.0	29.9	7.5
T_4	2.37	33.6	33.7	32.5	10.3
T_5	2.79	36.0	35.9	36.1	12.2
T_6	2.60	34.9	32.6	34.7	11.3
T_7	2.41	31.7	32.1	32.2	9.3
T_8	2.75	37.5	37.4	34.7	11.2
$CD_{0.05}$	**NS**	**3.4**	**3.5**	**3.1**	**1.85**

***average value of two year data**

The favorable effects of drip irrigation on growth and fruit yield of apple may be attributed to the fact that water was applied in precise amounts and at frequent intervals, directly in the root zone. It thus, resulted in uniform moisture distribution in the root zone and also maintained the moisture content near the field capacity during the entire growth period, thereby leading to more favorable soil conditions for better plant growth. On the other hand, conventional surface irrigation not only resulted in water loses due to deep percolation below the root zone, but also set a chain of undesirable reactions such as leaching of available nutrients and poor soil aeration, consequently resulting in comparatively lesser growth parameters. These results get further support from the data on soil moisture distribution recorded in present investigation (Figure 1). Raina *et al.* (1998) also reported that drip irrigation maintained better soil moisture condition for a longer period of time, instead of wide moisture fluctuations under conventional flood irrigations thereby resulted in higher growth and yield of crops. It may therefore, be drawn that drip irrigation resulted in about 25 per cent higher fruit yield as compared to surface irrigation beside savings about 25 per cent in irrigation water in apple.

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