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WATER REQUIREMENT AND SOIL MOISTURE DISTRIBUTION STUDIES OF DRIP IRRIGATED ONION CROP UNDER PLASTIC MULCHED AND NON MULCHED CONDITION

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Abstract: Polyethylene mulching with drip irrigation is widely adopted technology for enhancing production and quality of vegetable crops. Black polyethylene is widely used due to its excellent properties and low cost. An experiment was conducted to ascertain the effect of different types of black polyethylene mulches for water requirement and soil water content distribution up to 30 cm soil depth with onion crop. In plastic mulched condition soil moisture under line source of irrigation, increases along the vertical direction while in open field condition, soil moisture is increased along vertical and decreases in horizontal direction from emitter point. Higher water use efficiency of onion under mulched condition is indicative of the fact that water requirement of drip irrigated onion can be further reduced due to lower evapo-transpiration losses and results in significantly higher crop yields compared to non mulched condition.

Keywords: Poly ethylene mulch, drip irrigation, onion, water use efficiency, soil moisture.

Introduction

Onion (*Allium cepa L.*) is an important underground bulbous, commercial vegetable and spice crop grown in fairly large area in India. The area under onion has increased in Rajasthan in last three years from 49,000 ha in 2010-11 to 1, 39,050 ha in 2012-13 (NHB, 2013). It is predominantly a rabi season crop. Onion is a close growing bulbous crop and is very sensitive to soil moisture distribution in the soil profile.

Trickle Irrigation has increased considerably worldwide during the past decades. Its main advantage consists in the possibility to increase crop yields and to reduce water application as well as fertilizer. Drip Irrigation with plastic mulch has been introduced as a moisture conservation technique. Drip Irrigation can distribute water uniformly, precisely control the water amount, and decrease the danger of soil degradation and salinity. On the other side,

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mulching is always used to prevent soil water evaporation and elevate soil temperature. Plastic mulching is a soil moisture conservation method that involves placing poly film over raised or a flat bed to provide a more favorable environment for growth and production. Plastic mulch normally is used in conjunction with drip irrigation to maintain optimum soil moisture and for improved stand establishment. Plastic film mulching with drip irrigation is a proven technology for vegetable production and its popularity is ever increasing among vegetable growers.

Water movement under the point source of drip irrigation is quite complex. When applied through emitter, the water spreads in all direction, i.e. above the soil surface, its entry into the soil and its movement within the soil. A comprehensive understanding of the mechanism of soil water distribution and movement in root zone is essential for the design and management of drip irrigation system and irrigation strategies. The advance of wetting front in a soil under an irrigation source is related to soil type, initial moisture content, and water application rate (Hacchum et al., 1976). For mulched drip irrigation, the plastic film covers an asymmetric pattern of individual drippers and the plastic mulching may induce pronounced changes in soil water flow (Amayreh and Al-Abed, 2005).

Materials and Method

Site description

Field experiment was conducted during 2014-15 at the Plasticulture farm, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur. Geographically, Udaipur is located at 24° 35 N latitude and 73° 44 E longitude. The altitude of the site is 582.17 m above mean sea level. The area has a sub-humid climate. The average annual rainfall in the region is 662.5 mm and more than 80% of this amount is received as a part of south-west monsoon during the period of 16^{th} June to 15^{th} September.

Experimental details

The seeds of onion variety Agri-Found Dark Red (AFDR) were sown directly in nursery beds of size 1m x 3m keeping the seed rate 10 kg /ha. Vermi compost @ 1.5 kg/m^2 was added and mixed with soil media. The seed was sown in lines of 10cm apart in raised beds on 10^{th} October 2014. Light watering was done on alternate day to provide sufficient moisture in raised bed for proper germination and vegetative growth. 49 days old seedlings were transplanted in different treatments on raised bed under gravity fed drip irrigation.

Six treatments comprising five poly-mulches (black) of different thickness (M_1-20µm, M_2-25µm, M_3-30µm, M_4-35µm and M_5-50µm-recycled) was compared with control (M_0-no mulch) in a randomized block design with four replications. The irrigation consists of over head tank, PVC pipes of 63 mm and 50 mm diameter as main and sub main lines and 12 mm diameter of linear low density polyethylene pipes (LLDPE) as lateral was used. The inline emitters of 2.0 lph spaced at 0.3 meter on lateral laid in between rows along the bed.

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 initiation and water uptake. To study how much water that soil maintains in root zone post irrigation, soil moisture content was measured within soil depth and across the mulched and non mulched bed after irrigation. Since the soil was sandy loam with high infiltration rate (2.2 cm/hr), water was applied in a bed with two laterals placed at a distance of 50 cm apart with a dripper spacing of 30 cm so as to act as a line source of irrigation.

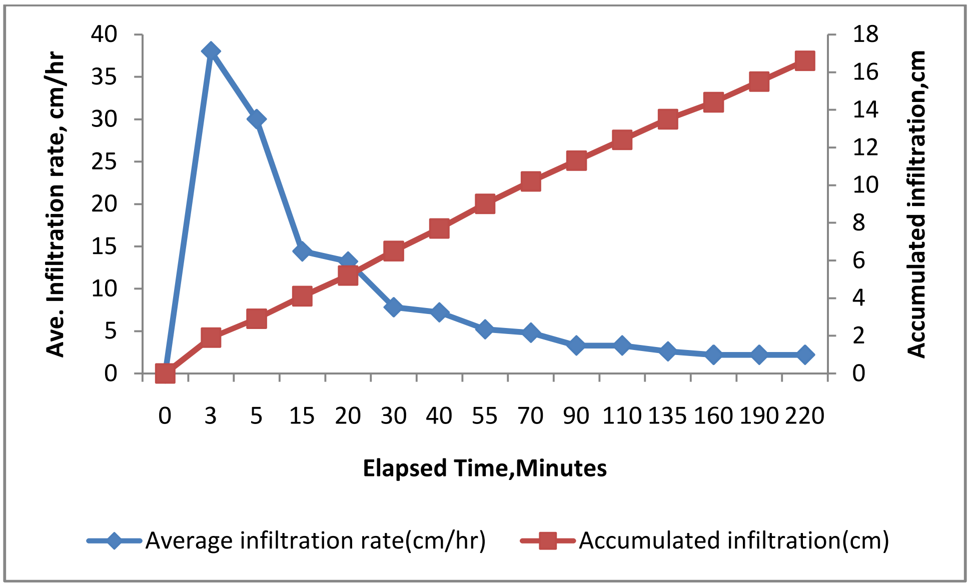


Fig. 1 Infiltration rates and accumulated infiltration versus elapsed time of the study area

Determination of Crop Water Use

Available soil moisture is the difference between volumetric soil moisture at field capacity and permanent wilting point. The soil moisture depletion method was employed to determine the consumptive use of the crop. This study involved measurement of soil moisture from various depths at a number of times throughout the growth period. Crop water use was calculated from the change in soil water content in successive samples from the following relationship as given by the soil moisture depletion method (Micheal,1999), with the expression given as:

$$CWU = \frac{\sum_{i=1}^{n}(MC1i - MC2i) * Asi * Di}{t}$$

Where,

CWU = average daily crop water consumptive use between successive soil moisture content sampling periods (mm/day)
MC_{1i} = Soil Moisture content (g/g) at the time of first sampling in the i^{th} soil layer.
MC_{2i} = Soil Moisture content (g/g) at the time of second sampling in the i^{th} soil layer
A_{si} = bulk density of the i^{th} layer.
D_i = Thickness of the i^{th} layer (mm).
n = the number of soil layers sampled in the root zone depth D.

The amount of water to be applied through drip irrigation was based on depletion of moisture upto 25% of available moisture content (ASM). Soil moisture status was constantly recorded at 10 cm, 20 cm and 30 cm soil depths through soil moisture probes in combination with gypsum blocks and gravimetric method. At the end of the experiment, total amount of water applied was calculated for each irrigation treatment and the water use efficiency (kg/ha-cm) was calculated as per the formula:

$$\text{Water Use Efficiency (WUE)} = \frac{\text{Total yield of onion (kg/ha)}}{\text{Total water applied (cm)}}$$

Plant growth parameters *viz.* plant height, number of leaves were observed at 30 days interval after transplanting till harvest. Other data recorded were maximum and minimum soil temperature at 5 and 10 cm depths. Impact of mulch on soil compaction was measured with cone penetrometer at 60 and 120 days after transplanting.

Soil moisture distribution

Soil moisture readings before and after irrigation were taken from locations 0 cm 15 cm and 25cm away from the emitter and at 10 cm, 20 cm and 30 cm soil depths, to characterize the soil water distribution pattern

Soil moisture Depletion

The soil moisture was recorded at 15 days interval during crop growth period prior to irrigation so as to study the per cent depletion over field capacity. Soil sample were collected from vertical depth of 10, 20 and 30 cm.

Results

Crop water requirement and irrigation scheduling

Irrigation scheduling was estimated based on soil moisture depletion method. The available soil water on volume basis was determined as the difference between field capacity (21.8%) and permananet wilting point (8.74%). Irrigation was scheduled to commence when soil moisture was depleted to 25% of available soil moisture. Therefore the irrigation trigger level for the experiment was (18.53%). Irrigation was applied to ensure that soil moisture remain between field capacity and the required irrigation threshold. The results on estimated irrigation interval and number of irrigation for the entire cropping season are given in table 2. Use of mulch in conjunction with drip irrigation significantly reduced the number of irrigations and increased the irrigation interval compared to non mulched drip irrigated plots. This is attributed to the effectiveness of mulch to conserve soil moisture and the decreased crop evapo-transpiration associated with water stress.

Table 1. Irrigation scheduling, seasonal crop evapotranspiration and crop water requirement in mulched and unmulched plots

Treatments	**No. of Irrigation**	**Irrigation interval (days)**	**Crop ET(mm/day)**	**Crop water Requirement(mm)**
Mulched Plots	28	3-4	3.35	301.5
Un mulched plots	41	2 -3	4.54	408.6

Black Plastic mulches were effective in reducing soil moisture loss through evaporation. Through the use of plastic mulches, crop ET was reduced by 26.11 compared to non mulched plots

Soil Moisture distribution

The study was under taken to know the effect of quantity of water applied under different levels of irrigation on moisture distribution in crop root zone. The soil water status were recorded after 24,48 and 72 hours of irrigation at 10 cm, 20 cm and 30 cm vertical distance and at placement of lateral emitters , 12.5 cm and 25 cm away in the radial direction.

Table 2. Variation in moisture content (%) in mulched and non mulched bed after irrigation.

Moisture Distribution under plastic mulched and non mulched bed after 24h						
Depth	**Soil Moisture Content(%) in mulched bed**			**Soil Moisture Content(%) non mulched bed**		
	at emitter	**12.5cm**	**25cm**	**at emitter**	**12.5cm**	**25 cm**
10cm	20.70	20.68	20.51	20.46	18.88	17.26
20cm	21.46	21.04	20.96	21.19	19.61	18.00
30cm	22.22	21.71	21.40	21.93	20.35	18.73
Moisture Distribution under plastic mulched and non mulched bed after 48h						
10cm	19.85	19.54	19.48	18.27	17.10	16.99
20cm	20.60	20.30	19.93	19.01	17.83	17.72
30cm	21.37	21.07	20.70	19.74	18.57	18.46
Moisture Distribution under plastic mulched and non mulched bed after 72h						
10cm	18.47	18.35	18.41	17.46	17.32	17.10
20cm	19.23	19.10	18.57	18.20	18.05	17.83
30cm	19.99	19.87	19.34	18.93	18.79	18.57

It is seen from the table that after 24 hours of irrigation in non mulched plots, the moisture content in horizontal distance at the dripper emission point was higher and it decreased as the distance increased from the dripper. It was seen that the moisture content in the vertical direction increased with the increased depth. The mean moisture content after 24 hours of irrigation near the dripper point (at 10 cm) was 20.46 per cent and decreased to 17.26 per cent at 25 cm radial distance, but it increased to 22.22 per cent at 30 cm vertical depth. The similar trend for moisture content was also observed after 48 hours and 72 hours after irrigation although moisture level was on a decreasing trend. However, the trend for mulched plots were slightly different especially in radial direction at lower vertical depths.

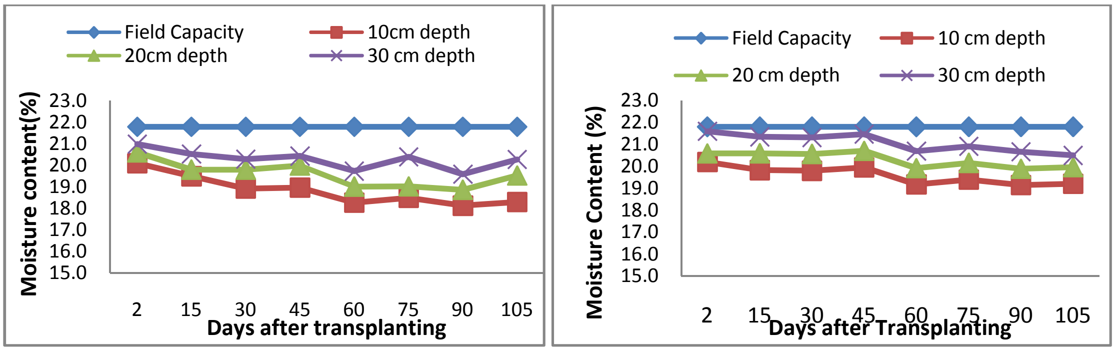
Discussion

In mulched plots, the moisture content in the vertical direction increased with the increased depth, but along radial direction at 10 cm depth soil moisture did not decrease as significantly as in un mulched plots and they were almost neck to neck at emitter point, 12.5 cm and 25 cm horizontal distance. This may be due proper redistribution of water within mulch and the condensation of evaporated moisture on lower side of the mulch and its subsequent dripping to the soil surface. The mean moisture content after 24 hours of irrigation near the dripper point (at 10 cm) was 20.70 per cent and was almost maintained at 20.51 per cent at 25 cm radial distance, but lower depths (10 cm and 20 cm) moisture at radial depth decreased. Along vertical depth soil moisture increased from20.70 at 10 cm to 22.22 at 30 cm. Similar trend for moisture content was also observed after 48 hours and 72 hours after irrigation although moisture level was on a decreasing trend. Overall, under plastic mulched soil beds soil moisture status was raised by 4- 6%. Aggrawal et al. (2003) and Spehia et. al (2011) also reported similar findings.

Soil Moisture Depletion

The soil moisture prior and post irrigation at 15 days interval was determined by gravimetric method from 10, 20 and 30 cm depth of soil profile for all mulched and non mulched plots. Soil water content at field capacity was 21.80 percent. Soil moisture was always closer to field capacity throughout the period and the irrigation differed for mulched and non mulched plots depending upon soil moisture depletion till 25 % of available soil moisture level called the trigger irrigation level. So soil moisture to reach the trigger level in mulched plot was 3 to 4 days and 2 to 3 days for mulched and non mulched plots. The mean moisture content in plastic mulched plots observed at 10, 20 and 30 cm depth of soil profile was in the range of 19.15 to 20.20, 19.97 to 20.60 and 20.50 to 21.60 per cent, respectively at

72 hours after irrigation. Whereas in non mulched plots the moisture content values observed at 10,20 and 30 cm depth were in the range of 18.13 to 20.10, 18.86 to 20.60 and 19.60 to 21.00 at 48 hours after irrigation. Thus overall we can see that soil moisture under mulched plots even after 72 hour of irrigation were higher than non mulched plots at 48 hours after irrigation.



(a) (b)

Fig.2 Variation in moisture content (%) at different depth under a)un mulched and b) mulched condition

The mean moisture depletion over field capacity under non mulched plots and mulched plots ranged from 6.94 to 13.59 per cent and 3.32 to 10.14 per cent respectively at 10, 20 and 30 cm depth. It was also observed that soil moisture fluctuation in 10 cm and 20 cm depth was more than 30 cm depth of soil and in all cases, which declined gradually with increase in depth. Similar trend was also observed in soil moisture depletion by Kumar and Sahu (2013)**.**

Onion growth parameters

Significant difference was observed in plant height, during 30 DAT, 60 DAT and 90 DAT in all mulched treatment over non- mulched treatments. However, no. of leaves were non significant. Bulb size and average yield was also significantly superior in M_3, M_4 and M_2 compared M_1, M_5 and M_0. Bulb size (equatorial diameter-7.5cm and polar diameter-5.1cm) and bulb yield (57.60 t/ha) were obtained in M_3 i.e. poly- mulching with 30 µm film. This was closely followed by M_4 (57.33 t/ha) treatment i.e. mulching with 35 µm poly- film. In treatment M_0 (No Mulching) the lowest Bulb size (equatorial diameter-6.7 and polar diameter- 4.7) and bulb yield per square meter area (38.23 t/ha) were observed.

Table 3. Effect of mulching with different thickness on growth and yield characteristics

Treatments	**Plant Height (cm)**			**No. of Leaves**			**Bulb Size (cm)**		**Avg. Yield (t/ha)**
	60DAT	**75DAT**	**90DAT**	**60DAT**	**75DAT**	**90DAT**	**Eq.Dia**	**Pol. Dia**	
M_0	17	47.4	60.1	3.9	6.3	8.6	6.7	4.7	38.20
M_1	19.5	52.8	65.6	4.3	6.7	11.2	7.1	5.1	48.27
M_2	20.1	52.6	63.9	4.3	6.8	11	7.2	4.8	51.33
M_3	21.4	53.8	65.6	4.2	7	9.75	7.5	5.1	57.60
M_4	20.6	52.6	65.5	4.1	6.8	9.9	7.3	4.8	57.33
M_5	20.4	53.4	62.6	4.3	6.6	9.9	6.9	4.7	44.53
SEm±	0.820	1.497	1.190	0.188	0.155	0.489	0.167	0.124	2.67
CD at 5%	2.470	4.513	3.587	NS	NS	1.475	0.504	0.375	8.07

Water Use Efficicecy (WUE)

Water use efficiency is a measure of performance of crop in terms of water used. Mulched crop outperformed the non mulched plots in terms of WUE. Mulched crop was able to produce more green onion during all harvest period with lesser amount of water. WUE of mulched plot (average of all mulch treatments) was 1718.47 kg/ha-cm as against non-mulched plot (M_0) where the WUE was 934.89 kg/ha-cm.

Table 4. Total water applied and water use efficiency in non-mulched and mulched plots

Treatments	**Total Water Applied (cm)**	**Yield (kg/ha)**	**WUE (kg/ha-cm)**
Non Mulched Plots	40.86	38200	934.89
Mean of Mulched plots(M_1,M_2,M_3,M_4 & M5)	30.15	51812	1718.47

In mulched plots (M_1,M_2, M_3, M_4 and M_5) moisture depletion was significantly less compared to non-mulched plots. This may be due to the fact that drying trend was markedly reduced as in mulched plots plants were not subjected to water stress and thus helped in better root growth and bulb development.

Conclusion

Water requirement under drip irrigated plastic for all mulched plots was on an average 26.11% less than non mulched plots. Moisture distribution pattern under plastic mulching is more uniform and well distributed along radial direction in the top 10 cm depth compared to non mulched plots. Soil moisture depletion in mulched plots was lesser than non mulched plots. It could be also concluded from the studies that overall black poly-mulching have a positive impact on yield and growth parameters in onion production. Water use efficiency of the irrigation method can be enhanced by the use of polyethylene mulching and hence, significant water savings can be achieved.

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