Indian Journal of Agricultural Sciences **83** (11): 1184–8, November 2013/Article

Effect of irrigation levels and polyethylene mulching on growth, yield and quality of *rabi* onion (*Allium cepa*)

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Received: 16 November 2011 ; Revised accepted: 1 May 2013

ABSTRACT

Water conserving irrigation technologies, are used now a days for economic and environmental sustainability of commercial agriculture. An experiment was laid in randomized block design to find out the effect of two irrigation methods on onion (*Allium cepa* L.) crop. The treatments comprised conventional furrow irrigation and drip irrigation at three levels, viz. 100, 80 and 60% of the ET (*i.e.* DI_{100}, DI_{80} and DI_{60}) with and without polythene mulch. The study indicated that irrigation methods and levels manipulated the moisture content of the soil comprehensively and soil moisture was near to the field capacity throughout the growth period in DI_{100} and DI_{80} with mulch, whereas, in conventional furrow irrigation, the soil moisture status varied from field capacity to about 50% moisture depletion conditions. Plant height, equatorial and polar diameter of the bulbs was observed to be significantly affected by irrigation methods, levels and mulching treatments. The total and grade wise bulb yield was appreciably higher under DI_{100} and DI_{80} with as compared to furrow irrigation. Water use efficiency was found to be the highest in the DI_{80} application of polyethylene mulching further increased the water use efficiency to the tune ranging from 5-15%.

Key words: Drip irrigation, Mulch, Onion, RBD, Water use efficiency

Irrigation is very important in onion (*Allium cepa* L.) production. In present time of acute water shortage, the effective and economic utilization is essential and can be achieved through the use of improved techniques, viz. drip irrigation. Further, significant water savings can be achieved with deficit irrigation. To manage plant water stress, it is necessary to schedule irrigation carefully. There are two main methods to schedule irrigation: 1) by replacing crop evapo-transpiration (ET_c) fractions according to soil water balance, or 2) by triggering irrigation according to water content status of soil and allowable depletion levels. In the present study, first approach was followed to determine the amount and timing of irrigation.

The moderation of soil hydrothermal regimes by application of mulch results in better nutrient uptake, water absorption, metabolite production and carbohydrate storage and reflects in better growth and higher yield of crops. In addition, mulches control weed incidence, reduce nutrient losses and affect various physical, chemical and biological reactions involved in plant growth and development, besides considerable savings in irrigation water (Gupta and Acharya 1993). Hence, the deficit irrigation combined with mulching may prevent crop water stress and therefore the present studies were undertaken to establish the effects of various drip irrigation levels and black polyethylene mulching on growth, yield and quality of onion.

MATERIALS AND METHODS

The study was conducted during *rabi* season (October - April) of 2008-09 and 2009-10 at the Experimental Farm (77º08'30"E longitude and 30º50'30" N latitude) of Dr YS Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, located at an elevation of 1150 m amsl with average annual rainfall of 1100 mm. The soil was Typic Entrocrept and some physico-chemical properties before the start of the experiment are enumerated in Table 1.

Experimental plots were prepared in 1.0 m wide raised beds and surface drip irrigation system was installed using drip tape (Netafim, 2 lph flow rate). The onion variety Nasik Red was transplanted at a spacing of 15 cm × 10 cm. Recommended dose of P (SSP @ 475 kg/ha) and K (MoP @100 kg/ha) fertilizers was applied at the time of land preparation and N fertilizer (CAN@ 500 kg/ha) was applied

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Table 1 Characteristics of the soil before experiment

Soil characteristics	Value
Bulk Density (kg/m)	1.28
Particle density (kg/m)	2.54
Porosity (%)	47.54
Field capacity (v/v %)	29.8
pH	6.85
Electrical Conductivity (dS/m)	0.22
Organic Carbon(g/kg)	9.18
Available N(kg/ha)	248.60
Available P(kg/ha)	42.10
Available K(kg/ha)	215.25

in three split doses. Half of the total dose was applied at the time of field preparation, rest after one and two months after transplanting in equal amounts. Standard practices for onion production were followed.

The experiments were laid out in randomized block design with following treatments:

Irrigation levels = 4

DI_{100} - Drip irrigation with 'V' volume of water

DI_{80} - Drip irrigation with '0.8 V' volume of water

DI_{60} - Drip irrigation with '0.6 V' volume of water

Is - Surface irrigation

Mulch levels = 2

M_0 - Without mulch

M_1 - With mulch

Replications = 3

The amount of water to be applied through drip irrigation was calculated by the formula given below and the amount of water calculated for the whole month, was applied at alternate days.

$$V = Ep \times Kc \times Kp \times A \times N - (Re \times A)$$

where, V, Volume of water (litres); A, area of the plot; Ep, average daily pan evaporation (last 15 years); N, number of days in the month; Kc, crop coefficient; Re, effective rainfall; Kp, pan factor.

Furrow irrigation was scheduled at an interval of 15 days and 5 cm water was applied at each irrigation.

Moisture status of the soil was constantly recorded at 10 and 20 cm soil depths. Plant growth parameters, i.e. plant height, number of leaves etc. was determined during the experiment and the total and grade wise yield of bulbs per plot was also recorded at the end of the experiment. The quality parameters, viz. total soluble solids; equatorial diameter and polar diameter were determined using standard procedures. The results obtained during two years were pooled and data thus obtained were subjected to statistical analysis as per methods outlined by Gomez and Gomez (1984). At the end of the experiment, total amount of water applied was calculated for each irrigation treatment and the water use efficiency (tonnes/ha cm) was calculated as per the formula:

Water use efficiency = Total yield of bulbs (tonnes/ha) / Total water applied (cm)

RESULTS AND DISCUSSION

Moisture status of the soil

Moisture status in each of the irrigation treatments (Fig 1) depicts that under unmulched conditions during both the seasons, soil moisture was nearly at field capacity throughout the growth period in DI_{100} at 10 and 20 cm depths. In DI_{80}, 10-18% and in DI_{60}, 15-35% reduction in moisture status curve from field capacity line was observed, whereas in I_S, the curve traveled from above field capacity to 50% moisture depletion condition. This may be ascribed to the fact that water amounting to 100% of ET was applied in DI_{100}, whereas in DI_{80}, only 80% of the actual ET was replaced and hence moisture status throughout the growth period was observed to be just below or near to the field capacity. Under DI_{60}, application of even lower amount of water resulted in the condition where field capacity could not be achieved throughout the growth period and the crop was subjected to water stress. Heavy water application under surface irrigation temporarily decreased aeration in the root zone and wider frequency introduced the crop to water stress, which is very detrimental for crop production. Pawar *et al.* (2002) have also reported better availability of moisture throughout the growth period in drip irrigation and variation of moisture from above field capacity to 50% depletion in surface irrigation.

As depicted in Fig 2 during both the seasons, application of polyethylene mulch under all the irrigation levels and methods raised the soil moisture status by 4-6% approximately. This may be due to the fact that drying trend is markedly reduced as evaporation during day time is the main reason of moisture depletion in the unmulched soil. Furthermore, condensation of evaporated moisture on the lower side of the mulch and its subsequent dripping to the soil surface and lower weed population also help conserve soil moisture. Aggarwal *et al.* (2003) and Singh *et al.* (2004) also reported similar findings.

Onion growth parameters

Significant difference in growth and yield of onion was observed under different irrigation levels and methods and under mulched and unmulched conditions (Table 2). Plant height was observed to be highest under the treatment DI_{100} (58.4 cm) and was found to be statistically at par with DI_{80} (55.2 cm), whereas, lowest (43.9 cm) was recorded in DI_{60} without mulch. It can further be depicted that mulch also significantly affected the plant height and M_1 (53.6 cm) recorded significantly higher values over M_0 (49.5 cm). Number of leaves per plant was not affected significantly by any treatment. Onion yields combined over the two years of the study were not significantly different between DI_{100} (42.4

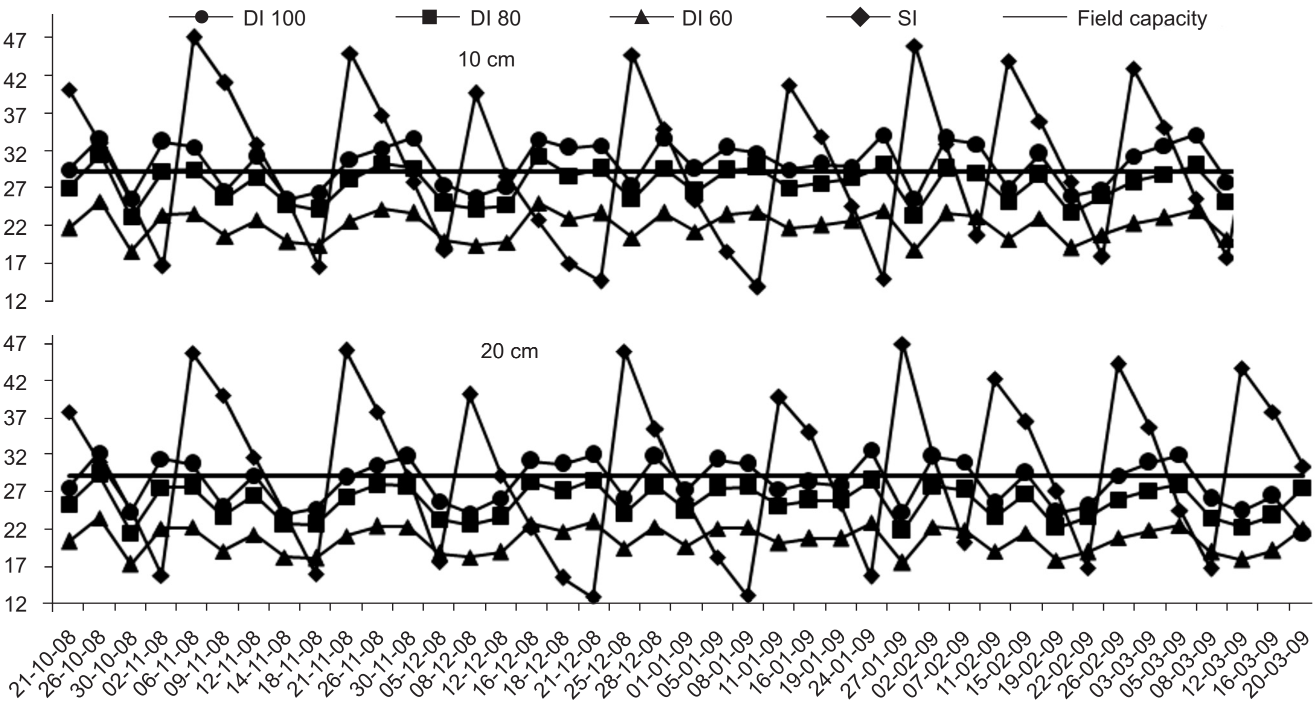

Fig. 1 Volumetric water content (%) of soil (10 and 20 cm depth) under different irrigation methods and levels during 2008-09 under unmulched condition

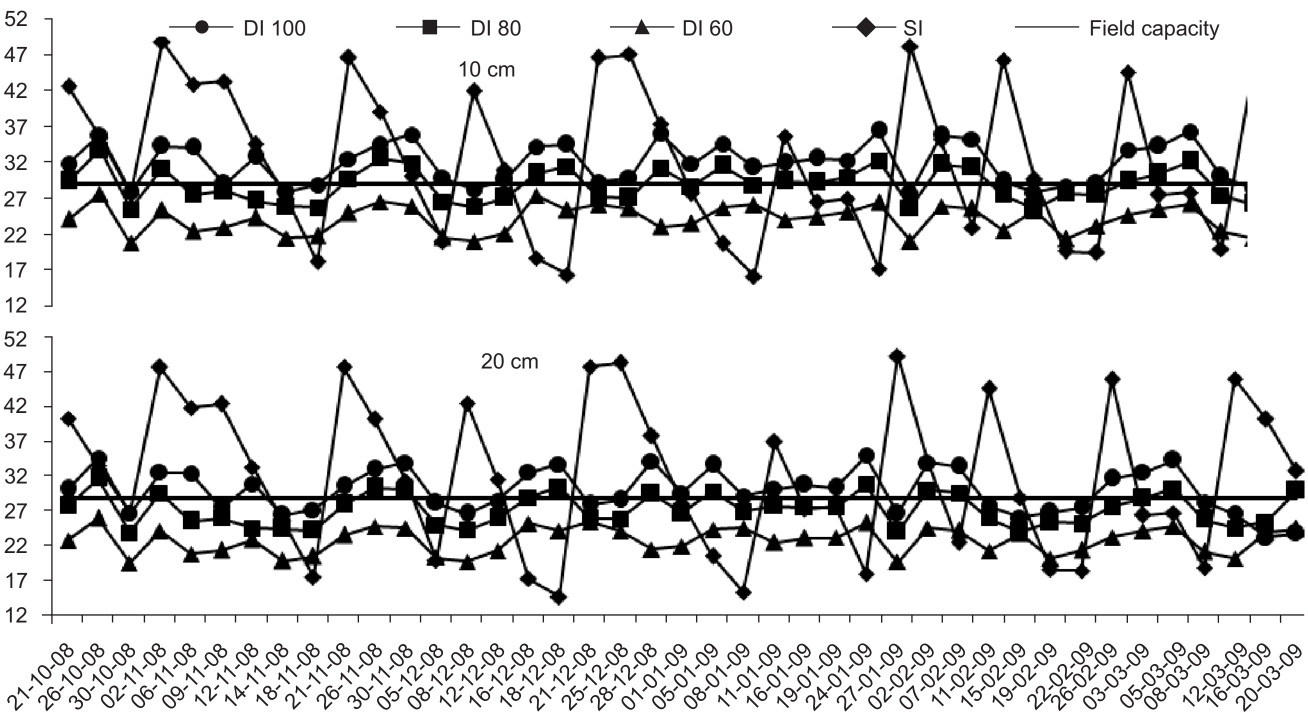

Fig. 2 Volumetric water content of soil (%) (10 and 20 cm depth) under different irrigation methods and levels during 2008-09 under mulched condition

Mt/ha) and DI_{80} (40.6 Mt/ha), whereas statistically lower yields were observed for DI_{60} and Is treatments (Table 2). Mulching also influenced the total yield of onion and M_1 (39.3 Mt/ha) recorded significantly higher values than unmulched treatment. Higher yields in DI_{100} and DI_{80} may be attributed to higher plant stand and better plant growth, which enabled higher accumulation of photosynthates, which was ultimately reflected in higher yields. Furthermore, it is

Table 2 Effect of different irrigation levels, methods and mulching on plant height and number of leaves of onion

Irrigation	Plant height (cm)			Number of leaves			Total Yield (Mt/ha)		
levels	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean
DI_{100}	57.0	59.9	58.4	9.1	8.4	8.8	43.1	45.5	44.3
DI_{80}	52.8	57.6	55.2	8.8	8.3	8.5	37.6	43.5	40.6
DI_{60}	41.5	46.3	43.9	8.0	8.4	8.2	27.4	30.1	28.8
Is	46.6	50.5	48.6	8.3	8.3	8.3	32.1	36.3	34.2
Mean	49.5	53.6		8.6	8.3		35.3	39.8	

Plant height
$CD_{0.05}$ Irrig. levels = 5.52
$CD_{0.05}$ Mulch = 3.90
$CD_{0.05}$ I × M = NS

Number of leaves
$CD_{0.05}$ Irrig. levels = NS
$CD_{0.05}$ Mulch = NS
$CD_{0.05}$ I × M = NS

Total yield
$CD_{0.05}$ Irrig. levels = 6.17
$CD_{0.05}$ Mulch = 4.37
$CD_{0.05}$ I × M = NS

well known fact that drip irrigation ensures better moisture, aeration in the root zone and fluctuation in soil moisture is less (Tiwari *et al.* 2003) soil moisture status in DI_{100} and DI_{80} remained near to the field capacity and constant moisture regime throughout the growth season, indicating that the plants were not subjected to water stress and thus helped in better root growth and bulb development, whereas, in DI_{60} and I_s the moisture status in the root zone attained its optimum value for a very short duration. Beneficial effects of polyethylene mulching, i.e. moisture conservation, moderation of hydrothermal regimes in the soil, weed control etc. might have contributed for the better performance of plants under mulched conditions.

The equatorial diameter of the bulbs (Table 3) was highest (73.1 mm) under DI_{100}, statistically at par with DI_{80} and lowest (55.2 mm) values were recorded for DI_{60}. Similar observations were recorded for polar diameter of the bulbs, highest (43.8 mm) under DI_{100} being statistically at par with DI_{80} and lowest (33.4 mm) under DI_{60} treatment. Surface irrigation although resulted in higher values for these parameters than DI_{60}, but was statistically lower than DI_{100} and DI_{80}. Mulching also influenced both the equatorial and polar diameter of the bulbs and statistically higher values were registered under mulched conditions as compared to unmulched control. The reason might be better moisture regimes, under DI_{100} and DI_{80} as compared to DI_{60} and I_s and also beneficial effects of polyethylene mulching. No significant difference in the total soluble solids in the bulbs produced under different irrigation levels, methods and mulching practices was observed (Table 3). The reason might be that the total soluble solids are more influenced by the genotype than the cultural practices. Tripathi *et al.* (2010) also reported no difference in total soluble solids in the bulbs produced under different irrigation methods.

The total water applied (Table 4) in different irrigation levels and methods during both the seasons was lowest (23.3 and 24.8 cm) in DI_{60} followed by DI_{80} (31.1 and 33.1 cm) and DI_{100} (38.9 and 41.4 cm), respectively. Surface irrigation during both the seasons used highest (55.0 cm) quantity of water. Water saving over surface irrigation was around 30% in DI_{100}, whereas in DI_{80}, further saving of 20% water was achieved. During both the years of study, highest water use efficiency was recorded in DI_{80}, whereas, surface irrigation (I_s) recorded the lowest values. It can further be observed that mulching also increased WUE over the unmulched conditions under all the treatments. The higher water saving and water productivity in drip irrigation system is due to the reduction of various types of water losses, e.g. seepage,

Table 3 Effect of different irrigation levels, methods and mulching on total soluble solids and bulb characters of onion

Irrigation	Equatorial dia. of bulb (mm)			Polar dia. of bulb(cm)			Total soluble solids (^{0} Brix)		
levels	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean
DI_{100}	72.1	74.0	73.1	43.2	44.4	43.8	11.9	11.4	11.6
DI_{80}	66.3	72.2	69.3	40.5	43.2	41.9	11.4	11.5	11.5
DI_{60}	52.1	58.2	55.2	31.3	35.5	33.4	10.4	11.7	11.0
Is	58.2	61.0	59.6	35.4	37.0	36.2	10.8	11.4	11.1
Mean	62.2	66.2		37.5	40.0		11.1	11.5	

Total soluble solids
$CD_{0.05}$ Irrig. levels = NS
$CD_{0.05}$ Mulch = NS
$CD_{0.05}$ I × M = NS

Equatorial dia.
$CD_{0.05}$ Irrig. levels = 7.81
$CD_{0.05}$ Mulch = 3.22
$CD_{0.05}$ I × M = NS

Polar dia.
$CD_{0.05}$ Irrig. levels = 6.83
$CD_{0.05}$ Mulch = 2.44
$CD_{0.05}$ I × M = NS

Table 4 Water use efficiency (tonnes ha/cm) under different irrigation levels, methods and mulching during 2008-09 and 2009-10

Irrigation levels	Total water applied (cm)		Water use efficiency (t ha/cm)	
	M_0	M_1	M_0	M_1
2008-09				
DI_{100}	38.9	38.9	1.05	1.11
DI_{80}	31.1	31.1	1.15	1.33
DI_{60}	23.3	23.3	1.12	1.31
Is	55.0	55.0	0.55	0.63
2009-10				
DI_{100}	41.4	41.4	1.10	1.15
DI_{80}	33.1	33.1	1.20	1.38
DI_{60}	24.8	24.8	1.16	1.27
Is	55.0	55.0	0.62	0.69

evaporation and deep percolation etc. during surface irrigation.

It can be concluded from the studies that drip irrigation at 100 and 80% of ET maintains the moisture status in the root zone near to the field capacity, whereas, in surface irrigation very high variation from field capacity is observed. Application of polyethylene mulch raises the moisture status of the soil owing to reduction of evaporation and weed control. No statistical difference in growth, yield and quality of bulbs under DI_{100} and DI_{80} implies that stressing the crop up to a certain level can be useful in water saving without significant reduction in yield and quality of the produce. 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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