The Bioscan 8(1): 201-206, 2013
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

EFFECT OF WATER REGIME ON GROWTH AND YIELD OF LETTUCE (*LACTUCA SATIVA* L.)

S. K. ACHARYA*, Y. R. SHUKLA AND P. C. KHATIK
Department of Vegetable Science, Dr. Y. S. Parmar Uniersity of Horticulture and Forestry
Nauni, Solan, Himachal Pradesh, INDIA 173230
e-mail: sanjay.acharyahort@gmail.com

KEYWORDS
Water regime
Lettuce
Lactuca sativa and
irrigation water.

Received on :
09.10.2012

Accepted on :
22.01.2013

***Corresponding author**

ABSTRACT

Lettuce (*Lactuca sativa* L.) is one of the most important salad vegetables of the world due to its potential to return profit, nutritional value and production potential. Experiment was carried out in a naturally ventilated polyhouse erected at the experimental farm of the Department of Vegetable Science, Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H P) during 2009-10 and 2010-11. Twelve treatment combinations comprising of three depths of irrigation water (1.0, 1.5 and 2.0cm) and four irrigation intervals (4, 6, 8 and10 days) were replicated thrice in a randomized block design (factorial) having plot size of 1.80m X 1.80m with a spacing of 45 X 30cm. The observations were recorded on ten randomly selected plants on days to marketable maturity, gross head weight (g), number of non wrapper leaves, net head weight (g), heading (%) and yield/m^2 (kg). Analysis of variance showed highly significant differences among different treatments for all the characters studied but treatment combination comprising of 1.5cm of irrigation water applied after 8 days was rated as the best combination for characters like yield, net head weight and number of non wrapper leaves followed by the treatment combination involving 1.5cm of irrigation water when applied after 6 days for characters like gross head weight and days to marketable maturity. About 21.50cm of irrigation water was consumed for producing 43.10 tonnes/ha yield with optimum water productivity of 2.00 tonnes/ha/cm in the treatment combination involving 1.5cm of irrigation water applied after 8 days interval.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is one of the most important salad vegetables of the world. It belongs to family Asteraceae and believed to have originated in Mediterranean region. It was introduced into India by Portuguese (Rai and Yadav, 2005). Lettuce is mainly grown in Europe, Africa and America (Pink and Kaene, 1993). The exact area under lettuce crop is not available, however, in India, lettuce and chicory is grown over an area of 0.159 million hectares with a production of 0.99 million tonnes and productivity of 6.23 t/ha (FAO, 2010). Iron, magnesium, potassium and sodium. It is also known to be sedative, diuretic and Lettuce is a cool season crop grown for its tender head and leaves which are chopped and used as salad with salt and vinegar. It is rich in vitamins A and C and minerals like calcium, expectorant (Kalloo and Parthasarthy, 2003). Lettuce is first cultivated salad crop which is commercialized internationally (Abu-Rayyan *et al.*, 2004). It is the most popular salad egetable according to the highest consumption rate and economic importance throughout the world (Coelho *et al.*, 2005). It is a valuable nutritive food with good taste and thus can be sold at higher prices. However, farmers need to be educated for its production technology including judicious water management. The farmers in this region have adopted high yielding varieties of lettuce having substantial yield potential, but yields are still very low. Different organic constituents of plants such as carbohydrates, proteins, nucleic acids, enzymes etc. lose their physical and chemical properties under water stress. It acts as a solvent and carrier for many substances and helps in the absorption of mineral nutrients. Availability of irrigation water is generally the most important natural factor limiting the widespread development of lettuce production. Due to the number of benefits, cultivation in greenhouse is being promoted in recent years (Kadayifci *et al.*, 2004). Major challenge in greenhouse production is to design package of practices for cropping system management that improves product quality and control environmental impacts (Tourdonnet *et al.*, 2001). Many vegetable crops are shallow rooted and sensitive to mild water stress. The aforesaid constraint can be successfully overcome by developing optimum irrigation schedule under protected conditions. In, successful vegetable production under protected conditions, optimal and timely application of irrigation water is important factor to harvest maximum yield per unit of area and water. Lettuce growth as well as yield has been reported to increase in response to water application (Sanchez, 2000). On the contrary, excessive application of irrigation water results in some serious problems like soft rot (Turkmen *et al.*, 2004). To make optimal use of available water resources, for sustainable agriculture and to eliminate the negative effect of low or high irrigation, the main objective of irrigation is to apply the water only when the plant need it with minimal water loss. The study was carried out with following objectives:

To work out the effect of different water regime on the growth of lettuce.

To find out the effect of different water level on the yield of lettuce.

MATERIALS AND METHODS

The experiment was conducted in Randomized Block Design (Factorial) with12 treatments comprising of three irrigation depths 1.0, 1.5 and 2.0cm and four irrigation intervals at 4, 6, 8 and 10 days with three replication. The plot size 1.8 x 1.8m and spacing 45 x 30cm were kept. The Line CGN-10944, obtained from the Crop Genetic Resources, the Netherlands was selected for the study. The seeds were sown in the month of October 2009 and 2010 in well prepared nursery beds and 30 days old seedlings were transplanted in month of November. All the package of practices and plant protection measures were followed from time to time to ensure a healthy crop stand (Anonymous, 2010). About half litre of water was applied daily to each plant for 10 days for the better establishment of seedlings after transplanting. Measured quantity of irrigation water was applied to each plot in splits as per the treatments with the help of water canes. Water was applied in the plots slowly with care to avoid the over flowing. Observations pertaining to the days to marketable maturity, gross head weight (g), number of non wrapper leaves, net head weight (g), heading (%) and yield/m^2 (kg) were recorded on ten randomly selected plants from each plot. The number of days taken from the date of transplanting to the date when 50 per cent of plants formed marketable heads, Gross head weight included the weight of head at marketable maturity along with the weight of non wrapper leaves and stalk, The outer most leaves which did not wrap the heads at maturity were counted, Net head weight at maturity excluding non wrapper leaves and stalk was taken and heading (%) as well as yield were recorded as per the standard methods and data were analyzed as per the method of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Days to marketable maturity

Pooled analysis of data showed that the effect of depth of irrigation water was significant and the pattern was similar to both the years. Significantly minimum days to marketable maturity were observed with 1.5cm of irrigation water (81.38 days) as compared to D_1 (82.79 days) and D_3 (83.03 days). The effect of different irrigation intervals was also significant with minimum days to marketable maturity (81.38 days) recorded when water was applied after 6 days interval. The interaction effects (D×I) were also significant. Minimum (79.50) days to marketable maturity were recorded when 1.5cm of water was applied after 6 days interval and maximum (84.67 days) in D_3I_1 (2.0cm of irrigation water after 4 days interval). Days to marketable maturity is an important character which decides how early the crop reaches the market and how much additional income it generates by way of its earliness. Pooled analysis of data revealed that 1.5 cm depth of irrigation water produced the plant with earliest maturity and the maturity was delayed as the depth of irrigation water was decreased (1.0cm) or increased (2.0 cm). It appears that the amount of irrigation water supplied by D_2 (1.5cm) might have resulted into better microclimate responsible for water utilization (Taiz and Zeiger, 2002) and excellent soil-air-water relationship with higher oxygen concentration in the root zone (Rathore and Singh, 2009). On the other hand, Jaimez *et al.* (2000) were of the opinion that water stress not only retards growth of the plant but also enhances early maturity of the crop with poor yield in Capsicum. The present results are in line with those of Acar *et al.* (2008) and Bozkurt and Mansuroglu (2011b) who were of the opinion that excess water causes nitrogen losses due to deep percolation, volatilization and denitrification processes and limited water restricts the growth and development of plant. Both these conditions may lead to late maturity where as the optimum water results in better water usage and better soil-air-water relationship with higher aeration of the root zone resulting into normal physiological processes inside the plants and early maturity. Similar results have also been reported by Yazgan *et al.* (2008).

Gross head weight (g)

Pooled analysis showed that the effects of depths of irrigation water were also significant and the trend was similar in both the years. Maximum and significantly higher value was recorded (650.74g) with 1.5cm of irrigation water as compared to D_3 (606.31g) and D_1 (585.70g). The effects of different irrigation intervals were also significant. Maximum values (663.86g) being with 6 days interval and minimum (567.15g) with 8 days interval. The interaction effects (D×I) were also statistically significant. Maximum values (734.00g)

Table 1: Effect of depths of irrigation water and irrigation intervals on mean number of days to marketable maturity of Lettuce grown in polyhouse

Days to marketable maturity												
	2009-10				2010-11				Pooled			
DI	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
I_1	85.00	84.33	84.33	84.56	84.17	83.17	85.00	84.11	84.58	83.75	84.67	84.33
I_2	83.67	80.33	81.67	81.89	83.58	78.67	80.33	80.86	83.63	79.50	81.00	81.38
I_3	81.33	82.00	81.75	81.69	80.50	82.33	84.67	82.50	80.92	82.17	83.21	82.10
I_4	82.00	80.00	83.67	81.89	82.08	80.17	82.83	81.69	82.04	80.08	83.25	81.79
Mean	83.00	81.67	82.85	82.51	82.58	81.08	83.21	82.29	82.79	81.38	83.03	

SE(±)	CD (0.05)	SE(±)	CD (0.05)	SE(±)	CD (0.05)	
y					0.24	NS
D	0.18	0.54	0.56	1.65	0.30	0.85
I	0.21	0.62	0.65	1.91	0.34	0.97
D*I	0.37	1.07	1.13	3.30		
Y*D*I					0.84	2.39

I-Irrigation intervals; D- Depths of irrigation water

Table 2: Effect of depths of irrigation water and irrigation intervals on mean gross head weight (g) of Lettuce grown in polyhouse+

	2009-10				2010-11				Pooled			
DI	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
I_1	586.67	603.33	575.92	588.64	593.33	605.00	612.00	603.44	590.00	604.17	593.96	596.04
I_2	613.50	715.33	635.33	654.72	604.33	752.67	662.00	673.00	608.92	734.00	648.67	663.86
I_3	573.08	625.50	508.58	569.06	561.17	594.92	539.67	565.25	567.13	610.21	524.13	567.15
I_4	585.67	645.20	663.33	631.40	567.83	664.00	653.67	628.50	576.75	654.60	658.50	629.95
Mean	589.73	647.34	595.79	610.95	581.67	654.15	616.83	617.55	585.70	650.74	606.31	

	SE(±)	$CD_{(0.05)}$	SE(±)	$CD_{(0.05)}$	SE(±)	$CD_{(0.05)}$
Y					7.14	NS
D	10.85	31.83	13.72	40.24	8.75	24.93
I	12.53	36.75	15.24	46.46	10.10	28.78
D*I	21.70	63.66	27.44	80.47		
Y*D*I					24.74	70.50

I-Irrigation intervals; D- Depths of irrigation water

Table 3: Effect of depths of irrigation water and irrigation intervals on mean number of non wrapper leaves of Lettuce grown in polyhouse

Number of non wrapper leaves	2009-10				2010-11				Pooled			
DI	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
I_1	7.77	7.40	7.87	7.68	7.53	7.67	7.70	7.63	7.65	7.53	7.78	7.66
I_2	7.73	7.10	7.57	7.47	7.93	7.47	7.97	7.79	7.83	7.28	7.77	7.63
I_3	7.27	6.24	7.50	7.00	7.20	5.93	7.73	6.96	7.23	6.09	7.62	6.98
I_4	7.63	6.70	6.77	7.03	7.73	6.47	7.07	7.09	7.68	6.58	6.92	7.06
Mean	7.60	6.86	7.43	7.30	7.60	6.88	7.62	7.37	7.60	6.87	7.52	

	SE(±)	$CD_{(0.05)}$	SE(±)	$CD_{(0.05)}$	SE(±)	$CD_{(0.05)}$
Y					0.10	NS
D	0.04	0.12	0.25	0.74	0.13	0.37
I	0.05	0.14	0.29	NS	0.15	0.43
D*I	0.08	0.24	0.51	1.49		
Y*D*I					0.36	1.03

I-Irrigation intervals;D-

Table 4: Effect of depths of irrigation water and irrigation intervals on mean net head weight (g) of Lettuce grown in polyhouse

Net Head weight in (g)	2009-10				2010-11				Pooled			
DI	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
I_1	374.00	537.50	559.33	490.28	354.67	490.33	520.33	455.11	364.33	513.92	539.83	472.69
I_2	552.00	536.67	414.67	501.11	471.83	525.00	401.00	465.94	511.92	530.83	407.83	483.53
I_3	364.67	577.67	490.00	477.44	359.00	586.67	477.33	474.33	361.83	582.17	483.67	475.89
I_4	377.33	505.33	548.67	477.11	359.33	510.67	527.00	465.67	368.33	508.00	537.83	471.39
Mean	417.00	539.29	503.17	486.49	386.21	528.17	481.42	465.26	401.60	533.73	492.29	

	SE(±)	$CD_{(0.05)}$	SE(±)	$CD_{(0.05)}$	SE(±)	$CD_{(0.05)}$
Y					6.52	18.58
D	1.44	4.21	15.90	46.62	7.98	22.74
I	1.66	4.87	18.35	NS	9.21	NS
D*I	2.87	8.43	31.79	93.24		
Y*D*I					22.57	64.32

I-Irrigation intervals; D- Depths of irrigation water

were recorded when 1.5cm of irrigation water was applied after 6 days interval followed by 658.50 gram when 2.0cm irrigation water was applied after 8 days interval. The minimum values (524.13g) were, however recorded when 2.0cm of irrigation water was applied after 8 days interval.

Number of non wrapper leaves

Pooled data showed that the effects of depths of irrigation water were significant. Minimum number of non wrapper leaves (6.87) was recorded with 1.5cm of irrigation water as compared to D_3 (7.52) and D_1 (7.60). The effect of different irrigation intervals was also significant with minimum values of non wrapper leaves (6.98) recorded when water was applied after 8 days interval and maximum (7.66) when irrigation water was applied after 4 days interval. The interaction effects $(D \times I)$ were also statistically significant. Minimum number of non wrapper leaves (6.09) was recorded when 1.5 cm of water was applied after 8 days interval and maximum (7.83) in D_1I_2 (1.0cm of irrigation water after 6 days interval). Like yield, non wrapper leaves is an important characters as number of non

Table 5: Effect of depths of irrigation water and irrigation intervals on heading (%) of Lettuce grown in polyhouse

Heading (%)	2009-10				2010-11				Pooled			
DI	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
I_1	91.83 (9.58)#	98.50 (9.92)	98.67 (9.93)	96.33 (9.81)	82.33 (9.07)	97.33 (9.86)	96.33 (9.81)	92.00 (9.58)	87.08 (9.32)	97.92 (9.89)	97.50 (9.87)	94.17 (9.70)
I_2	83.83 (9.16)	88.00 (9.38)	98.17 (9.91)	90.00 (9.48)	79.67 (8.92)	84.57 (9.20)	97.83 (9.89)	87.36 (9.34)	81.75 (9.04)	86.28 (9.29)	98.00 (9.90)	88.68 (9.41)
I_3	70.06 (8.37)	82.67 (9.09)	88.00 (9.38)	80.24 (8.95)	73.69 (8.58)	83.17 (9.12)	87.17 (9.33)	81.34 (9.01)	71.87 (8.48)	82.92 (9.11)	87.58 (9.36)	80.79 (8.98)
I_4	74.08 (8.60)	76.83 (8.77)	85.00 (9.22)	78.64 (8.96)	71.00 (8.43)	79.67 (8.92)	85.67 (9.25)	78.78 (8.87)	72.54 (8.52)	78.25 (8.85)	85.33 (9.24)	78.71 (8.87)
Mean	79.95 (8.93)	86.50 (9.29)	92.46 (9.61)	86.30 (9.28)	76.67 (8.75)	86.18 (9.28)	91.75 (9.57)	84.87 (9.20)	78.31 (8.84)	86.34 (9.28)	92.10 (9.59)	

	SE (±)	$CD_{(0.05)}$	SE (±)	$CD_{(0.05)}$	SE (±)	$CD_{(0.05)}$
Y					0.52(0.03)	NS
D	0.67(0.04)	1.95(0.11)	1.08(0.06)	3.18 (0.17)	0.64(0.03)	1.00(0.09)
I	0.77(0.04)	2.26(0.12)	1.25(0.07)	3.67 (0.20)	0.74(0.04)	2.11(0.11)
D*I	1.33 (0.07)	3.91(0.21)	2.17(0.12)	6.36 (0.35)	1.27(1.07)	3.62(0.20)
Y*D*I					1.80(0.10)	5.13(0.28)

Figures in parenthesis represent square root transformation; I-Irrigation intervals; D- Depths of irrigation water

wrapper leaves is inversely proportional to yield. Less the number of non wrapper leaves more will be the yield and hence, more returns. In the present studies, minimum number of non wrapper leaves were recorded in D_2 (1.5cm) and the number increased when the amount of irrigation water either increased (D_3) or decreased (D_1). In a study with okra, Mishra *et al*. (2009) also reported increase in the number of leaves by increasing the amount of irrigation water and that highest increase in vegetative growth in their best treatment was also due to maintenance of soil moisture at optimum level. It appears that most of the horticultural characters in their studies produced best results at optimum level of irrigation. Similar are the findings of Bozkurt and Mansuroglu (2011a) who also reported that excessive irrigation reduce yield by increasing more number of non wrapper leaves while inadequate irrigation caused water stress and reduced production. Maximum number of non wrapper leaves were produced when irrigation interval was decreased to 4 days (I_1) where as minimum when the irrigation interval was extended to 8 or 10 days. The present results are in line with those of Bozkurt and Mansuroglu (2011a) who reported that excessive irrigation in the form of more frequency reduced the yield and increased the number of non wrapper leaves where as inadequate irrigation caused water stress. Similar are the findings of Yazgan *et al*. (2008). The interaction studies reveals that 1.5cm of irrigation water after 8 days interval produced minimum number of non wrapper leaves probably due to better water utilization and excellent soil-air-water relationship with higher oxygen concentration in the root zone in this combination. Almost identical findings have also been reported by Gornat *et al*. (1993) and Acar *et al*. (2008).

Net head weight (g)

Pooled analysis showed that the effects of depths of irrigation water were significant. Maximum and significantly higher value was observed (533.73g) with 1.5cm of irrigation water as compared to D_3 (492.29g) and D_1 (401.60g). On the other hand, the interaction effects (D×I) were statistically significant. Maximum value (582.17g) was recorded when 1.5cm of irrigation water was applied after 8 days interval and minimum (361.83g) when 1.0cm of irrigation water was applied after 8 days interval. Net head weight gives exact picture of yield as this character is directly correlated with the total marketable yield, since it excludes non wrapper leaves. In the present studies, net head weight was more when 1.5 cm (D_2) of irrigation water was applied than less (1.0cm) or more (2.0cm) water. There was linear increase in the net head weight with the gradual increase in amount of irrigation water from D_1 (1.0cm) to D_2 (2.0cm) but later on the net head weight decreased when the quantity of irrigation water was further increased. Bozkurt *et al*. (2009) were also of the opinion that increasing or decreasing the amount of irrigation water directly affects the net head weight and yield in lettuce. The reduction in net head weight due to excessive water may be because of 'N' losses especially deep percolation, volatilization and denitrification processes where as more head weight was due to optimum water usage and better soil-air-water relationship with higher aeration in the root zone. In an irrigation study with radish, Kapur *et al*. (2006) reported increase in yield by increasing the water from 0.6 to 0.8 IW/CPE ratio, however,

Table 6: Effect of depths of irrigation water and irrigation intervals on mean yield / m² (kg) of Lettuce grown in polyhouse

Yield per m² (kg)												
	2009-10				2010-11				Pooled			
DI	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
I_1	2.77	3.98	4.15	3.63	2.63	3.63	3.85	3.37	2.70	3.81	4.00	3.50
I_2	4.09	3.97	3.07	3.71	3.50	3.89	2.97	3.45	3.79	3.93	3.02	3.58
I_3	2.70	4.28	3.63	3.54	2.66	4.34	3.53	3.51	2.68	4.31	3.58	3.52
I_4	2.80	3.74	4.06	3.53	2.66	3.78	3.90	3.45	2.73	3.76	3.98	3.49
Mean	3.09	3.99	3.73	3.60	2.86	3.91	3.56	3.45	2.98	3.95	3.65	

SE(±)	CD $_{(0.05)}$	SE(±)	CD $_{(0.05)}$	SE(±)	CD $_{(0.05)}$	
Y					0.05	0.14
D	0.01	0.03	0.12	0.35	0.06	0.17
I	0.01	0.04	0.14	0.40	0.07	NS
D*I	0.02	0.06	0.24	0.69		
Y*D*I					0.17	0.48

I-Irrigation intervals; D- Depths of irrigation water

the water use efficiency and yield declined when quantity of irrigation water was further increased from 0.8 to1.0 IW/CPE ratio. There was a significant effect of irrigation intervals and irrigating the crop after 6 days (I_2) produced maximum net head weight instead of 4, 8 or 10 days. It has been reported by Adentuji (1990) that higher or lower irrigation frequency is of no use and that appropriate frequency could be used to alleviate soil moisture stress and increased yield. Caldwell *et al*. (1994) were of opinion that medium frequency is responsible for higher irrigation water use efficiency mainly because of better storage of irrigation water in the root zone and the reduction of deep percolation below the root zone. In the present studies, irrigating the crop after 8 days interval with 1.5cm of irrigation water produced the best results in terms of net head weight probably due to better water utilization and excellent soil-air-water relationship with higher oxygen concentration in the root zone. Similar are the findings of Manfrinato (1971), Gornat *et al*. (1993) and Acar *et al*. (2008). Lam and Trooein (2003) were of the opinion that increase in corn production is a function of climate, soil and crop production practices and is rarely affected by other factors like irrigation interval or level.

Heading (%)

Pooled analysis of data showed that the effects of depths of irrigation water were also significant and the pattern was similar in both the years. Maximum and significantly more head formation (92.10%) was observed with 2.0cm of irrigation (D_3) water as compared to D_2 (86.34%) and D_1 (78.31%). The effects of different irrigation intervals were also significant with maximum values (94.17%) recorded when water was applied after 4 days interval and minimum (78.71%) when water was applied after 10 days interval. The interaction effects (D×I) were also statistically significant. Maximum (98.00%) head formation was recorded when 2.0cm of irrigation water was applied after 6 days interval and minimum (71.87%) when 1.0cm of irrigation water after 8 days interval. The results of both the years (2009-10 and 2010-11) depicted that the heading percentage was not affected significantly by different years of study. Acar *et al*. (2008) observed increase in compact leaf number and plant head weight with increase in amount of irrigation water resulting into more yield and heading probably due to better water utilization and excellent soil-water-air relationship with higher oxygen concentration in the root zone. Almost similar results have also been observed by Manfrinato (19971) and Gornat *et al*. (1993). The present studies also reveal that by decreasing the irrigation frequency the heading percentage decreased. The interaction results reveal that irrigating the crop after 6 days with 2.0cm of irrigation water produced the plants with maximum percentage of heading than by irrigating the plants at 8 days interval with 1 .0cm of irrigation water. The present studies shows that irrigating the crop frequently with little bit more water resulted in increased heading than irrigating with less amount of water at slightly longer irrigation intervals. Similar are the findings of Bozkurt *et al*. (2009).

Yield/m² (kg)

Pooled analysis of the data showed that the effect of depths of irrigation water was significant. Maximum and significantly higher yield/m² was observed (3.95 kg/m²) with 1.5cm of irrigation water as compared to D_3 (3.65 kg/m²) and D_1 (2.98 kg/m²). Maximum values (3.58 kg/m²) being with 6 days interval and minimum (3.49 kg/m²) with 10 days interval. The interaction effects (D×I) were statistically significant. Maximum values (4.31 kg/m²) were recorded when 1.5cm of irrigation water was applied after 8 days interval followed by 4.00 kg/m² when 2.0cm irrigation water was applied after 4 days interval. The minimum values (2.68 kg/m²) were, however recorded when 1.0cm of irrigation water was applied after 8 days interval. The pooled analysis of data shows that more yield was produced in the interaction D_2I_3 (1.5cm of irrigation water was applied after 8 days) which was comparatively more as compared to D_3I_1 (2.0cm of irrigation water was applied after 4 days) and D_3I_4 (2.0cm of irrigation water was applied after 10 days). This may be due to the fact that 1.5cm of irrigation water might have been utilized completely by the plants in 8 days rather than little more water during shorter period or less water during shorter or extended period. The present results are in accordance with the earlier findings of Adentuji (1990) and Lorenz and Maynard (1980). Water is an essential component of photosynthesis and plays a key role in transpiration, stomatal opening and growth and expansion of leaf. In the present findings also, optimum performance of all the components as a result of water balance provided by appropriate quantity of water at desired interval may have resulted in steady active plant growth resulting into maximum possible yield. Rathore and Singh (2009) also emphasized the importance of irrigation at appropriate time as plant tissue contains more than 95 per cent of water which should be maintained for keeping the plant photosynthetically active resulting into proper growth and development and ultimately yield. Increasing the amount of irrigation water after certain period increased the water available for both evaporation and transpiration. Also, frequent or delayed irrigation adversely affected the yield especially in the polyhouses where the evaporation and transpiration loses are more compared to open, thus the yield is not only a function of varieties or climate but also a function of improved cultural practices specially the amount of water applied and its exact interval. Almost identical results have also been reported by Garcia *et al*. (2010).

REFERENCES

Abu-Rayyan, A., Kharawish, B. H. and AlIsmail, K. 2004. Nitrate content in lettuce (*Lactuca sativa* L.) heads in relation to plant spacing, nitrogen form and irrigation level. *J. Science and Food Agriculture*. **84**: 931-936.

Acar, B., Paksoy, M., Turkama, O. and Seyman, M. 2008. Irrigation and nitrogen level affect lettuce yield in greenhouse condition. *African J. Biotechnology*. **7(24):** 4450-4453.

Adetunji, I. A. 1990. Effect of mulches and irrigation on growth and yield of lettuce in semi arid region. *Biotronics*. **19**: 93-98.

Anonymous 2010. Package of practices for vegetable crops. Directorate of Extension Education, Dr. Y.S. Parmar UHF, Nauni, Solan, HP, 202p.

Bozkurt, S. and Mansuroglu, G. S. 2011a. Lettuce yield responses to different drip irrigation levels under open field condition. *J. Cell and Plant Science*. **2(2):**12-18.

Bozkurt, S. and Mansuroglu, G. S. 2011b. Effect of drip line depths and irrigation levels on yield, quality and water use characteristics of lettuce under greenhouse condition. *African Journal of Biotechnology*. **10(17):** 3370-3379.

Bozkurt, S., Mansuroglu, G. S., Kara, M. and Onder, S. 2009. Response of lettuce to irrigation levels and nitrogen forms. *African J. Agricultural Research*. **4(11):** 1171-1177.

Caldwell, D. S., Spurgon, W. E. and Manges, H. L. 1994. Frequency of drip irrigation for subsurface drip irrigated corn. *Trans ASAE*. **41(5):**1099-1103.

Coelho, A. F. S., Gomes, E. P., Sousa, A., De, P. and Gloria, M. B. A. 2005. Effect of irrigation level on yield and bioactive amine content of American lettuce. *J. the Science of Food and Agriculture*. **85(6):** 1026-1032.

FAO 2010. http://www.faostat./site/567/default.aspx.

Garcia, A. G., Persson, T., Guerra, L. C. and Hoogenboom, G. 2010. Response of soybean genotype to different irrigation regimes in a humid region of the southeastern USA. *Agricultural Water Management*. **97:** 981-987.

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for Agricultural Research. *J. Wiley and Sons. Inc.*, New York pp. 357-427.

Gornat, B., Goldberg, D., Rimon, D. and Asher, Ben J. 1993. The physiological effect of water quality and method of application on tomato, cucumber and pepper. *Journal of American Society of Horticulture Science*. **98(2):** 202-205.

Jaimez, R. E., Vielma, O., Rada, F. and Garcia Nunez, C. 2000. Effect of water deficit on the ynamics of flowering and fruit production in *Capsicum chirences* Jasg in a tropical semi arid region of Vinezuela. *J. Agronomical Crop Sciences*. **185**:113-119.

Kadayýfcý, A., Tuylu, G. I., Uçar, Y. and Çakmak, B. 2004. Effects of mulch and irrigation water amounts on lettuce's yield, evapotranspiration, transpiration and soil evaporation in Isparta location. *Turky J. Biological Sciences***. 4(6):** 751-755.

Kalloo, G. and Parthasarthy, V. A. 2003. Lettuce. *In*: Bose, T. K., Kabir, J. and Maity, T. K. (*eds*). Vegetable Crops. *Kolakta; Naya Prokash*. pp. 347-398.

Kapur, O. C., Masand, S. S. and Sharma, Pradeep K. 2006. Effect of irrigation management and mulching on Radish under limited water resource. *J. Water Management*.**14(2):**128-132.

Lorenz, O. A. and Maynard, D. N. 1980. *Knoff's Handbook for Vegetable growers. 2nd ed.* Wiley-*Interscience Publication,* New York p.582.

Manfrinato, H. A. 1971. Effect of drip irrigation on soil water plant relationship. Second International Drip Irrigation Congress, pp 446-451.

Mishra, J. N., Paul, J. C. and Pradhan, P. C. 2009. Response of okra to drip irrigation and mulching in coastal Orissa. *Indian J. Soil Conservation*. **37(2):**129-132.

Pink, D. A. C. and Kaene, Eavan, M. 1993. Lettuce (In) : Genetic improvement of vegetable crops (ed. Kalloo G and Bergh B O), *Pergamon Press, Oxford*. pp. 543-572.

Rai, N. and Yadav, D. S. 2005. Advances in vegetable production. New Delhi, Researchco Book Centre. pp. 550-558.

Rathore, A. C. and Singh, J. N. 2009. Optimization of nitrogen application and irrigation for improved growth and spike production of tuberose (*Polianthus tuberose* L.). *Indian J. soil Conservation*. **37(1):** 45-49.

Sanchez, C. H. A. 2000. Response of lettuce to water and nitrogen on sand and the potential for leaching of nitrate N. *Horticulture Science*. **35(1):** 73-75.

Taiz, L. and Zeiger, E. 2002. "Stress Physiology" In:Plant Physiology, 3rd ed., Sunderland, Massachusetts, USA: Sinaeur Assoc. *Inc. Pub*. pp. 591-620.

Tourdonnet, S., Meynard, J. M., Lafolie, F., Roger-Estrade, J., Lagier, J. and Sebillotte, M. 2001. Non-uniformity of environmental conditions in greenhouse lettuce production increases the risk of pollution and lower product quality. *Agronomie*. **21**: 297–309.

Turkmen, O., Bozkurt, M. A., Yýldýz, M. and Çimrin, K. M. 2004. Effect of nitrogen and humic acid applications on the head weight, nutrient and nitrate contents in lettuce. *Advanced Food Science*. **26(2):** 59-63.

Yazgan, S., Ayas, S., Demirtas, C., Buyukcangaz, H. and Candogan, B. N. 2008. Deficit irrigation effects on lettuce (*Lactuca sativa var. Olenka*) yield in unheated greenhouse condition. *J. Food Agriculture and Environment*. **6(2):** 357- 361.