Indian J. Hort. 69(3), September 2012: 360-368

Influence of irrigation interval, nitrogen level and crop geometry on production of trickle irrigated lettuce

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ABSTRACT

Field experiments were conducted during winter season (October to February) of 2008-09 and 2009-10 to investigate the growth and yield response of lettuce to different irrigation intervals, nitrogen application rates and different crop geometries under trickle irrigation. The plan of experiment included three crop geometries [45 × 30 (G_1); 30 × 30 (G_2) and 17.5 × 30 (G_3) (Row × plant spacing in cm)], two irrigation schedules [2 days (I_1) and 4 days (I_2) interval] and two levels of nitrogen application [60 kg ha^{-1} (N_1) and 100 kg ha^{-1} (N_2)]. For both the experiments there were three replications. The coefficient of variation of the emitter discharge used in trickle irrigation system was 0.059 and 0.091 in 2008-09 and 2009-10, respectively. The results revealed that lettuce raised with 17.5 cm × 30 cm crop spacing, along with two day irrigation interval and 100 kg N ha^{-1} application gave the maximum plant height (18.5 and 17.3 cm), leaf area index (2.37 and 2.27) and marketable yield (43.06 and 39.64 t/ha). Maximum number of leaves (19 and 16), head weight (347.4 and 312.6 g) and head diameter (13.9 and 12.5 cm) with 45 cm × 30 cm crop spacing, along with two day irrigation interval and 100 kg N ha^{-1} application rate. It can be concluded from field experimental data that two day irrigation interval with 100 kg N ha^{-1} application if coupled with closer row spacing may result in higher marketable yield in lettuce.

Key words: Crop geometry, growth, lettuce, trickle irrigation, yield.

INTRODUCTION

Water availability is a major limiting factor for successful agriculture in arid and semi-arid regions. Thus, sufficient and balanced use of water and nutrients is essential to obtain maximum productivity (Turkmen *et al.*, 18). To make optimal use of water resources for sustainable agriculture and to eliminate the negative effects of irrigation to the ecology, the main objective of irrigation should be to apply water in that quantity and timing as required by the plant. The highest crop yield and water use efficiency (WUE) could be achieved in trickle irrigation as compared to surface irrigation (Rajput and Patel, 13).

Lettuce (*Lactuca sativa* L.), a cool-season vegetable crop, is most popular according to the consumption rate and economic importance throughout the world (Coelho *et al.*, 5). In India, lettuce is cultivated on an area of about 0.12 M ha with an average productivity of 6.58 t ha^{-1} (FAO, 7). Major reasons of the low productivity of lettuce may be attributed to faulty irrigation methods, improper fertigation and lack of knowledge regarding optimum crop geometry. Presently, entry of multi-national companies into Indian food and catering industries and economic growth has dramatically changed the eating habits and consumption pattern of people. This has resulted into more use of salad crops like lettuce in the Indian diet. Because of this, the lettuce crop may have a greater demand in domestic market in future. Besides, it has a good export potential (Sidhu, 14). Very few studies have been done to standardize the irrigation and fertigation strategies along with crop geometry for trickle irrigated lettuce (Bozkurt *et al.*, 4). Hence, the present study was conducted with the objective of evaluating the impact of different irrigation schedules and nitrogen application rates in combination with different crop geometries on lettuce crop.

MATERIALS AND METHODS

The experiments were conducted with lettuce crop (cv. Iceberg) at the Centre for Protected Cultivation Technology (CPCT), IARI, New Delhi during winter season (Oct. to Feb.) in 2008-09 and 2009-10. The experimental site is located at 28° 38’ 22” N, 77° 10’ 24” E with an altitude of 228.61 m amsl. Overall weather conditions during crop growing season in both of the experiments was optimal (Table 1).

Soil analysis revealed that the soil was sandy clay loam in texture, with a neutral pH (7.2) and low in organic carbon (0.23%). Average field capacity and permanent wilting point of soil were 26 and 9% respectively. Porosity was approximately 40%, soil belongs to good class with average hydraulic conductivity of 1.1 cm h^{-1}. The depth-wise properties of soil in the experimental field are given in Table 2. The trickle irrigation system

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was designed and installed to meet the layout and design of experiment. The system consisted of pump, a control head unit, polyethylene mainline (Diameter (Φ) 75 mm) and laterals with inline emitters spaced at 30 cm operating at a constant pressure of 2 kg cm^{-2} with 2 l h^{-1} (Φ 16 mm). Sand and disc filters were installed on the mainline to minimize emitter blockage. Laterals were laid adjacent to crop row spaced at 45 cm. Each experimental plot had a separate control valve to deliver the desired amount of water.

The experiment was laid out following factorial randomized block design (RBD) with three main treatments and three replications. These treatments were three crop geometries [G_1: 45 × 30; G_2: 30 × 30 and G_3: 17.5 × 30] (Row × Plant spacing in cm), two irrigation schedules [2 day (I_1) and 4 day (I_2) interval] and 2 levels of nitrogen (N) application [60 kg N ha^{-1} (N_1) and 100 kg N ha^{-1} (N_2)]. Twenty-one-day-old lettuce (cv. Iceberg) seedlings were transplanted on 11th November during 2008-09 and 16th November during 2009-10, as per crop geometry treatments. The growing period of lettuce was around three months (transplanting to final picking). During the field preparation, Confidora (2 ml l^{-1}) was sprayed to prevent termite infestation. Similarly, carbendazim (1 g l^{-1}) and captan (2 g l^{-1}) were sprayed twice to prevent root rot disease. Before transplanting, 15 t ha^{-1} of farm yard manure (FYM) was applied to the field. The recommended basal dose of fertilizers for lettuce crop, 60_P : 45_K kg ha^{-1} was given through soil application of single super phosphate and muriate of potash, respectively. Treatment wise requirement of urea was determined according to the net plot size, and applied in three splits 15, 35 and 65 days after transplanting. Just prior to transplanting, the entire field was uniformly pre-irrigated and light irrigations were applied after planting to ensure establishment of seedlings. Hand weeding was carried out five times during the growing season.

Irrigation in all treatments was scheduled based on reference evapo-transpiration (ET_0) to avoid any moisture stress during crop growth period. ET_0 was estimated as per the equation given by FAO-56 Penman-Montecito method (Allen *et al.*, 2) using five years (2003 to 2007) meteorological data of the study site. During the occurrence of rainfall, irrigation requirement was calculated after subtracting corresponding effective rainfall from ET_0. During the year 2008-09, total depth of water applied for 2 and 4 day irrigation interval was 168 mm. While for the year 2009-10, it was 167 mm. Irrigation was stopped 10 days before harvest to allow the crop to mature.

The emission uniformity of water application was carried out at the start of the season. The discharge from 60 emitters were measured for 10 min. at pressure of 2 kg cm^{-2}, in three replications. The equation given by Nakayama and Bucks (11) was used to compute the statistical parameters and analyze uniformity of trickle system. Each biometric observation was recorded as

Table 1. Weather parameters recorded during the period of experimentation.

Month	T_{max} (°C)		T_{min} (°C)		RH (%)		Total rainfall (mm)		Evaporation (mm/day)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Oct	32.9	32.5	18.6	17.1	59.3	60.7	0.0	0.3	4.5	4.6
Nov	27.7	26.5	10.8	12.3	63.0	69.5	0.0	14.2	2.7	2.8
Dec	23.4	22.7	8.2	7.4	69.7	66.9	0.0	1.0	1.9	2.0
Jan	20.5	17.9	7.2	6.7	76.3	78.2	4.3	0.0	1.8	1.6
Feb	24.6	23.2	9.4	8.8	63.8	66.0	6.5	13.0	2.5	2.7

Source : Agromet. Observatory, Division of Agricultural Physics, IARI, New Delhi.

Table 2. Soil physical properties of the experimental field.

Depth (cm)	Mineral content (%) mass			Textural class	Hydraulic conductivity ($cm\ h^{-1}$)	Bulk density ($g\ cm^{-3}$)	FC (Vol. %)	PWP (Vol. %)
	Clay	Silt	Sand					
0-15	16	12	72	Sandy loam	1.22	1.56	20.67	6.48
15-30	21	10	69	Sandy clay loam	1.39	1.63	26.17	8.10
30-45	24	20	56	Sandy clay loam	0.70	1.57	27.11	10.27
45-60	22	26	52	Sandy clay loam	1.09	1.56	26.36	10.84

FC = Field capacity, PWP = Permanent wilting point average of three randomly selected plants of particular treatment. Plant height, number of functional leaves and leaf area were measured at initial, developmental and maturity stage of lettuce. Leaf area index (LAI) was estimated from leaf area. Yield attributes like head weight, head diameter, and marketable yield were determined using standard procedures. The total lettuce yield after each picking was computed and expressed as kg/ha. The data were analyzed using MSTATC (v.2.1, Michigan State University) software. Analysis of variance (ANOVA) was conducted and significance of differences among the treatments was tested using the least significant difference (LSD). The F-protected LSD was calculated at the 0.05 probability level according to Steel and Torrie (16).

RESULTS AND DISCUSSION

The results depicting the uniformity of trickle irrigation system for the experiments carried out during 2008-09 and 2009-10 have been presented in Table 3. The coefficient of variation of emitter flow rates were 0.059 and 0.091 during 2008 and 2009, respectively. Low CV indicated good performance of the system throughout the cropping season. The values of emission uniformity (EU) were greater than 90.0% during the two cropping seasons. According to Pitts (12), EU greater than 90.0% implied excellent functioning of the drip system. Results of growth and yield attributes have also been presented in Table 4. Data from both the years indicate that irrigation treatment I_1 had highest plant height values (16.6 and 15.5 cm), maximum number of leaves (15 and 14) and higher leaf area index (1.57 and 1.51). This treatment also sustained its superiority in terms of highest values of yield attributes. The lettuce head weight (293.84 and 267.16 g), head diameter (12.6 and 11.5 cm) and total yield (34.4 and 31.3 t ha^{-1}) had maximum values. The effect of irrigation frequency on growth and yield attributes has been investigated and similar results reported by Jordan *et al*. (8).

The maximum nitrogen application treatment (N_2) resulted in higher plant height (16.7 and 15.3 cm), higher number of leaves (15 and 13) and higher leaf area index (1.59 and 1.49) during both seasons. As expected, this treatment gave maximum head weight (277.05 and 231.37 g) and diameter (11.9 and 9.9 cm), ultimately resulting into maximum yield (25.5 and 27.1 t ha^{-1}). The increase in growth and yield attributes as a response to increased N fertilization is probably due to enhanced availability of nitrogen which enhanced leaf area resulting in higher photoassimilates, thereby more dry matter accumulation. Squire *et al*. (15) established that the main effect of N fertilizer was to increase the rate of leaf expansion, leading to increased interception of daily solar radiation by the canopy. Boroujerdnia and Ansari (3) also reported similar findings.

The crop geometry of wider spacing (G_1) resulted in lettuce crop having heads with higher weight (298.43 and 246.70 g) and diameter (12.0 and 9.1 cm). Higher number of leaves (17 and 14) was also observed in wider crop geometry. Whereas plants with closer spacing (G_3) exhibited higher plant height (16.9 and 15.4 cm) and higher leaf area index (2.1 and 1.9), in turn resulting in higher total yield (37.02 and 31.28 t ha^{-1}) during both years. Das *et al*. (6) reported similar findings wherein closely spaced plants with higher plant height absorbed more solar radiation owing to their superior intra-specific competence for light, water and nutrients. Crop geometry significantly affected yield attributes such as single head weight, head diameter and marketable yield (Karam *et al.*, 9; Bozkurt *et al.*, 4).

Among the treatments combining irrigation interval and nitrogen application (Fig. 1), $I_1 \times N_2$ was superior during both the crop seasons. The plants exhibited maximum values of plant height (17.4 and 16.3 cm), number of leaves (16 and 14), leaf area index (1.68 and 1.51), single head weight (307.8 and 279.8 g), head diameter (13.2 and 12.0 cm) and ultimately total yield (36.0 and 32.8 t ha^{-1}). In both seasons, minimum values of lettuce growth and yield parameters were observed in $I_2 \times N_1$. The continuous wetting of active root zone and easy availability of nutrients at upper layer leads to more yield under the I_1xN_2 treatment. The present results are in line with the findings of Acar *et al*. (1). Fig. 2 indicates that lettuce crop subjected to treatment combination $I_1 \times G_1$ exhibited maximum number of leaves (18 and 15), single head weight (331.59 and 298.43 g) and head diameter (13.3 and 12.0 cm). While the combination $I_1 \times G_3$ resulted in maximum values for plant height (17.6 and 16.5 cm), leaf area index (2.21 and 2.12) and total yield (41.1 and 37.8 t ha^{-1}). The continuous wetting of active root zone with higher plant density resulted into maximum

Table 3. Coefficient of variation (CV) and emission uniformity of inline surface drip system.

Year	Coefficient of variation (CV)	Emission uniformity (%)
2008-09	0.059	95
2009-10	0.091	92

Table 4. Growth and yield parameters of lettuce as affected by irrigation frequency, nitrogen and crop geometry.

Treatment	Plant height (cm)		No. of leaves/plant		Leaf area index		Head wt. (g)		Head dia. (cm)		Yield (t/ ha)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
I_1	16.6	15.5	15	14	1.57	1.51	293.8	267.2	12.6	11.5	34.4	31.3
I_2	15.3	14.3	14	12	1.42	1.37	235.1	213.7	10.1	9.2	27.5	25.1
CD at 5%	0.086	0.078	0.235	0.256	0.008	0.007	2.61	2.59	0.1124	0.1102	0.3063	0.3053
N_1	15.2	13.7	14	12	1.39	1.28	251.9	210.3	10.8	9.0	29.47	24.7
N_2	16.7	15.3	15	13	1.59	1.47	277.0	231.4	11.9	9.9	32.42	27.1
CD at 5%	0.086	0.064	0.235	0.209	0.008	0.006	2.61	2.12	0.1124	0.08995	0.3063	0.2493
G_1	14.9	13.5	17	14	0.91	0.84	298.4	246.7	12.0	9.9	26.51	21.9
G_2	16.0	14.5	14	12	1.47	1.35	258.5	216.1	11.3	9.5	29.32	24.5
G_3	16.9	15.4	12	11	2.10	1.93	236.4	199.8	10.8	9.1	37.02	31.3
CD at 5%	0.047	0.031	0.381	0.229	0.027	0.007	1.37	0.829	0.02737	0.00688	0.2370	0.1685
$I_1N_1G_1$	14.8	13.8	17	15	0.89	0.86	315.8	284.2	12.7	11.4	28.1	25.3
$I_1N_1G_2$	15.9	14.8	14	13	1.43	1.38	273.5	248.9	12.0	10.9	31.0	28.2
$I_1N_1G_3$	16.8	15.7	12	12	2.06	1.98	250.2	230.2	11.4	10.5	39.2	36.0
$I_1N_2G_1$	16.3	15.2	19	16	1.03	0.99	347.4	312.6	13.9	12.5	30.9	27.8
$I_1N_2G_2$	17.5	16.3	15	15	1.65	1.58	300.9	273.8	13.2	12.0	34.1	31.0
$I_1N_2G_3$	18.5	17.3	14	13	2.37	2.27	275.2	253.2	12.6	11.6	43.1	39.6
$I_2N_1G_1$	13.6	12.7	15	13	0.80	0.78	252.6	227.4	10.1	9.1	22.4	20.2
$I_2N_1G_2$	14.6	13.7	13	11	1.29	1.25	218.8	199.1	9.6	8.7	24.8	22.6
$I_2N_1G_3$	15.4	14.4	11	10	1.85	1.80	200.2	184.1	9.2	8.4	31.3	28.8
$I_2N_2G_1$	15.0	14.0	17	15	0.93	0.89	277.9	250.1	11.1	10.0	24.7	22.2
$I_2N_2G_2$	16.1	15.0	14	12	1.48	1.44	240.7	219.0	10.5	9.6	27.3	24.8
$I_2N_2G_3$	17.0	15.9	12	11	2.13	2.07	220.2	202.6	10.1	9.3	34.5	31.7
CD at 5%	0.095	0.075	0.762	0.561	0.017	0.017	2.74	2.03	0.05474	0.01685	0.4740	0.4128

Irrigation frequency
I_1 : Two day irrigation interval
I_2 : Four day irrigation interval

Nitrogen application rate
N_1 : 60 kg/ha N application
N_2 : 100 kg/ha N application

Crop geometry
G_1 : 45 cm x 30 cm
G_2 : 30 cm x 30 cm
G_3 : 17.5 cm x 30 cm

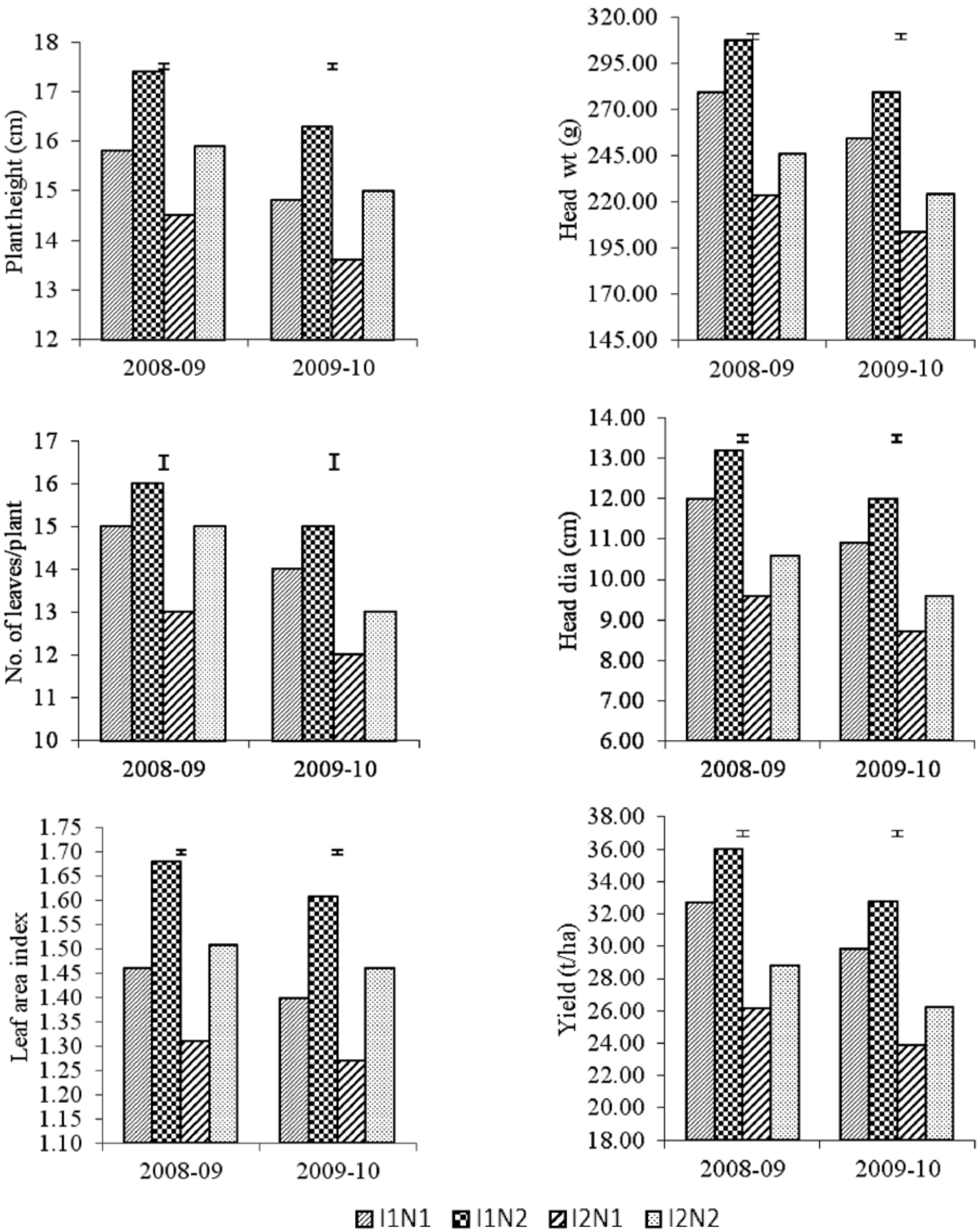

Fig. 1. Interactive effect of irrigation interval and N application rate on growth and yield parameters.

plant height, LAI and yield, whereas continuous wetting coupled with lesser plant density led to higher single head weight and head diameter, thus enhancing the crop quality parameters.

The interactive effect of nitrogen application and crop geometry on lettuce (Fig. 3) revealed that treatment combination $N_2 \times G_3$ exhibited higher values of plant height, leaf area index and total

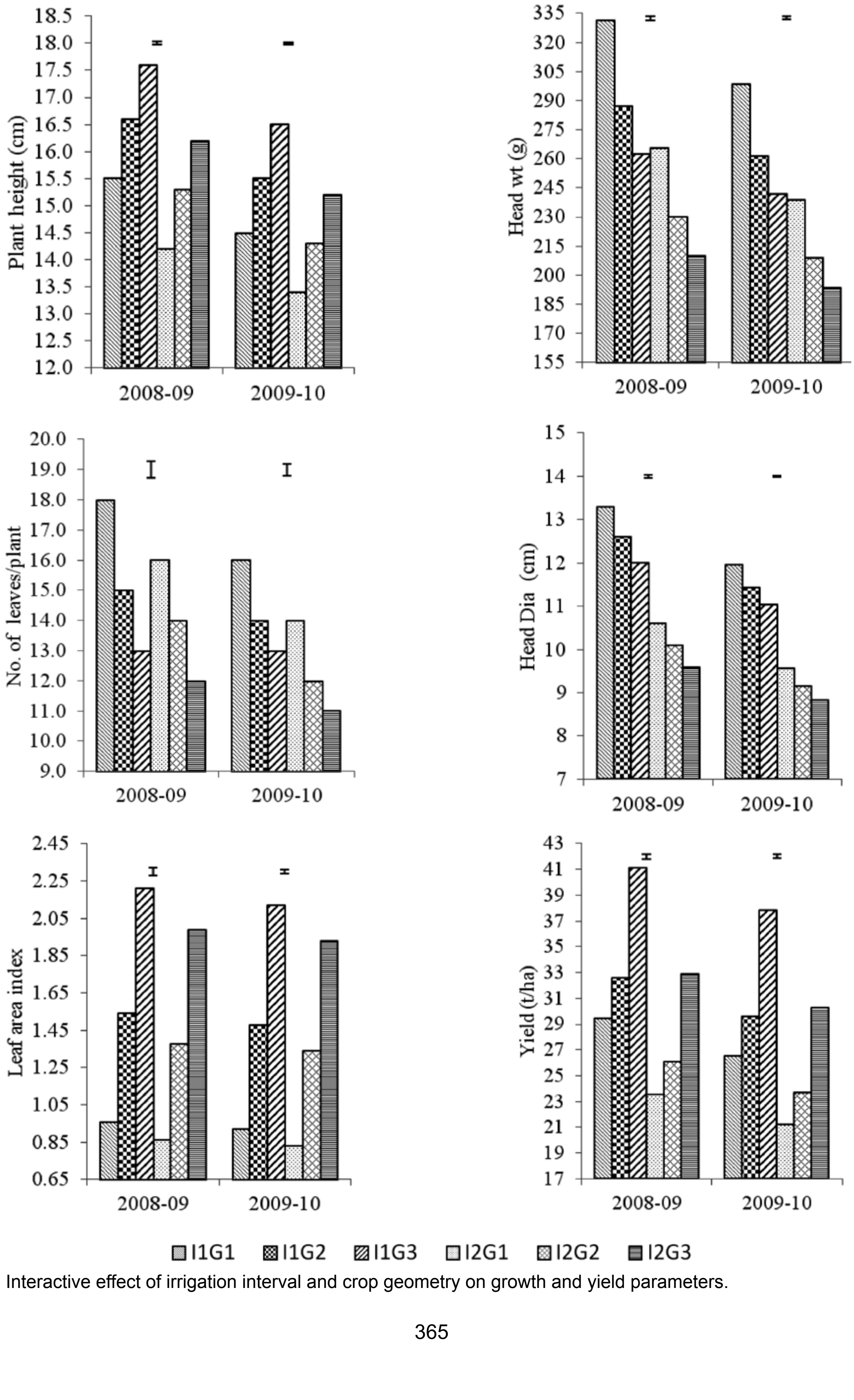

Fig. 2. Interactive effect of irrigation interval and crop geometry on growth and yield parameters.

yield, while maximum values for single head weight and, head diameter and number of leaves were observed in treatment $N_2 \times G_1$ during both seasons. Significant effects on growth and yield parameters due to nitrogen levels and spacing has also been reported by Mahmood *et al*. (10). Interactive effect of the three factors on lettuce growth and yield attributes are presented in Tables 4, respectively. Treatment $I_1 \times N_2 \times$

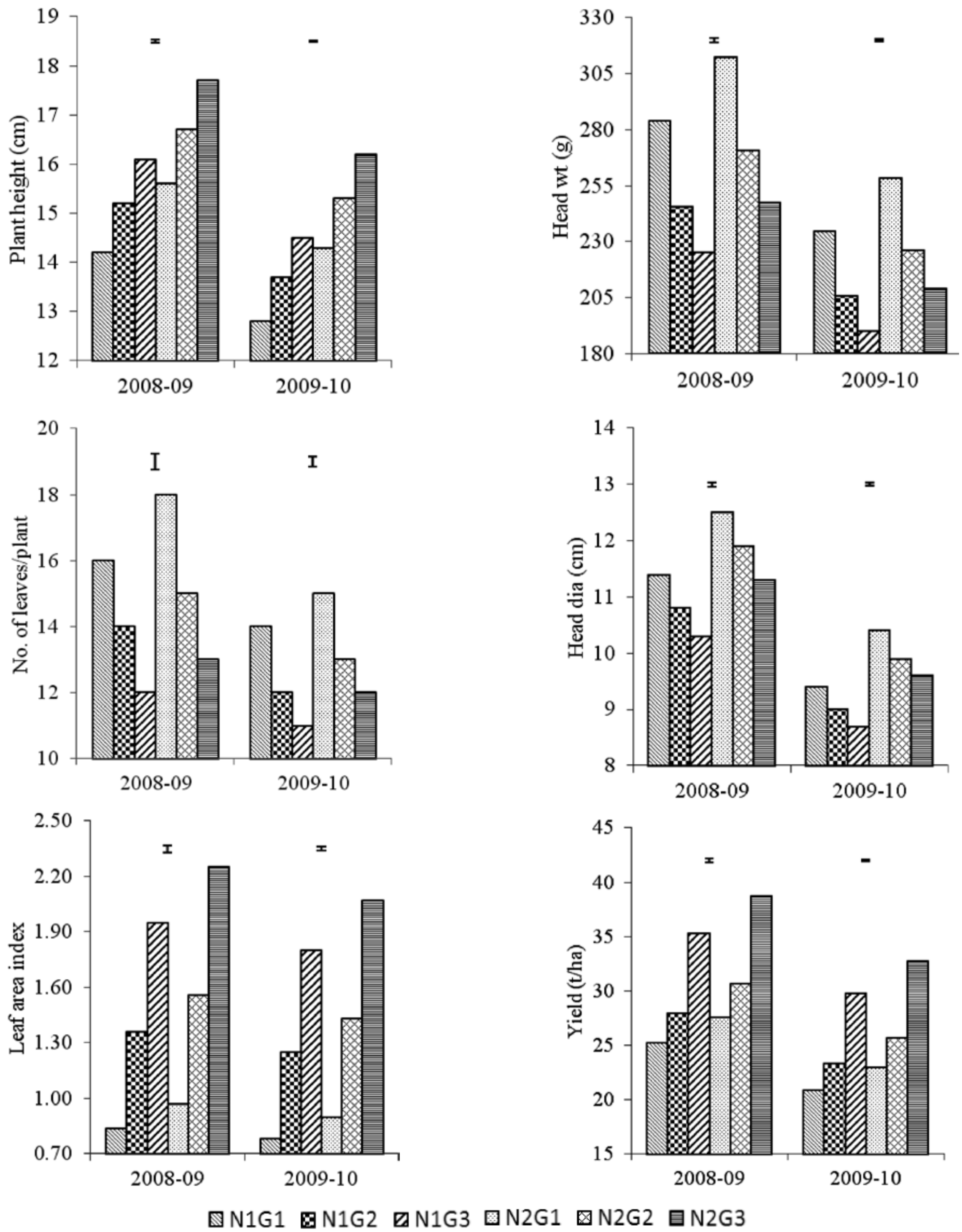

Fig. 3. Interactive effect of N application rate and crop geometry on growth and yield parameters in lettuce.

G_3 showed the maximum plant height, leaf area index and total yield, whereas plants grown under treatment combination $I_1 \times N_2 \times G_1$ exhibited maximum number of leaves, head weight and head diameter during both crop seasons. The combined effect of irrigation interval, nitrogen application and crop geometry, as observed from the data revealed insignificant differences for number of leaves. In terms of single head weight and head diameter, the combination $I_2xN_1xG_3$ during both seasons showed the least values for yield attributes. Analysis of lettuce growth and yield attributes revealed that treatment combination $I_2 \times N_1 \times G_1$ during both seasons showed least values for plant height, leaf area index and total yield.

As depicted by the results of field experiment carried out in 2008-09 and 2009-10, wider row spacing (45 cm × 30 cm) along with frequent irrigation application and higher nitrogen application rate had a significant effect on head weight and diameter. This may be attributed to the utilization of the extra ground area provided by wider row spacing. Inspite of increased head weight in wider row spacing, marketable yield was more in closer row spacing because of higher plant population and LAI, leading to higher photosynthesis rate. The overall improvement of crop growth reflected from maintenance of a better source-sink relationship, in turn enhanced yield attributes. Thavaprakash *et al.* (17) reported similar findings wherein yield was higher under closer row geometry (45 cm) than wider row geometry (60 cm). In the light of results obtained, it can be concluded that lettuce raised under 17.5 cm × 30 cm spacing along with two day irrigation interval and 100 kg N ha^{-1} application resulted in significantly higher marketable yield. Wider crop spacing led to higher single head weight and head diameter, thus enhancing lettuce quality parameters.

ACKNOWLEDGEMENTS

Authors are thankful to the staff of Water Technology Centre and Centre for Protected Cultivation Technology (CPCT), IARI, New Delhi for providing the lab facilities. We also acknowledge the financial support provided by IARI and Council for Scientific and Industrial Research, New Delhi.

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Received: November, 2011; Revised: May, 2012;
Accepted: August, 2012