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Response of Lettuce (*Lactuca sativa* L.) to Trickle Irrigation under Different Irrigation Intervals, N Application Rate and Crop Geometry

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ABSTRACT

Field experiments were conducted on the sandy loam soils of Center for Protected Cultivation Technology (CPCT), Indian Agricultural Research Institute (IARI), New Delhi, India during October - February seasons for 2 years (2008-2010) to evaluate the economic feasibility of trickle irrigation in combination with different irrigation intervals, N application rate and crop geometry for lettuce crop. Reference evapo-transpiration for lettuce crop was estimated using FAO-56 Penman-Monteith method. The net irrigation volume (V) was determined after deducting the effective rainfall. 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 day (I_1) and 4 day (I_2) interval] and 2 levels of nitrogen application [60 kg ha^{-1} (N_1) and 100 kg ha^{-1} (N_2)]. For both the experiments, three replications were given. The study indicated that 2 day irrigation interval with 100 kg N ha^{-1} application in 17.5 × 30cm crop geometry gave the highest yield (41.4 t ha^{-1}) with 6 per cent increase in yield as compared to rest of the treatments. The same treatment has resulted into maximum net seasonal income, benefit-cost ratio (BCR) and lowest payback period for both the years, respectively.

Keywords: Trickle irrigation, Irrigation interval, Crop geometry, Lettuce crop, Financial analysis.

JEL: Q15, Q16, Q25.

I

INTRODUCTION

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*., 2005). 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, 2009). The nutritional value of 100 g of edible portion of lettuce contains 96.5 g of water, 0.9 g of protein, 0.1 g fat, 18 mg calcium, 10 mg sodium, 1.2 g fiber, besides enriched in Vitamins A, B and C. Presently, the entry of multinational companies into Indian food and catering industries and economic growth has dramatically changed the eating habits and

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consumption pattern of the people. This has resulted into more use of salad crops like lettuce in the Indian diet. Because of this, it has a vast potential as one of the foreign exchange earner crops (Sidhu, 1998). Very few studies have been done to standardise the irrigation and fertigation strategies along with crop geometry for trickle irrigated lettuce (Bozkurt *et al.*, 2009).

Water is one of the most important inputs essential for the production of crops. India is blessed with abundant water resources, however, due to various physiographic constraints, existing legal constraints and the present method of utilisation, the utilisable water for irrigation is very limited. The misuse of water leads to water logging and salinity problems. There exists a large gap between the irrigation potential created and utilised due to losses through conveyance system and application while adopting surface irrigation system. In the present day context, improvements in irrigation practices are needed to increase crop production and to sustain the productivity levels. Therefore, adoption of modern irrigation techniques is needed to be emphasised to increase water use efficiency and cover more area under cultivation. Drip irrigation is the most effective way to supply water and nutrients to the plant which not only save water but also increases yield of fruit and vegetable crops (Tiwari *et al*., 1998 a,b). It maintains a near optimal soil moisture environment in the root zone of the crop. Therefore the use of trickle irrigation is rapidly increasing in India as well as around the world and is expected to continue to be a viable irrigation method for agricultural production in the foreseeable future (Yazar *et al*., 2002). Application of trickle irrigation has gained more importance in horticultural, vegetable and ornamental crops (Government of India, 2006). A number of researches (Kadayifci *et al.,* 2004; Acar *et al*. 2008; Yazgan *et al.,* 2008; Bozkurt *et al.,* 2009, Castro *et al.,* 2009) based on productivity, economics, physiology, nutrient uptake and water-yield relationship of lettuce crop was performed in Western Europe and North America. However, local information from the Indian region on the response of lettuce yield and economics under open field conditions is very limited. The present experiment was undertaken to study the influence of various irrigation levels through drip system under different crop geometry on yield and to evaluate the economics of the cultivated lettuce crop.

II

MATERIALS AND METHODS

The experiments were conducted with lettuce crop (cv. Iceberg) at the Centre for Protected Cultivation Technology (CPCT), Indian Agricultural Research Institute (IARI), New Delhi during winter season (October to February) 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 the weather conditions during crop growing season in both of the experiments was optimal as required by lettuce crop (Table 1).

TABLE 1. WEATHER PARAMETERS RECORDED DURING THE PERIOD OF EXPERIMENTATION

Month	T_{max} (˚C)		T_{min} (˚C)		RH (per cent)		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
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
October	32.9	32.5	18.6	17.1	59.3	60.7	0.0	0.3	4.5	4.6
November	27.7	26.5	10.8	12.3	63.0	69.5	0.0	14.2	2.7	2.8
December	23.4	22.7	8.2	7.4	69.7	66.9	0.0	1.0	1.9	2.0
January	20.5	17.9	7.2	6.7	76.3	78.2	4.3	0.0	1.8	1.6
February	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.

The soil analysis carried out in the experimental field revealed that the soil was sandy clay loam in texture, with a neutral pH (7.2) and low in organic carbon (0.23 per cent). The average field capacity and permanent wilting point of soil were 26 and 9 per cent respectively. Porosity was approximately 40 per cent soil belonged 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 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 minimise 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.

TABLE 2. SOIL PHYSICAL PROPERTIES OF THE EXPERIMENTAL FIELD

Depth (cm)	Mineral content (per cent) mass			Textural class	Hydraulic conductivity (cm h^{-1})	Bulk density (g cm^{-3})	FC (Vol. per cent)	PWP (Vol. per cent)
	Clay	Silt	Sand					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
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.

The experiment was laid out following factorial randomised 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 confidor (2 ml l^{-1}) was sprayed to prevent termite infestation. Similarly, carbendazim (1g 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 fertilisers 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 to 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-Monteith method (Allen *et al.*, 1998) 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, the total depth of water applied for 2 and 4 day irrigation intervals was 168 mm. While it was 167 mm for the year 2009-10 (Table 3).

TABLE 3. ACTUAL IRRIGATION APPLIED AT DIFFERENT INTERVALS DURING CROP GROWTH SEASON

Particulars (1)	2008-09: 2 day irrigation interval (2)	2008-09: 4 day irrigation interval (3)	2009-10: 2 day irrigation interval (4)	2009-10: 4 day irrigation interval (5)
Calculated ET_0, (mm)	168.00	168.00	167.00	167.00
Effective rainfall, (mm)	4.90	4.90	12.40	12.40
Actual irrigation applied, (mm)	163.10	163.10	154.60	154.60

To determine the uniformity in application of water, it is necessary to evaluate emitter discharge uniformity and system performance. The emission uniformity of water application was carried out at the start of the season. The discharges 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 (1986) was used to compute the statistical parameters and analyse the uniformity of trickle system.

In post-harvest observations, marketable yield of lettuce was determined using standard procedure. The yield data for each treatment were collected after the harvesting of the lettuce and expressed as the weight of fruit in kg/ plot and converted as kg/ha (fresh fruits).

Benefit-cost analysis was carried out to determine the economic feasibility of using trickle irrigation. The operating cost of the trickle irrigation system includes cost of cultivation and energy cost for running the irrigation system. Energy cost includes the electrical cost which was taken as Rs. 5 per kwh which are the existing energy charges. The energy consumed is calculated based on the operating hours of the irrigation system. The cost of cultivation of lettuce includes expenses incurred on the preparation of field, ploughing, mulching, seeds, sowing, cost of fertiliser, manure and their application, weeding, crop protection measures, and cost of irrigation water and harvesting. The seasonal cost of drip irrigation includes depreciation, prevailing bank rate of interest and repair and maintenance @ 12 per cent per annum and 2 per cent of the fixed cost respectively (Rao, 1994). The useful life of the drip system was considered to be 10 seasons (5 years) and three seasons, respectively. The income from produce was estimated using prevailing average market price as Rs. 30000 t^{-1}. The net seasonal income from produce was estimated by subtracting the total seasonal cost from the income of the produce. The benefit-cost ratio (BCR), payback period, the total cost of production and net return from cultivation of lettuce over 1 ha were then estimated (Table 4).

III

RESULTS

3.1 *Uniformity of Trickle Irrigation System*

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 5. 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 per cent during the two cropping seasons. According to Pitts (1997), EU greater than 90.0 per cent implied excellent functioning of the drip system.

3.2 *Lettuce Yield*

The effect of different levels of irrigation on yield was analysed statistically. The experimental results of this observation for all the two years are presented in Table 6. The results of the analysis of variance showed that variation among three replications for all the treatments and all the three years was found to be statistically insignificant both at 5 per cent level of significance. The analysis of observations showed that different levels of irrigation with drip responded differently to yield of crop. Data from both the years indicate that irrigation treatment I_1 had highest total yield (34.4 and 31.3 t ha^{-1}). The effect of irrigation frequency on yield has been investigated and similar results reported by Jordan *et al.* (2003).

Similarly, it can be seen that fruit yield of lettuce (34.42 and 27.1 t ha^{-1}) was recorded to be the highest in all the 2 years for treatment of maximum nitrogen application (N_2). The increase in yield as a response to increased N fertilisation is probably due to enhanced availability of nitrogen which enhanced more leaf area resulting in higher photoassimilates, thereby more dry matter accumulation. Squire *et al.* (1987) established that the main effect of N fertiliser was to increase the rate of

TABLE 4. ECONOMIC ANALYSIS OF VARIOUS TREATMENTS FOR LETTUCE

Cost economics		Year	Treatments											
			$I_1N_1G_1$	$I_1N_1G_2$	$I_1N_1G_3$	$I_1N_2G_1$	$I_1N_2G_2$	$I_1N_2G_3$	$I_2N_1G_1$	$I_2N_1G_2$	$I_2N_1G_3$	$I_2N_2G_1$	$I_2N_2G_2$	$I_2N_2G_3$
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Total yield (t/ha)		2008-09	28.05	32.97	39.17	30.86	34.12	43.09	22.44	24.82	33.54	24.68	27.30	34.47
		2009-10	25.25	28.23	36.04	27.77	31.05	39.64	20.20	22.58	28.83	22.22	24.84	31.71
Annualised cost (Rs./ha)		2008-09	231902	231902	231902	231902	231902	231902	231902	231902	231902	231902	231902	231902
		2009-10	231902	231902	231902	231902	231902	231902	231902	231902	231902	231902	231902	231902
Operating cost (Rs./ha)		2008-09	59301	63501	69101	59997	64197	69797	59310	63510	69110	60006	64206	69806
		2009-10	59270	63470	69070	59966	64166	69766	59279	63479	69079	59975	64175	69775
Total cost (Rs./ha)		2008-09	291204	295404	301004	291899	296099	301699	291213	295413	301013	291909	296109	301709
		2009-10	291173	295373	300973	291868	296068	301668	291182	295382	300982	291877	296077	301677
Gross income (Rs./ha)		2008-09	841500	930600	1175100	925800	1023600	1292700	673200	744600	940200	740400	819000	1034100
		2009-10	757500	846900	1081200	833100	931500	1189200	606000	677400	864900	666600	745200	951300
Net income (Rs./ha)		2008-09	550295	635195	874095	633900	727500	991000	381986	449186	639186	448490	522890	732390
		2009-10	466326	551526	780226	541231	635431	887531	314817	382017	563917	374722	449122	649622
BCR	Without	2008-09	1.89	2.15	2.90	2.17	2.46	3.28	1.31	1.52	2.12	1.54	1.77	2.43
	subsidy	2009-10	1.60	1.87	2.59	1.85	2.15	2.94	1.08	1.29	1.87	1.28	1.52	2.15
	With 50 per	2008-09	3.60	3.97	5.09	4.04	4.44	5.68	2.68	2.98	3.87	3.03	3.36	4.34
	cent subsidy	2009-10	3.14	3.52	4.61	3.53	3.96	5.14	2.31	2.62	3.48	2.63	2.96	3.91
Pay-back	Without	2008-09	42	38	31	38	35	28	52	48	38	47	43	35
period	subsidy	2009-10	46	42	33	42	38	30	58	52	42	53	48	38
month	With 50 per	2008-09	26	24	20	24	22	18	33	30	25	30	28	22
	cent subsidy	2009-10	29	27	21	26	24	20	36	33	27	33	30	24

Source: www.grocery.ebest.in, www.tradeboss.com

Note: The income from produce was estimated using prevailing average market price of Rs. 30 per kg since the price for last five years was Rs. 22, 27, 30, 35 and 40 per kg.

TABLE 5. COEFFICIENT OF VARIATION (CV) AND EMISSION UNIFORMITY OF INLINE SURFACE DRIP SYSTEM

Year (1)	Coefficient of Variation (CV) (2)	Emission uniformity (per cent) (3)
2008-09	0.059	95
2009-10	0.091	92

TABLE 6. YIELD OF LETTUCE AS AFFECTED BY IRRIGATION FREQUENCY, NITROGEN AND CROP GEOMETRY

Treatments (1)	Yield, t/ ha		
	2008-09 (2)	2009-10 (3)	Average (4)
I_1	34.4	31.3	32.9
I_2	27.5	25.1	26.3
CD at 5 per cent	0.3063	0.3053	
N_1	29.47	24.7	27.1
N_2	32.42	27.1	29.8
CD at 5 per cent	0.3063	0.2493	
G_1	26.51	21.9	24.2
G_2	29.32	24.5	26.9
G_3	37.02	31.3	34.2
CD at 5 per cent	0.2370	0.1685	
$I_1N_1G_1$	28.1	25.3	26.7
$I_1N_1G_2$	31.0	28.2	29.6
$I_1N_1G_3$	39.2	36.0	37.6
$I_1N_2G_1$	30.9	27.8	29.4
$I_1N_2G_2$	34.1	31.0	32.6
$I_1N_2G_3$	43.1	39.6	41.4
$I_2N_1G_1$	22.4	20.2	21.3
$I_2N_1G_2$	24.8	22.6	23.7
$I_2N_1G_3$	31.3	28.8	30.1
$I_2N_2G_1$	24.7	22.2	23.5
$I_2N_2G_2$	27.3	24.8	26.1
$I_2N_2G_3$	34.5	31.7	33.1
CD at 5 per cent	0.4740	0.4128	

Notes: **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 X 30 cm; G_2 : 30 X 30 cm; G_3 : 17.5 X 30 cm

leaf expansion, leading to increased interception of daily solar radiation by the canopy. Boroujerdnia and Ansari (2007) also reported similar findings, which indicated that nitrogen status significantly influenced growth and yield attributes of lettuce.

The crop geometry of closer spacing (G_3) exhibited higher total yield (37.02 and 31.28 t ha^{-1}) during both years. Das *et al*. (2009) reported similar findings wherein closely spaced plants with higher plant height absorbed more solar radiation owing to their superior intra-specific competence to obtain light, water and nutrients. Crop geometry significantly affected yield. The overall results of our study were in good agreement with the findings reported by Karam *et al.* (2002) and Bozkurt *et al.* (2009).

Likewise, it can be seen that yield of lettuce was recorded the highest in all the 2 years for treatment of 2 day irrigation interval with 100 kg ha^{-1} N application rate (I_1xN_2) with pooled average value of 34.4 t ha^{-1}. In both seasons, a minimum value of lettuce yield was observed in I_2xN_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 results of the study were in line with the findings of Acar *et al* (2008). Among the different treatments tried, 2 day irrigation interval with closer row spacing (I_1xG_3) responded the highest yield in all the years with pooled average value of 39.4 t ha^{-1}. The continuous wetting of active root zone with higher plant density resulted into maximum yield.

The interactive effect of nitrogen application and crop geometry on lettuce revealed that treatment combination N_2xG_3 exhibited higher value of total yield (38.8 and 32.8 t ha^{-1}), during both the seasons. Significant effects on yield due to nitrogen levels and spacing has also been reported by Mahmood *et al.* (2001).

Interactive effect of the three factors on lettuce yield is presented in Table 6. $I_1xN_2xG_3$ combination showed the highest yield (43.1 and 39.6 t ha^{-1}), whereas plants grown under treatment combination $I_2xN_1xG_1$ exhibited least yield with pooled average value of 21.3 t ha^{-1}, during both crop seasons. As depicted by the results of field experiment carried out in 2008-09 and 2009-10, closer row spacing (17.5×30 cm) along with frequent irrigation application and higher nitrogen application rate had a significant effect on yield. The overall improvement of crop growth reflected from maintenance of a better source-sink relationship, in turn enhancing yield attributes. Thavaprakash *et al.* (2005) 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. The results of the present study may serve as a guideline for the optimal use of irrigation water, balanced fertiliser use and appropriate crop geometry for obtaining higher yield and good quality of lettuce.

Financial Analysis

Table 4 presents the economic analysis of cultivation of lettuce under various treatments from 1 ha area in both seasons. It was carried out using mainly two parameters, viz., BCR and payback period. The net seasonal income was found to be higher (Rs. 9.91 and Rs. 8.87 lakh) in 2 day irrigation interval along with 100 kg N ha^{-1} application in 17.5×30 cm crop geometry followed by 2 days irrigation interval along with 60 kg N ha^{-1} application in 17.5×30 cm crop geometry treatments (Rs. 8.74 and Rs. 7.80 Lakh) in that order. The reduction in yield was estimated to be 9 per cent due to an event of hail-storm that occurred on 09th February 2010 and hence resulted in net income lower than that of the year 2008-09.

The BCR vary between 3.28 (higher) for $I_1xN_2xG_3$ to 1.31 (lower) for $I_2xN_1xG_1$ in the year 2008-09. A similar trend was observed in the year 2009-10, while payback period was found to be lowest (28 and 30 months) in $I_1xN_2xG_3$. With prevailing subsidy of 50 per cent on trickle irrigation system (Government of India, 2006), a similar trend was observed in BCR and payback period during the respective years.

IV

CONCLUSION

The trickle irrigation is an economical and cost effective irrigation method. The use of 2 day irrigation interval either alone or in combination with N application in different crop geometry can increase the lettuce crop yield significantly than the rest of treatment to the tune of 25-76 per cent. There exists variation in yield under different treatments. The greatest yield was recorded under 2 day irrigation interval with 100 kg N ha^{-1} application in 17.5 × 30cm crop geometry. The highest benefit-cost ratio and lowest payback period was found for treatment under 2 day irrigation interval with 100 kg N ha^{-1} application in 17.5 × 30cm crop geometry followed by 2 day irrigation interval with 60 kg N ha^{-1} application in 17.5 × 30cm crop geometry in that order.

Finally, the overall results suggest that a simple irrigation management approach, which is easily adoptable by farmers, can be used to obtain optimum yield, and net return from lettuce in Indian condition. Despite high initial investment, trickle irrigation for vegetable production in the research plot was highly profitable because of the high market price of the produce and subsidy support provided by government.

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