Water - yield relationships of lettuce plants for different irrigation strategies

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Abstract: *The greatest fresh water user sector is agriculture worldwide. The optimum utilization of current water supplies is necessarily prerequisites particularly in water poor climates. It is almost impossible to obtain economical crop yield without irrigation in those types of environments. In general, vegetables are high water consuming crops and well responses to the adequate soil moisture levels in rooting depths. Correct irrigation program is vital important for reaching target optimal production. The present study aimed to analyze irrigation programs affect on yield and water use efficiency, WUE, of lettuce plant for different growing conditions. In accordance of previous studies, maximum yield was obtained from full irrigation treatment. Lettuce plants were not tolerant wide irrigation intervals e.g. 2 or 3-day ideal for optimal yield and quality. Evapotranspiration, ETc, was highly dependent on lettuce varieties, availability of soil moisture content in root systems as well as climatological factors, and ranged between 413 mm and 208 mm. The planting geometry also had effect on lettuce yield. The irrigation system is important, but the most important issue is proper water management for enhancing crop production. Use of sprinkler or drip irrigation system should be highly recommended for better yield, quality as well as efficient water usages or water savings in vegetable farming under correct irrigation program.*

KEYWORDS*: LETTUCE PLANT, IRRIGATION SYSTEM, AGRO - WATER MANAGEMENT.*

1.Introduction

Lettuce, well adapted to cool ecology, is one of the most used items at salad as well as widely growing plant due to better economy for farmers [1]. It is known as high water consuming plant and has positive response to sandy loam or clay loam soil as well as well drainage condition. The head yield of lettuce varies from 30 to 40 t/ha depending on the lettuce variety and agricultural practices as well as growing ecologies [2]. Vegetables as well as fruits are rich of mineral matters and vitamins whereas they have low energy content. Therefore, they are very important role to play for human health. The balanced consumption of those may result reductions in risks of heart and vessel diseases, hypertension, and problems relevant to digestive systems as well as chronic diseases [3]. Water and fertilizer are two important components to achieve maximum yield. Drip irrigation having high water productivity has produced better lettuce yield under well management. The reason behind that such irrigation system results optimal water status within root systems via frequent and light water applications, consequently high and qualified lettuce yield [4-5]. Water and energy efficiencies as well as crop yield can be improved noticeable under pressurized irrigation methods such as sprinkler or drip with well agricultural water management [6]. Irrigation is very important role to play in increasing crop yield in water shortage areas. Agriculture is plenty freshwater user sector so water saving should be started at irrigation in first [1, 7, 8] and increasing water use efficiency, WUE, is the main strategy particularly at water limited environments [9-10]. In irrigation program, proper estimation of crop coefficient, kc, is very important, and under well-moisture status, kc values of lettuce may be as 0.7, 1.0 and 0.95 for initial, mid-season and end of late season, respectively [11-12].

The main aim of present study is to assess influence of irrigation water management on yield and water productivity of lettuce for different environments.

2. Material and Methods

In this paper, yield, some yield components and WUE values were obtained from literatures relevant to the lettuce irrigation researches performed at different growing ecologies. The findings of those studies were analyzed, and then practical solutions for better lettuce production were presented.

3. Results of the previous studies and discussion

a) In first study, lettuce (cv Royal) yield and WUE were researched under different irrigation regimes at Bekaa Valley, Lebanon [13]. The soil of research had 170 mm/m available water capacity, AWC, with 1.41 g/cm^3 bulk density. The irrigation was based on 30% depletion of AWC in soil depth of 0-90 cm. Evapotranspiration was determined by using both lysimeter, placed on center of the experimental field, as well as water budget equation. Irrigation regimes were I-100 (100% replenishment of soil water depletion), I-80 (80% of applied water of I-100), and I-60 (60% of applied water of I-100). Soil moisture monitoring was made by gravimetric method.

In results, ETc values for 70-day growing season, from planting to harvest, were found as 433 mm for lysimeter and 413 mm for I-100 treatment by water budget equation. ETc values obtained from the water budget equation were determined as 375 mm and 337 mm for I-80 and I-60 treatments, respectively. ETc finding from present study is higher than report of Santosh *et al.* [14].

The WUE values for I-100, I-80 and I-60 were calculated as 17.7, 13.7, and 13.4 kg/ha/mm, respectively. The difference of WUE between lysimeter and control treatment of I-100 was found not significant. The WUE value of present study is higher than findings of winter and summer growing season, but lower than the fall growing season by report of da silva *et al.* [15].

The yield of lettuce for lysimeter, I-100, I-80, and I-60 treatments were as 7.7, 7.3, 5.1, and 4.5 t/dry matter/ha, respectively. There was little difference between lysimeter and I-100 treatment. The study clearly showed that lettuce plant is highly sensitive to the water deficiency so deficit irrigation has resulted yield difference e.g. although 20% deficit irrigation applied to the I-80 treatment, the yield reduction was more than 30% in that irrigation program by comparison to I-100 (full-irrigation) treatment.

b) In second study, effects of different irrigation and nitrogen regimes on yield and yield components of drip-irrigated lettuce (*Lactuca sativa* var. longifolia) were researched under glasshouse condition at Konya, Turkey [5]. In such study, irrigation regimes were amount of water depth of 100% evaporation from Class A Pan (I1), 80% of I1 (I2), and 60% of I1 (I3). Four nitrogen levels were 0 (N1), 100 (N2), 200 (N3) and 300 kg N /ha (N4).

In results, head weights were 355 g, 340 g, and 338 g for I1, I2, and I3 treatments, respectively. The marketable head weights were found as 335 g, 322 g, and 308 g for I1, I2, and I3 treatments, respectively (Table 1). Different irrigation regimes as well as N doses had no significant differences in both yield and yield components of lettuce plant. In that case, it is obvious that I3 treatment can be highly recommended in areas having water shortage regions such as Konya Closed Basin of Turkey for irrigation of more areas with current water supplies. In addition, low N level is suggested to avoid contamination of groundwater supplies, and N saving since groundwater has used intensively during irrigation season in Konya plain.

c) In third study, irrigation, nitrogen and planting geometry effects on yield of drip-irrigated lettuce was examined at New Delhi, India during the growing seasons (October-February) of 2008-2009 and 2009-2010 under Sandy Clay Loam (SCL) with bulk density of 1.58

g/cm^3 [16]. Two irrigation intervals namely 2-day (I1) and 4-day (I2); two nitrogen doses namely 60 kg N/ ha (N1) and 100 kg N/ha (N2) and three different plant geometries namely 45 x 30 cm (row spacing cm x plant spacing cm) (P1), 30 x 30 cm (P2), and 17.5x30 cm (P3) were studied. In results, I1 produced maximum yield as about 34 t/ha and 31 t/ha for first and second growing year, respectively (Table 2). N2 had the highest yield as about 32 t/ha and 27 t/ha for those growing years, respectively. P3 was found superior in accordance of yield over other plant geometries of P1 and P2. As expected from the table 2, I1N2P3 combination led to maximal yield for both growing seasons. As a result, 2-day irrigation interval, 100 kg N/ ha and 17.5x30 cm planting arrangement produced the greatest yield. The yield obtained from current study is inline with Santosh *et al.* [14] as about 32 t/ha, and as about 30 t/ha of da Silva *et al.* [15] for fall growing season.

d) In fourth study, different irrigation levels affect on yield and some yield parameters of drip irrigated-lettuce plant growing at plastic house and under field conditions were idenfified during the periods November-February of 2014 – 2015 and 2015-2016 growing season at Khangpur, India [14].

The irrigation regimes were based on the crop water requirement, CWR, as follows;

I1- Application of 120% of CWR within plastic house
I2- Application of 100% of CWR within plastic house
I3- Application of 80% of CWR within plastic house
I4- Application of 60% of CWR within plastic house
I5- Application of 1000% of CWR at outside plastic house (open field environment).

In results, maximum plant height as 36.3 cm was obtained from I2 treatment whereas the lowest one as 26.1 mm from I-5 treatment (Table 3). The finding is almost full agreement with result of Acar *et al.* [5] since they found that value around 30 cm. The greatest head diameter was found as 13.3 cm and 13.5 cm from I1 and I2 treatments, respectively.

The leaf number per plant was about average 30 for growing plastic house condition. This value is lower than the report of Acar *et al.* [5] since they found as about 42 depending on the irrigation regimes. The reason behind producing better leaf number could be differences in variety, cultural practices, and management of water and N doses as well as mainly environmental conditions.

The highest yield was found in I2 treatment as about 36 t/ha. Among treatments, I5 resulted minimum values in all examined parameters. The seasonal water requirements of lettuce for plastic house and open field conditions were determined as 219 mm and 339 mm, respectively. Growing lettuce in plastic house was more favorable over open fields due to the possibly better environmental control in protected environments.

e) In fifth study, effects of growing seasons of winter, summer and autumn on yield, ETc and WUE of micro-sprinkler irrigated three lettuce varieties were researched at Brazil [15]. The lettuce cultivars were planted 40 cm apart between rows and plants. The micro-sprinkler had 60 L/h discharge rate. Irrigation was performed twice a day.

Autumn growing resulted better yield comparison to winter and summer growing e.g yields for winter, summer and autumn seasons were about 20, 13 and 41 t/ha at Curly lettuce variety (Table 4). The lowest yield was obtained from Red variety in whole growing seasons. The average yield of combined three varieties for fall growing season is around 30 t/ha and is agreement with some reports [16, 14].

The maximum and minimum ETc values were determined from summer growing season as 208 mm and from winter growing season as 125 mm. The kc values for entire, initial, middle and final stages were found as 0.82, 0.80, 1.07, and 0.70, respectively.

Autumn growing season produced maximum WUE in all lettuce verities. In such growing season, curly variety had greatest WUE as 28.5 kg/ha/mm (Table 5). Autumn is favorable for ideal lettuce growing in tropical environment like Brazil. The WUE values of this present study relevant to winter and summer growing seasons are lower, but higher in fall growing season than results of Karam *et al.* [13].

f) In sixth study, 4 levels of N levels, as Control (N0: no Nitrogen application), 25 (N25), 50 (N50), and 100% (N100) of the ideal crop N requirement and 4 levels of irrigation, as Control (I0: no irrigation), 25 (I25), 50 (I50), and 100% (I100) of crop water needed were researched to determine response of drip irrigated-lettuce (*Lactuca sativa* L. var. longifolia) at Pomona, California during the periods fall 2017 and spring 2018 [17].

In general, biomass yield was found higher in 2018-spring growing condition (Table 6). The maximum biomass yields were obtained from treatments of I100 as 3632 kg/ha and N100 as 2763 kg/ha in spring growth period. In accordance of yield value, spring growing is favorable for lettuce farming.

However, the maximum WUE was found as 7.46 kg DM/m^2 from I25 treatment at fall growing season. Among the irrigation treatments, the highest nitrogen use efficiency, NUE, was calculated as 38 kg DM / kg N from the spring growing condition. In N treatments, the maximum NUE was found as 57 kg DM / kg N from spring growing. In study, I100N100 had resulted higher lettuce yield and I50N25 resulted maximum WUE and NUE in both research seasons. In better water saving at water shortage regions such as California, and avoid contamination of groundwater resources via more N applications in agriculture, I50N25 combination can be highly recommended for lettuce farming.

g) In this seventh field study, irrigation intervals of 1 (I1), 2 (I2), 3 (I3) and 4-day (I4) affect on yield and WUE were investigated for drip irrigated lettuce plant (*Lactuca sativa* L.) at King of Estawani under soil condition of sandy-loam [18]. In results, I3 treatment gave the highest mean fresh weight of 319 g/plant whereas I4 (stressful treatment) resulted minimum as 155 g/plant. Similarly the maximum and minimum mean dry weights of 17.4 g/plant and 8.8 g/plant were recorded from the I3 and I4 treatments, respectively.

The applied water was found the highest as 304 mm in I1 treatment whereas the lowest at I4 treatment as 64 mm (Table 7). WUE was found as maximum at treatment of I3 as about 3.9 g/mm. As a result, although applied water was 82 mm at I3 treatment, it produced greatest mean fresh weight, mean dry weight as well as WUE of 3.89 g/mm. I3, three-day irrigation interval, treatment could be resulted better income for farmers producing lettuce under field condition as well as greater water saving due to the less amount of water use or higher WUE.

4. Conclusion

Proper selections of lettuce variety, growing season with environments are very important role to play for improving lettuce yield. In general, full irrigation has resulted maximum lettuce yield so it can be recommended. Beside those, irrigation interval is very important for ideal lettuce growing consequently better yield and quality. In the light of the this assessment, 2 or maximum 3-day irrigation interval is highly recommended since greater than 3-day e.g. 4-day or over may cause great yield and quality reductions due to the occurrence water stress through root systems. Sprinkler and drip irrigation systems are well adapted to the lettuce irrigation. They are also very water productive technologies and have resulted high irrigation efficiency under correct management. Therefore, utilization of those irrigation techniques should be improved for putting more areas into lettuce production.

Table 1. *Irrigation regimes affect on yield and yield components of lettuce [5]*

Irrigation levels	Head weight (g/plant)	Marketable head weight (g/plant)	Leaf number per plant	Head height (cm)	Head diameter (cm)	Root length (cm)
I1	355	335	42	31	40	18
I2	340	322	40	30	45	18
I3	338	308	44	31	40	17
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS

NS: None significant

Table 2. *Drip-irrigated lettuce yield under different irrigation interval, N levels and planting designs [16]*

Treatments	**Lettuce Yield (t/ha)**	
	2008-2009	2009-2010
I1	34.4	31.3
I2	27.5	25.1
N1	29.5	24.7
N2	32.4	27.1
P1	26.5	21.9
P2	29.3	24.5
P3	37.0	31.3
I1N1P1	28.1	25.3
I1N1P2	31.0	28.2
I1N1P3	39.2	36.0
I1N2P1	30.9	27.8
I1N2P2	34.1	31.0
I1N2P3	**43.1**	**39.6**
I2N1P1	22.4	20.2
I2N1P2	24.8	22.6
I2N1P3	31.3	28.8
I2N2P1	24.7	22.2
I2N2P2	27.3	24.8
I2N2P3	34.5	31.7

Table 3*. Yield and yield components of lettuce for combine 2-year [14]*

Irrigation Levels	Plant height (cm)	Head diameter (cm)	Leaf number per plant	Leaf fresh weight (g/plant)	Leaf dry weight (g/plant)	Yield (t/ha)
I1	32.1	13.3	30.4	400	35.6	31.7
I2	36.3	13.59	31.8	409	38.2	35.7
I3	31.8	11.2	28.5	357	28.7	29.5
I4	30.3	10.4	25.7	332	26.4	26.4
I5	26.1	9.8	22.5	298	23.7	18.2

Table 4. *Lettuce yields in accordance of varieties and growing seasons [15]*

Lettuce cultivars	Yield (t/ha)		
	Winter	Summer	Autumn
Looseleaf	11.6	18.5	22.1
Curly	19.7	13.4	40.7
Red	8.0	7.5	27.1

Table 5. *ETc and WUE of lettuce depending on variety and growing season [15]*

Growing period	ETc (mm)	WUE (kg/ha/mm)		
		Looseleaf	Curly	Red
Winter	125	9.3	15.8	6.4
Summer	208	8.9	6.4	3.6
Autumn	143	15.5	28.5	19.0

Table 6. *Irrigation and N levels affect on yield, Water Use Efficiency, WUE, and Nitrogen Use Efficiency, NUE [17]*

Treatments	Biomass (kg/ha)		WUE (kg DM/m^2)		NUE (kg DM/ kg N)	
	2017-Fall	2018-Spring	2017-Fall	2018-Spring	2017-Fall	2018-Spring
I0	1274	1117	0.00	0.00	13.20	13
I25	1606	1869	7.46	4.71	15.94	20
I50	1854	3114	4.29	3.95	20.10	33

I100	2120	3632	2.45	2.24	22.07	38
N0	1525	1968	4.60	3.58	0.00	0
N25	1628	2388	5.00	4.27	38.77	57
N50	1770	2613	5.43	4.85	21.06	31
N100	1932	2763	5.81	5.23	11.50	17

Table 7. *The irrigation interval-yield and WUE relationships [18]*

Irrigation Interval	Mean Fresh Weight (g/plant)	Mean dry weight (g/plant)	Applied water (mm)	WUE (g/mm)
I1	239	13.4	304	0.79
I2	266	13.4	147	1.81
I3	319	17.4	82	3.89
I4	155	8.8	64	2.40

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