Journal of Agriculture and Environment Vol. 14 No. 2, 2018: 123-139
ISSN 1595-465X

AGRO-PHYSIOLOGICAL CHARACTERISTICS OF LETTUCE (*Lactuca sativa* L.) CULTIVARS AS INFLUENCED BY IRRIGATION AND MULCHING IN A SEMI-ARID REGION OF NIGERIA

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ABSTRACT

Series of experiments were conducted to assess the response of agro physiological characters of three lettuce (*Lactuca sativa* L.) cultivars under different irrigation water application depths and mulch in a semi-arid ecology of Northern Nigeria. The experiments were conducted during three seasons of 2015/2016, 2016/2017and 2017/2018 irrigation seasons at Kadawa Irrigation Research Station farm (IRS) of the Institute for Agricultural Research, Samaru, Nigeria. The experimental design was split plot and consisted of three irrigation levels (50, 75and 100% of weekly reference evapotranspiration (WRET), two levels of mulch (no-mulch and mulch) and three lettuce cultivars (Great Lake, Slaai and Baby Leaf Mix). Irrigation levels and cultivars were assigned to main plots while mulch level as sub-plots. Treatments were factorial combined and replicated three times. Water applied before and after irrigation was monitored throughout the seasons. The study revealed that reducing irrigation level to 50% of WRET with or without mulch significantly ($P<0.05$) lowered leaf area index, dry weight per plant (g), total dry matter in kg ha^{-1}, crop growth rate, relative growth rate, net assimilation rate and irrigation water use efficiency (IWUE). Reducing water deficit to 50% WRET reduced TDM to the turn 37.3, 37.5 and 34.2% in 2015/2016, 2016/2017 and 2017/2018 respectively. Results also revealed that mulching significantly resulted in higher agro-physiological characters. Based on the results obtained in this study, it can be concluded that the use of cultivar Slaai with irrigation at 75% WRET had resulted in good agro-physiological characters of lettuce in Kadawa, Since there were only minor significant differences between yields of lettuce obtained from 75 and 100% irrigation levels, 75 emerges as a more suitable practice and might be recommended to tolerate the negative effects of excess water application to the ecology and for a better water economy especially in semi-arid regions of the world.

Keywords: Agro-physiological characteristics; Lettuce cultivar; irrigation; mulch

INTRODUCTION

Plant physiologists apply growth indices as useful tools for quantitative analysis of growth in different subjects such as plant breeding, plant ecology and physiology (Ebrahim*et al.*, 2014). Saki (2012) stated that one of the most important approaches of plant breeding for higher yield is evaluation of effective physiological traits in yield differentiation and recognition of their genetic controlling. Existing evidences suggest that all of the physiological components have a genetic diversity. The percentage of light penetration, photosynthesis active radiation, light use efficiency, dry matter partitioning to different parts are affected by the amount of water. Dry matter partitioning to the reproductive organs depends on number, capacity and activity of physiological sinks (Fageria and Baligar, 2005; Fageria, 2007).

Lettuce (*Lactuca sativa* L.) is an important leafy vegetable crop and it is considered as an excellent nutritive source of minerals and vitamins. It is usually consumed as fresh green salad and the first cultivated salad crop and commercialized internationally (M'hamdi *et al.*, 2014). It is the most popular vegetable in term of its highest consumption rate and economic importance throughout the world (Bozkurt *et al.*, 2009; M'hamdi *et al.*, 2014).

Efficient water use by irrigation systems is becoming increasingly important especially in arid and semi-arid regions with limited water resources. In agricultural practice, the sufficient and balanced application of irrigation water and nutrients are important management to obtain maximum yield per unit area. Bilal *et al.* (2008) demonstrated that lettuce yield increased in response to increase water supply. Irrigation of crops sensitive to water stress such as lettuce requires a systematic approach to irrigation scheduling (Ayas, 2013). This involves preventing the soil water deficit from falling below some threshold level for a particular crop and soil condition. However, the management practices that influence soil moisture include irrigation techniques, irrigation strategies and mulching practices (Chukalla *et al.*, 2015). Nevertheless, most studies assessed either irrigation technique, irrigation strategy or mulching practice.

For several decades, mulching has bemused in several parts of the world to evade drought and increase crop yield (Fan *et al.*, 2012). The practice of mulching has been utilized to great advantage in the development of horticultural crops (Al-Rawahy *et al.*, 2011) and has been proven to significantly improve the growing conditions of vegetables grown in the tropics, including onions and lettuce (Fan *et al.*, 2012). Mulching is highly effective in checking evaporation as it improves water infiltration (Laila and Ali, 2011) and conserved soil moisture (Pandey *et al.*, 2013). Hence recommended for most vegetable crops such as lettuce (Asaduzzaman *et al.*, 2010). A study conducted by Adnan *et al.* (2012) reported that mulching caused an approximately 100 percent increase in the available moisture content of the soil at each watering level.

Mulching has much beneficial importance to crops in terms of improvement of soil properties that relate to better crop performance. Alhassan *et al.* (2017) reported that the addition of mulch resulted in significant increase in soil water contents and reduced runoff. The increase in soil water was effective in ensuring better germination and higher yield. Nutrients were available to plant roots in presence of moisture, leading to higher vegetative yield. It was also reported that mulch increases the soil moisture and nutrients availability to plant roots, in turn, leading to higher yield (Azad *et al.*, 2015). Earlier Ayas (2013) reported that mulching increases soil water and reduce soil temperature significantly. Mulching has much beneficial importance to crops in terms of improvement of soil properties that relate to better crop performance. Zhang *et al.* (2014) reported that mulching combined with surface irrigation is a useful technique for maximizing water use efficiency. Importance of using soil mulching to agriculture is to reduce water usage, and conserve soil moisture according to

(Bunna *et al.*, (2011) and improves water infiltration Laila and Ali (2011). Mulching reduced water evaporation from soil (Kar and Kumar, 2007; Bafeel and Moftah, 2008).

Identification of growth physiological indices in analysis of factors affecting yield and its components has a great importance and its stability determines the dry matter production which is a criterion of yield components and in this regard leaf area index (LAI), total dry weight (TDW) and leaf dry weight (LDW) should be measured in periodic intervals during the growing season (Ebrahim *et al.*, 2014). The above indices plus crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) are indices which are often used for evaluation of plant productivity capability and environmental efficiency (Anzoua *et al.*, 2010; De Sclaux *et al.*, 2000).

However, many researchers have emphasized the crucial role of physiological features in crop performance improvement but detailed and comprehensive studies in this area have not been conducted yet. Yield is a complex feature which depends on the function of physiological combined processes in particular, the limiting components that change with the cultivar. The cultivar of lettuce with higher physiological indices has better growth and higher yield (Esfahani *et al.*, 2006; Katsura, 2007; Mahdavi *et al.*, 2006). Hence, this experiment was conducted to evaluate the effect of irrigation depth and mulching on growth physiological indices of lettuce cultivars in Kadawa, Sudan Savanna Ecological Zone of Nigeria.

MATERIALS AND METHODS

Experimental Site

Experiments were conducted during the dry season periods of 2015/2016,2016/2017 and 2017/2018at Irrigation Research Sub-Station farm (IRS) of the Institute for Agricultural Research, Ahmadu Bello University at Kadawa, ($11^0\ 39'$ N, $080^0\ 027'$ E and 500 m. a. S. l.) which lied in the Sudan Savanna Ecological Zone of Nigeria. The area has a cool dry season that has the north-eastern winds, which are cool and contain dust blown from the Sahara Desert. The minimum temperature ranges between 11 and 18°C in the cool months (November to March) with maximum temperatures of 40°C in the warmer months (April to October) which is ideal for cultivation of wide variety of crops in the dry season.

Experimental Treatment and Design

Treatments consist of two levels of mulch (mulch and no-mulch), three irrigation levels (100, 75 and 50% WRET) at application depth: 100% of weekly reference evapotranspiration WRET on weekly basis; and three lettuce varieties (Great Lake, Slaai and Baby Leaf Mix). The treatment was combined in a factorial arrangement and laid out in a split plot design with three replications. Irrigation and cultivar were assigned to main plots while mulch was assigned to sub plots. A distance of 1m between replicates and 0.5 between plots was left as intervals. The plot size was 2 x 2 m, while the net plot was 0.6 x 2 m.

Characteristics of the Lettuce Cultivars

Great Lake: This variety produces tasty large heads, ideal for summer harvest. The seed takes about 5 to 10 days to germinate. It produces crisp, bright green leaved heads and matures in

50-60 days. The plant can resist bolting during hot summer weather (Davey *et al.*, 2007). It grows to a height of 20 cm. This cultivar is most common in Nigeria.
Slaai: This variety forms a crisp head with strong resistance to bolting in hot weather. It takes about 70 days to maturity (Davey *et al.*, 2007). Lettuce Slaai was sourced from SAKATA SEED, South Africa (Pty) Ltd.
Baby Leaf Mix: Germination takes about 7 to 14 days and the plant matures in 35 to 45 days. This type does not form hearts and comes in different colours with various types of mottling or patterns; and it is considered the easiest type of lettuce to grow (Zohany *et al.*, 2012). Baby leaf mix lettuce was sourced from Starke Ayres (Pty) Ltd, Gauteng South Africa.

Agronomic Operations and Treatment Impositions

Lettuce seeds were sown according to variety on well prepared nursery beds by drilling and was mulched after sowing and irrigated regularly (every day) with watering can. The mulch was removed after seedling emergence and rearranged between drill-rows of the emerged seedlings. Two weeks to transplanting, the seedlings were hardened. This was done by irrigating the nursery at two days' intervals. After 33 days of sowing when seedlings reach an average of five to six true leaves, they were transplanted at a spacing of 30 x 30 cm intra–row and inter–row. This was done in the evening to reduce transplanting shock on the seedlings.

Irrigation Practice

Surface irrigation was used; Water was released from the canal into the lateral ditches which service the basins. A PVC pipe of 4.5 cm diameter of about 50 cm long was installed through the embankment of each basin with one end in the basin and the other in the ditch which give free orifice flow into the basin. Stage gauges were placed at the water inlet of each basin to measure the depth of water over each tube as water enters the basin. PVC corks were placed at the entrance such that when the cork is remove, water flows into the basin until the desired depth was applied, the PVC cork was placed back to stop the water flowing into the basin. Using the orifice flow equation and the depth of flow recorded from the stage gauge, the flow rate into the basin was quickly determined and related to time of application to give to each basin the desired depth of water application. The time required to apply the depth of water was monitored using a stop watch. The amount of water applied at each irrigation was based on the reference evapotranspiration amount for that week of irrigation and the experimental treatment. Water application depth per irrigation was calculated using the following equations;

$$Q = C_d A\sqrt{2gh} \qquad \text{Eq. 1}$$

Where, Q = Discharge m^3/sec, C_d = Coefficient of discharge taking to be 0.65, A = Area of orifice m^2, h = Height of water above orifice (m)

$$t = \frac{Ad}{Q} \qquad \text{Eq.2}$$

Where, A = Area of basin in m^2, n = Application Efficiency taken to be 75%, d = Depth of water applied to each basin with respect to ET_o,t = time (sec)

Following transplanting, all the plots were irrigated at 3days' intervals up to 2 WAT. Thereafter, irrigation treatments were imposed on designated plots at 4 WAT.

During land preparation, 50 kg P_2O_5, and 50 K_2O per hectare using single superphosphate (SSP) and muriate of potash (MOP) respectively, was applied to the entire plots. Urea (46% N) was applied at the rate of 120 kg ha^{-1} to all plots in two split, (60 kg N ha^{-1}), during transplanting and the other half was applied at 2 WAT. Mulching material (rice straw) was laid after transplanting to designated plots at 5 t ha^{-1}. Weeding was carried out when the need arises,un-mulched plots were weeded manually using a hand hoe while the mulched plots were by hand picking.; these kept the field weed-free during the trials. Soil moisture content of the soil was monitored using ML3 Theta Kit (Soil moisture measurement kit) in percentage

Data Collection

Sampling of plant was done through destructive sampling and partial replacement procedure was followed. The following parameters were computed as indicated leaf area index, crop growth rate, relative growth rate, net assimilation rate at 8 and 10 WAT; dry weight per plant and total dry weight.

Leaf Area Index (LAI) was obtained by dividing the mean leaf area of one plant (LA), in m^2, by the surface area occupied by the plant (SA) in m^2. LAI is an expression for plant density per area under cultivation, given by the relationship between plant leaf area and surface area for this plant (spacing).

$$\text{Leaf Area Index(LAI)} = \frac{\text{Leaf area per plant}}{\text{Area of ground covered per plant}}$$

Crop Growth Rate (CGR), expressed in grams per $m^2$of ground per day, is a physiological variable that indicates the quantity of dry matter accumulated per unit of area under cultivation during a period of time at 8 and 10 WAT using the formula described by Radford (1967).

$$\text{Mean CGR} = \frac{W2-W1}{T2-T1} X \frac{1}{GR} (g/m2/wk)$$

Where: W_1 and W_2 = dry weight in g/plant at T_1 and T_2 in weeks; GR = ground area.

Relative growth rate (RCR): This is an increase in plant biomass per unit of initial plantmaterial per unit of time and was expressed as described by Radford (1967) at 8 and 10 WAT.

$$\text{Mean relative growth rate (RGR)} = \frac{\log_e W2-\log_e W1}{T2-T1} (g/g/wk)$$

Where: W_1 and W_2 = Plant dry weight in g/plant at time T_1 and T_2 respectively.

Net assimilation rates (NAR) was calculated in grams of dry matter per $m^2$of leaves per day and represents the balance between the material produced by photosynthesis and the one lost by respiration. It was determined according to Radford (1967) thus:

$$NAR = \frac{W1-W2}{T2-T1} \times \frac{1}{LA} \ (g/cm^2/wk)$$

Where, W_1 and W_2 = dry weight in g per time (T_1 and T_2).
Dry weight per plant (g): This was determined after drying the harvested three randomly picked plants in an oven at 70 °C to a constant weight and mean was recorded.
Total dry weight (kg ha^{-1}): This was determined after drying the harvested net plot separately and dried in an oven at 70 °C to a constant weight and mean was recorded.

Data Analysis

Data collected were subjected to analysis of variance using General Linear Model Procedure of SAS and treatment means was separated using Duncan Multiple Range Test (DMRT) (Duncan, 1955) at 5% level of significance.

RESULTS

Tables 1 and 2 presented the m climate information and soil physical properties of the study area, respectively.

Table I: Mean monthly temperature, relative humidity, sunshine hours and rainfall at ten days' interval at Kadawa during the period of experimentation

Month/days	Rainfall(mm)	Temperature (°C) Maximum	Minimum	Relative humidity(%)
January				
1-10	Nil	30.0	18.8	49.9
11-20	Nil	32.1	19.1	38.0
21-31	Nil	30.0	20.4	17.9
February				
1-10	Nil	34.1	23.0	15.2
11-20	Nil	40.4	22.7	24.5
21-31	Nil	42.8	23.5	22.0
March				
1-10	Nil	44.7	25.2	36.1
11-20	Nil	43.2	25.2	50.1
21-31	Nil	36.8	24.3	22.8
April				
1-10	Nil	43.5	25.3	32.3
11-20	Nil	39.8	26.6	34.3
21-31	7.0	38.3	25.0	52.0
May				
1-10	67.5	36.1	25.8	41.9
11-20	Nil	38.2	30.0	67.6
21-31	27.0	33.9	24.1	60.0

Source: Meteorological unit, Institute for Agricultural Research, (I.A.R.) Samaru Zaria

Table 2 shows result on the Physico-chemical properties of the experimental site before planting and application of treatment. The result reveals that the textural class of the soil was loamy. Particle size distribution of clay was low (150 g kg^{-1}),silt (480 g kg^{-1}) and 370 g kg^{-1} sand within the top 0-15 cm depth. The loamy texture indicates that the soil was suitable for lettuce production (Abu and Malgwi, 2011). Soil organic carbon in the site was low (0.88%), total Nitrogen was low (0.52%) available phosphorus was medium (9.3 mg kg^{-1}). Exchangeable calcium (Ca) and Mg were 3.80 (medium) and 1.03 cmol (+) kg^{-1}, respectively. Exchangeable potassium (K) and sodium (Na) were low at 0.11 and 0.10 cmol (+) kg^{-1}, respectively. Cation exchange capacity status (CEC) was rated medium (6.33 cmol (+) kg^{-1}), the soil reaction was (7.40), generally the soil at the experimental site had good physic-chemical properties for production of most crops.

Table 2: Physio-chemical properties of soil in the experimental site at 0-15cm and 15-30cm depth for Kadawa

Soil Compositions	Depth (cm) 0-15	15-30
Sand (g kg^{-1})	370	390
Clay (g kg^{-1})	150	380
Silt (g kg^{-1})	480	230
Texture	Loam	Loam
Chemical Compositions		
pH in H_2O(1:2.5)	7.40	7.30
pH in $CaCl_2$(0.01m)	6.90	6.90
Organic Carbon (g/kg)	0.88	2.40
Total Nitrogen (g/kg)	0.52	0.30
Available Phosphorus(ppm)	9.28	5.95
Exchangeable bases (cmol kg^{-1})		
Ca	3.80	4.20
Mg	1.03	1.13
K	0.11	0.14
Na	0.10	0.13
CEC	6.33	6.72

Source: Soil Science Department, Ahmadu Bello University, Zaria.

Leaf area index (LAI)

The effects of irrigation level and mulch in on leaf area index (LAI) and crop growth rate of lettuce at 8 and 10 WAT during the study period is shown on Table 3. Application of water level and mulching had significant effect on leaf area index throughout the course of the study except at 10 WAT and 8 WAT in 2015/2016 and 2016/2017 respectively. The maximum leaf area index (LAI) was recorded at 100 % WRET but comparable to 75 % WRET throughout the sampling period, while minimum leaf area index value was recorded at 50 % WRET level throughout the experimental periods, Results also indicated that LAI increased per week, the increased per week between 8 and 10 WAT for 50 %WRET was 18.6% in 2015/2016, 8.8% in 2016/2017 and in 2017/2018 was 24.3%. Weekly increase due to water application level on LAI for 70 and 100% WRET between 8 and 10 WAT was 15.1 and15.9 %, in 2015/2016, in 2016/2017 was 31.1 and 22.7 %, and in 2017/2018 was 19.1 and 28.3% respectively.

It was also observed that LAI decreases due to deficit irrigations, the decreased due to water deficit (75 and 50 % of WRET) at 10 WAT was 23.0 and 1.3% in 2016/2017, 19.4 and 20.8% and 12017/2018 was 2.3 and 17.0%.

Cultivar variation significantly influenced leaf area index at 8 WAT in 2015/2016 and 10 WAT in 2016/2017, no significant effect in 2017/2018. In 2015/2016, cultivar Great Lake and Slaai were statistically similar but significantly ($P<0.05$) higher than Baby Leaf. While in 2016/2017 season, Slaai had the highest LAI (0.49) compared to the other two cultivars with LAI values of 0.41 and 0.42.

It was observed that leaf area Index under mulch treatment was higher than the control (no mulch) in 2016/2017 and 2017/2018 only. LAI increase due to mulching were 26.3 and 20.4% at 8 and 10 WAT in 2016/2017. In 2017/2018, decrease in LAI due to mulching was 34.0 and 26.0%. Interaction between irrigation level and mulch was significant at 1% probability only at 8 WAT in 2015/2016 on LAI.

Crop Growth Rate (CGR)

The effects of irrigation levels and mulch on crop growth rate (CGR) of lettuce cultivars for 2016, 2017 and 2018 are shown in (Table 3). Irrigation had significant effect on crop growth rate except at 10 WAT in 2017 and at 8 WAT in 2018. 100 % WRET water application significantly produced plants recorded the highest crop growth rate (CGR) throughout the study periods. Although, increasing levels of irrigation increased the crop growth rate across the three years. However, application of 75 and 100 % WRET had no significant difference in crop growth rate throughout the study periods. When 50% WRET was applied, the plants growth rates were significantly lower than the values recorded with 75 and 100 % WRET across the sampling periods.

Cultivar had no significant effect on crop growth rate throughout the period of study. Cultivating any of the three lettuce cultivars resulted in similar crop growth rates across the sampling periods.

Mulching had significant effect on crop growth rate only at 8 WAT in 2017 and 2018 cropping seasons. Mulching resulted in the production of plants with significantly higher crop growth rate compared to the un-mulched plants at 8 WAT in 2017 and 2018.

Table 3: Response of lettuce cultivar to irrigation and mulch levels on leaf area index and crop growth rate in 2015/2016, 2016/2017 and 2017/2018

Treatment	Leaf area index						Crop growth rate (CGR), ($g/m^2/wk$)					
	2015/2016		2016/2017		2017/2018		2015/2016		2016/2017		2017/2018	
	8 WAT	10 WAT	8 WAT	10 WAT	8WAT	10 WAT	8 WAT	10 WAT	8 WAT	10WAT	8WAT	10WAT
Irrigation (I)												
50 % WRET	0.35b	0.43	0.52	0.57b	0.28b	0.37b	4.36b	6.9b	3.09b	4.3	5.4	10.2b
75 % WRET	0.37ab	0.44	0.51	0.74a	0.34a	0.42b	5.6ab	7.8ab	8.71a	7.6	5.9	12.2ab
100 % WRET	0.45a	0.53	0.58	0.75a	0.38a	0.53a	7.6a	10.3a	11.8a	6.72	8.7	19.1a
SE±	0.032	0.039	0.029	0.039	0.020	0.022	1.01	0.95	1.28	1.534	1.08	2.80
Cultivar (C)												
Great Lake	0.62a	0.74	0.36	0.41b	0.41	0.48	5.3	9.2	9.8	5.4	5.8	14.2
Slaai	0.57a	0.71	0.33	0.49a	0.38	0.47	5.7	8.2	7.3	6.0	7.9	14.2
Baby leaf Mix	0.42b	0.62	0.31	0.42b	0.37	0.45	6.5	7.5	6.5	7.2	6.4	13.2
SE±	0.029	0.039	0.020	0.022	0.032	0.039	1.01	0. .95	1.28	1.53	1.08	2.80
Mulch (M)												
No mulch	0.53	0.64	0.28b	0.39b	0.31b	0.40b	6.1	9.0	5.5b	6.0	3.7b	11.7
$5tha^{-1}$	0.54	0.73	0.38a	0.49a	0.47a	0.54a	5.6	7.7	10.2a	6.43	9.7a	16.0
SE±	0.024	0.032	0.016	0.018	0.026	0.032	0.82	0.78	0.05	1.25	0.88	2.29
Interaction												
I x C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x M	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x M	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x C x M	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means within each column and factor followed by same letter are statistically similar (p>0.05) using DMRT.
NS: Not significant. **: Significant at 1% significant

Table 4 shows the interaction between irrigation and mulch on leaf area index at 8 WAT in 2015/2016. Result indicated no significant difference among irrigation at 75 and 100% WRET treatment but irrigating at 50 % WRET level which resulted in low leaf area index. On the other hand, irrigating at 75% WRET recorded the highest LAI with no mulch but comparable to 100% WRET.

Table 4: - Irrigation level and mulch interaction on leaf area index at 8 WATin 2015/2016

	Mulch	
Irrigation level	No mulch	5tha^{-1}
50 % WRET	0.468c	0.496bc
75 % WRET	0.527ab	0.570ab
100 % WRET	0.629a	0.526abc
SE$\pm$	0.0411	

Means followed by same letter(s) are statistically similar (p>0.05) using DMRT

Dry Matter per Plant (g)

The response of irrigation and mulch on dry weight per plant and total dry matter (kg ha^{-1}) of lettuce in 2015/2016, 2016/2017 and 2017/2018 are presented in Table 5.

Irrigation levels had a significant effect on dry matter per plant throughout the course of the study except at 6 WAT in 2017/2018 season. The result indicates that irrigating at 50 % WRET resulted in significantly (P<0.05) lower dry matter per plant than irrigating at 75 and 100% WRET respectively throughout the sampled periods. Results further reviewed that dry matter per plant decreased with increase in water deficit. The decrease due to water deficit from 75 to 50% WRET at harvest was 18.6 and 17.3% in 2015/2016, 43.7 and 18.1% in 2016/2017 and 16.8 and 24.5% in 2017/2018.

The results indicate that cultivar differences significantly (P<0.05) influenced dry matter accumulation only at 6 and 8 WAT in 2015/2016 and 2016/2017 respectively. Cultivar Great Lake recorded statistically lower (15.4 and 34.2 g) dry matter per plant than the other two cultivars (Slaai and Baby Mix Leaf) which were statistically higher with values of 18.7 and 40.9, and 16.1 and 32.7g respectively.

Effect of mulch on dry matter per plant of lettuce was significant except at 8 and 10 WAT in 2015/2016 and 10 WAT in 2017/2018 seasons. Result reviewed that dry matter per plant decreased with increase in water deficit. The percentage decrease in dry mater per plant due to increase in water deficit for 75 and 50 % WRET in 2015/2016 is 15.9%, in 2016/2017 was; 34.4, 40.2 and 36.3 % and 2017/2017 was 37.2 and 48.6 % respectively.

Table 5: Response of lettuce cultivar to irrigation and mulch levels on dry matter (g) per plant and total dry yield (kg ha^{-1}) in 2015/2016, 2016/2017 and 2017/2018

Treatment	Dry weight per plant 2015/2016 6 WAT	8 WAT	10 WAT	2016/2017 6 WAT	8WAT	10 WAT	2017/2018 6 WAT	8WAT	10 WAT	Total dry yield 2015/2016	2016/2017	2017/2018
Irrigation (I)												
50 % WRET	12.8c	21.1c	35.1c	14.8b	21.0c	28.6c	16.2	27.1b	47.5b	4709.3c	4681.4c	5140.0c
75 % WRET	17.0ba	27.1b	43.1b	19.1ab	36.5b	50.8b	20.1	32.7ab	57.1b	6764.8b	6819.2b	6370.4b
100 % WRET	20.6a	35.0a	52.1a	26.8a	50.3a	62.0a	20.9	37.6a	75.6a	7507.6a	7488.0a	7814.4a
SE±	1.01	1.97	2.65	2.63	1.66	2.70	2.09	3.17	4.57	216.10	208.80	214.68
Cultivar (C)												
Great Lake	15.4b	26.3	42.8	19.7	34.2b	44.2	22.7	30.8	58.5	6400.3	6060.8	6404.0
Slaai	18.7a	28.4	45.4	21.4	40.9a	52.1	16.5	34.2	62.6	6359.6	6250.4	6502.4
Baby leaf Mix	16.1ab	28.5	42.0	19.7	32.7b	45.1	18.1	32.2	59.1	6221.7	6082.4	6418.4
SE±	1.01	1.97	2.65	2.63	1.66	2.70	2.09	3.17	4.57	216.10	208.80	214.68
Mulch (M)												
No mulch	15.2b	27.6	43.0	15.9b	26.9b	36.7b	14.7b	22.1b	45.4	5353.1b	5461.1b	5389.6b
5tha^{-1}	18.3a	27.8	43.8	24.6a	45.0a	57.6a	23.4a	42.7a	74.7	7301.4a	7180.8a	7592.8a
SE±	0.83	1.61	2.16	2.15	1.36	2.20	1.71	2.59	3.73	176.44	168.02	178.22
Interaction												
I x C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x M	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x M	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x C x M	NS	. NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means within each column and factor followed by same letter are statistically similar (p>0.05) using DMRT.
NS: Not significant.

Total dry Matter (kg ha^{-1})

The trend of total dry weight (TDW) under irrigation and mulch is shown on Table 5. There was significant effect on irrigation treatment across the three years. Maximum total dry matter accumulation in each treatment were 7507.6, 7488.0 and 7814.1 kg ha^{-1} in 2015/2016, 2016/2017 and 2017/2018, respectively. In general, it can be stated that the computed value of total dry matter accumulation was more at higher irrigation levels (100 % WRET) than lower ones (50 and 75% WRET). The percentage decrease of dry weight of 50, 75% WRET treatments was 30.9 and 9.9% respectively when compared to 100% WRET treatment in 2015/2016, in 2016/2017 and 2017/2018 the percentage was 31.4 and.8.9%; 19.3 and 18.5% respectively.

The trend of total dry weight in lettuce cultivars during the growth season showed that there was no significant differences between the cultivars on total dry weight accumulation throughout the sampling periods.

The result further revealed that total dry matter under mulch treatment was higher than the control in all the years. Increase in total dry matter (TDM) due to mulching was 26.7, 24.0 and 29.0 % in 2015/2016, 2016/2017 and 2017/2018 respectively. However, this patterns of increase due to mulching is expected because the high soil moisture under mulch cover encourage optimal transpiration, nutrient uptake and rate of photosynthesis required for plant growth.

Relative Growth Rate (RGR)

The response of relative growth rate and net assimilation of lettuce rate to irrigation and mulch in 2015/2016, 2016/2017 and 2017/2018 are presented in Table 6. Irrigation and cultivar treatments had no significant effect on relative growth rate throughout the period of the experiment.

Results indicated that RGR under the mulched treatment at 8 WAT in 2017/2018 was significantly higher than the control (no-mulch). Interaction among the factors was not significant on relative growth rate throughout the period of experimentation.

Net Assimilation Rate (NAR)

The trend of net assimilation rate (NAR) under irrigation treatments and mulch is shown in Table 6. Irrigation levels significantly ($P<0.05$) affected NAR across the three years except at 10 and 8 WAT in 2016/2017 and 2017/2018 respectively. NAR at 100% WRET treatment was significantly higher ($P<0.05$) than other treatments in 2015/2016 but in 2016/2017 and 2017/2018, Irrigation at 75% WRET recorded the highest NAR than other irrigation treatments but comparable to 100% WRET. It was observed that NAR decreased with increase in irrigation deficit. The percentage of decrease in NAR from 50 to 75% WRET treatments at 10 WAT was 16.7 and 20.0% in 2015/2016, 33.3 and 13.3% in 2016/2017 and 26.5 and 29.2% in 2017/2018 respectively. Cultivar variation across the three years on NAR was not significant.

Results indicated that NAR under the mulched treatments was significantly higher than that of the control (no-mulch). Increase in NAR due to mulch treatment at 10 WAT was; 25.6%, 2.2% and 1.5%for 2015/2016, 2016/2017 and 2017/2018 respectively. There was no significant interaction among the treatments on NAR across the three years.

Table 6: Response of lettuce cultivar to irrigation and mulch levels on crop growth rate and net assimilation rate in 2015/2016, 2016/2017 and 2017/2018

	Relative growth rate (RGR) (g/g/wk.)						Net assimilation rate (NAR) (g/cm²/wk)					
	2015/2016		2016/2017		2017/2018		2015/2016		2016/2017		2017/2018	
Treatment	8 WAT	10 WAT	8 WAT	10 WAT	8WAT	10 WAT	8 WAT	10 WAT	8 WAT	10 WAT	8 WAT	10 WAT
Irrigation (I)												
50 % WRET	0.09	0.12	0.07	0.08	0.09	0.12	0.010b	0.040b	0.008b	0.012	0.013	0.025b
75 % WRET	0.12	0.12	0.07	0.15	0.10	0.13	0.013b	0.048b	0.022a	0.018	0.015	0.034ab
100 % WRET	0.10	0.15	0.05	0.16	0.13	0.17	0.021a	0.060a	0.029a	0.021	0.022	0.048a
SE±	0.014	0.017	0.011	0.028	0.016	0.030	0.0016	0.0034	0.0032	0.0041	0.0027	0.0068
Cultivar (C)												
Great Lake	0.10	0.12	0.06	0.15	0.09	0.14	0.016	0.047	0.021	0.024	0.019	0.039
Slaai	0.10	0.14	0.06	0.13	0.12	0.15	0.017	0.052	0.018	0.015	0.020	0.033
Baby leaf Mix	0.12	0.14	0.07	0.11	0.10	0.14	0.017	0.050	0.016	0.019	0.016	0.035
SE±	0.014	0.017	0.011	0.028	0.016	0.030	0.0014	0.0034	0.0032	0.0041	0.0027	0.0068
Mulch (M)												
No mulch	0.14	0.11	0.07	0.12	0.08b	0.12	0.010b	0.043b	0.014b	0.016	0.011b	0.033
5tha^{-1}	0.12	0.10	0.06	0.13	0.14a	0.16	0.019a	0.057a	0.026a	0.018	0.024a	0.038
SE±	0.014	0.011	0.009	0.023	0.013	0.025	0.0013	0.0027	0.0026	0.0033	0.0022	0.0055
Interaction												
I x C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x M	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x M	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x C x M	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means within each column and factor followed by same letter are statistically similar (p>0.05) using DMRT. NS: Not significant.

DISCUSSION

The loamy texture indicates that the soil was suitable for lettuce production (Abu and Malgwi, 2011). The results of this study indicated that plants that received 75 and 100 % WRET irrigation depth grew vigorously and produced the highest leaf area index (LAI), crop growth rate (CGR), dry weight plant $^{-1}$, total dry weight, relative growth rate (RGR) and net assimilation rate (NAR) throughout the study periods. This observation might be as a result of water provided at full irrigation which provides optimum moisture that promote vegetative growth and stimulate the activities of micro-organisms thereby influencing the growth and yield greatly. The decrease in the LAI from the deficit irrigation treatments could be as a result of supplying inadequate water replenishment of the WRET. Krishna *et al.* (2013) reported that water stress decreases the leaf area due to reduced cell division and cell enlargement which could be caused by accumulation of unexpanded cells during the cycle.

It was also observed that dry matter accumulation decreased with increased in water deficit. The significant response to irrigation during the vegetative growth may be due to the fact that the roots were still developing, and hence had not reached deeper to tap moisture in the lower soil layers and this meant that varying irrigation level could affect the crop performance.

Variation among the three cultivars could be due to some inherent genetic and physiological differences that exist among the cultivars. Growth characters are genetically controlled and to some extent influenced by the environment (Boroujerdnia *et al.*, 2007). Higher content of total dry matter accumulation in Slaai cultivar was likely due to the higher difference between the total amount of current photosynthesis and plant respiration was than the other cultivars and as a result the surplus of this difference caused further increase in total dry weight of this cultivar compared to the other cultivars (Ebrahim *et al.*, 2014; Yang *et al.*, 2009). One of the most important growth indicators which have been being applied as a measure of total photosynthesis and respiratory tissues is total dry weight.

Mulching significantly increased leaf area index, crop growth rate, net assimilation rate, dry weight per plant and total dry yield per hectare when compared to the non-mulched plants. This pattern of increase due to mulch is expected because, the high soil moisture under mulch cover encourage optimal transpiration, nutrient uptake and rate of photosynthesis required for plant growth (Azad *et al.*, 2015). This could be due to the fact that mulching has much beneficial importance to crops in terms of improvement of soil properties that enhance to better crop performance. This study is in line with Zhang *et al.* (2010) who reported that rice straw enhanced crop performance compared to the control (no-mulch) treatment. A good mulching material with adequate supply of nutrients is essential for plants to attain maximum production.

CONCLUSION

The results of this study showed a significant response to variations in irrigation and mulch treatment by many of the parameters. Increase in irrigation levels significantly increased leaf area index, crop growth rate, dry weight per plant, TDM and net assimilation rate. Based on the results obtained, it can be concluded that cultivar Slaai and application of 75% WRET had resulted in better agro-physiological characters of lettuce cultivar at Kadawa.

Since there were only minor differences between yields of lettuce obtained from 75 and 100%WRET.

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Appendix I: Summary of lettuce yield, crop water use, irrigation water use, CWUE and IWUE as affected by deficit irrigation and mulch at Kadawa

	Deficit irrigation levels in %	Lettuce yield (kg ha^{-1})	SET (mm/season)	IWU (mm/season)	CWUE (kg/m^3)	IWUE (kg/m^3)
Mulch	I_{50}	85000.0	369.6	375.5	23.0	22.6
	I_{75}	86388.9	338.2	365.2	25.5	23.7
	I_{100}	109444.4	295.7	298.9	37.0	36.6
	I_{50}	66666.7	264.6	390.3	25.2	17.8
No-Mulch	I_{75}	70660.0	287.3	331.5	24.6	21.3
	I_{100}	79166.7	239.6	331.5	33.0	23.9