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EFFECT OF MULCH AND IRRIGATION ON GROWTH AND WATER USE EFFICIENCY OF LETTUCE (*Lactuca sativa* L.) CULTIVARS

Ichi, J. O.[1], Ibrahim, H.[2], Osunde, A. O.[3], Odofin, A. J.[3]

[1]Department of Agricultural and Bio-Resources Engineering, Institute for Agricultural Research Ahmadu Bello University Zaria.
[2]Department of Crop Production, School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Nigeria
[3]Department of Soil Science, School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Nigeria.

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ABSTRACT

A study was carried out to evaluate effect of mulch and irrigation on growth and water use efficiency of lettuce (*lactuca sativa* L.) cultivars under irrigation during 2016, 2017 and 2018 in semi-arid ecology of Northern Nigeria at 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 above sea level) in the Sudan Savanna Ecological Zone of Nigeria. Treatments were factorial combinations of three irrigation levels (50, 75 and 100 % of reference evapotranspiration (ET_o), three lettuce cultivars (Great Lake, Slaai and Baby leaf mix) and two levels of mulch (no-mulch and mulch) laid out in a split plot design with three replicates. Water applied before and after irrigation was monitored throughout the seasons. Results indicated that different levels of irrigation and mulch on all growth characteristics, crop water use efficiency and irrigation water use efficiency were significant with the highest irrigation level of 100 % ETo recording the highest yield of 8.5, 8.4 and 8.6 tonnes ha^{-1} in 2016, 2017 and 2018 seasons respectively while 50 % ETo recoded the least yield of 7.3, 6.7 and 7.5 tonnes ha^{-1} across the three years. Increase in water application increase yield of about 7.6% in 2016; 11.6 and 10.6 % in 2017 and 2018 respectively with 100% ETo. Mulching significantly improved the crop water productivity irrespective of the cultivar in the study area. Since there were only minor differences between growth characters of lettuce obtained from 75 and 100% ETo, it can be said that water application should be kept at 75% weekly crop consumptive use in this region.

Keywords: Mulch, Irrigation, Lettuce growth, Water use efficiency

Corresponding author email: janeoyidiya@yahoo.co.uk; Telephone: +234-8035930539

INTRODUCTION

Mulching has much beneficial importance to crops in terms of improvement of soil properties that relate to better crop performance. [1] 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. It was also reported that mulch increases the soil moisture and nutrients availability to plant roots, in turn, leading to higher yield [2]. In another research it was reported that mulching increases soil water and reduce soil temperature significantly [3]. [4] reported that mulching combined with surface irrigation is a useful technique for maximizing water use efficiency. Important of using soil mulching to agriculture is to reduce water usage, and conserve soil moisture according to [5] and improves water infiltration [6]. Mulching reduced water evaporation from soil [7]; [8].

Mulching of agricultural fields with organic or inorganic materials is an agricultural strategy that dates back beyond ancient Egypt. For several decades, mulching has been used in several parts of the world to evade drought and increase crop yield [9]. The practice of mulching has been utilized to great advantage in the development of horticultural crops [10] and has been proven to significantly improve the growing conditions of vegetables grown in the tropics, including onions and lettuce [9].

Irrigation is the artificial application of water to the soil to insure sufficient soil moisture for good plant growth as defined by several researchers ([11]; [12]), it is used to assist in the growing of agricultural crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas and during periods of inadequate rainfall [13].

The need for more efficient agricultural use of irrigation water arises out of increased competition for water resources and rising environmental anxiety that irrigation practice in some cases is facilitating degradation in the quality of those ground and surface waters that receive leachates from the root zone of irrigated fields [14]. The most limiting and variable environmental factor affecting the productivity of plants is water [12]. Additionally, irrigation also has a few other uses in crop production which include protecting plants against frost, and helping in preventing soil consolidation [15]. [16] reported that there are different approaches of irrigation scheduling which includes measuring soil and plant parameters to determine when and how much water to apply. The availability of water in the soil depends in several factors which is combined and known as water balance [12]. According to [17], irrigation scheduling is the decision of when and how much water to apply to a field. Its purpose is to maximized irrigation efficiency by applying the exact amount of water needed to replenish the soil moisture to the desired level and timing, irrigation scheduling saves water and energy. [18] revealed that increasing levels of irrigation increased plant height, canopy diameter, shoot length, number of leaves per shoot and leaf area. Deficit treatments strongly reduced vegetative growth [19]. [20] showed that vegetative growth parameters (shoot length, leaves density and leaf area) responded negatively to the regime water treatments. 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 methodology to obtain maximum yield per unit area. [21] reported that lettuce yield increased in response to water application.

Lettuce (*Lactuca sativa* L.) is a popular crop amongst the salad vegetables [22]. It ranked 4th in terms of consumption rate and 26th among vegetables and fruits in terms of nutritive value. World production of lettuce in 2010 was 24.8 metric tonnes. According to [23] estimates, China produced about 13.5 metric tonnes, United States of America (USA) produced 3.5 metric tonnes while India produced about 1,1 metric tonnes of lettuce. China's production is consumed locally. Spain is the world's largest exporter of lettuce, with the United States of America (USA) ranking second.

Lettuce is most often used for salads. It is also used in other dishes such as soup, sandwiches and wraps [24]. It is usually consumed individually as salad or shredded in mixed salad of onion, tomato, cheese and basil [25]. Lettuce is rich in vitamin A (carotene), vitamin C (ascorbic acid), calcium iron [26]. The antioxidants contained within lettuce may protect against serious diseases, including cardio-vascular disease and certain cancers.

Cultivars have a significant effect on growth, yield and characteristic of plants and consequently causing variation in size, form, leave shape, color and taste of plant. The choice of lettuce cultivar for increased yield depends mainly on the vegetative growth and resistance to bolting in hot weather [27]. Selection of cultivar has been noted to be among the factors that contributed to the realization of a successful cropping [28]. Many cultivars of lettuce exist with varying shapes, sizes and colour of leaves. These variations could be as a result of genetically composition or environmental factors. There is a high relation between cultivar selection and a successful cropping.

This study was therefore aimed to determine the effects of different water application levels and mulching treatment on the growth of lettuce cultivars and to determine the crop water productivity.

MATERIALS AND METHODS.

Study location

Field experiments were conducted during the 2016, 2017 and 2018 dry seasons respectively, at Irrigation Research Sub-Station farm (IRS) of the Institute for Agricultural Research, Ahmadu Bello University in Kadawa, (11^{o} $39^{/}$ N, 080^{o} $027^{/}$ E and 500 m above sea level) 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^{o}C and 18^{o}C in the cool months (November to March) with maximum temperatures of 40^{o}C in the warmer months (April to October) which is ideal for cultivation of wide variety of crops in the dry season. A composite soil sample was taken using soil auger at different locations from the field at 0-15 cm and 15-30 cm depth before land preparation. The soil samples were air dried, gently crushed and passed through 2 mm sieve, before analysis of the soil physical and chemical properties.

Experimental Treatment Description

The field experiment consists of two levels of mulch (mulch and no-mulch), three irrigation levels (50, 75 and 100 % ET_o) at application depth: 100% of reference evapotranspiration (ET_o) on weekly basis; and three lettuce cultivars (Great Lake, Slaai and Baby Leaf Mix). The treatment was combined factorially and laid out in a split plot design with three replications. Treatment combinations of 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. Lettuce cultivars used were:

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 [29]. 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 [29]. 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 [24]. Baby leaf mix lettuce was sourced from Starke Ayres (Pty) Ltd, Gauteng South Africa.

Agronomic Operations and Treatment Impositions

Seeds were sown according to cultivar on a 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 hardening. 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 cm 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 4.5cm diameter of about 50cm 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 was placed at the water inlet of each basin to measure the depth of water over each tube as water enters the basin. PVC corks was 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 (Eq.1) 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 (Eq.2) 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 weekly reference evapotranspiration (ETo) amount for that week of irrigation and the experimental treatment. Water application depth per irrigation was calculated using the following equations [30] as cited by [31];

$$Q = C_d A\sqrt{2gh} \quad \text{(Eq.1)}$$

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)

$$t = \frac{Ad}{Q} \quad \text{(Eq.2)}$$

Where, A = Area of basin in m^2, q= 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 was irrigated at 5 days intervals up to two weeks after transplanting (WAT) to enable the establishment of the seedlings. Thereafter, irrigation treatments were imposed on designated plots at 2 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 tonnes ha^{-1}. The un-mulched plots were weeded manually using a hand hoe while the mulched plots were weeded by hand picking. Weeding was carried out when the need arises; these kept the field weed-free during the trials. Soil moisture content of the soil was monitored using Theta probe (Soil moisture measurement kit) in moisture percentage. Three plants per net-plot was randomly picked and tagged at 4 WAT for the purpose of measuring the following crop parameters. Plant height was taken from tagged plants at 6 and 8 WAT. This was done by measuring the height (cm) of the plant from ground base to tip of the terminal leaflet, with a meter rule, and the mean was determined. Number of leaves per plant was determined at 6 and 8 WAT, mean was computed. Leaf canopy spread was taken at 6 and 8 WAT by measuring the leaf width of the tagged plants with tape rule and mean was determined. Stem diameter was taken at 6 and 8 WAT with veneer caliper and the mean was recorded. Root length was taken at 6 and 8 WAT by means of meter rules and average was recorded. Fresh yield ha^{-1} was done by harvesting all the net plots separately and taking their weight (g), and expressed in kg ha^{-1}.

Determination of Crop Water Use and Irrigation Water Use Efficiency

Soil moisture regimes of the experimental plots were monitored throughout the seasons using the ML3 Theta probe soil moisture sensor. The soil moisture content was taken at three different depths (15, 30 and 45 cm) by inserting the sensor head of the Theta probe into the soil through vertical installed PVC pipes which served as access to the desired depths. Moisture measurement of the soil was taken just before every irrigation and 24 hours after every irrigation event.

Crop water use between successive moisture measurements was estimated using the soil moisture depletion method [30] as cited by [31], with the expression given as

$$CWU = \sum_{i=1}^{n} \frac{(MC_{1i} - MC_{2i}) \times D_i}{t} \qquad (3)$$

where,

CWU= crop water use for 7-day irrigation interval sampling periods (mm/7 days); MC_{1i} is soil moisture content (% volume) irrigation (24 hours after irrigation) in the ith soil layer, MC_{2i} is soil moisture content (% volume) just prior to the next irrigation event (7 days after irrigation) in the ith layer), 'n' is number of soil layers sampled in the root zone depth D, and 't' is number of days between successive soil moisture content sampling.

Seasonal crop water use (SCWU) was calculated by summing the CWU values of each sampling interval. For each 7-day irrigation cycle, a correction was made by adding potential ETo value for accelerated water loss during the 1-day interval.

Water use efficiency was estimated on basis of yield for each treatment combination using the ratio of yield obtained per seasonal crop water use [14]. As expressed:

where:

$$WUE = Y/ET \qquad \text{(Eq. 4)}$$

WUE= Water Use Efficiency
Y = lettuce yield (kg)
ET = Evapotranspiration (mm)

Data collected was subjected to analysis of variance using General Linear Model Procedure of SAS and treatment means was separated using Duncan Multiple Range Test (DMRT) [32] at 5% level of probability.

RESULTS

The results of the soil analysis for the experimental site is presented on Table 1. The dominant soil texture was loamy. The chemical properties of the soils following critical values of soil nutrients showed that the pH in the location were moderately acidic. The total nitrogen, available phosphorus, calcium, magnesium, potassium and sodium were generally moderate and sodium and organic matter were low.

Table 1: - 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	37	39
% Silt	48	38
% Clay	15	23
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 (mol(+)kg)		
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.

The response of lettuce cultivars to irrigation levels and mulch treatment on plant height and number of leaves in 2016, 2017 and 2018 in 2017 and 2018 is shown on Table 2, application of 100 % ETo water rate significantly produced taller plants at 6 and 8 WAT but comparable to 75% ETo application level. 50 % ETo water application depth significantly produced shorter plants compared to 75 and 100 % water application levels in both years. Cultivar had no significant effect on plant height across the three years.

Mulching levels influenced plant height significantly only in 2017 season. Un-mulched plants were significantly WAT.

The response of lettuce cultivars to irrigation and mulch on number of leaves in 2016, 2017 and 2018 study seasons is shown in Table 2.

Depth of irrigation was significant on number of leaves on in 2017 season only, significantly higher leaf number per plant was recorded with water application of 100 % ETo as from 6 and 8 WAT. At 6 WAT, 100% ETo water application significantly produced plant with higher number of leaves (11) compared to 10 leaves produced by plants irrigated at 50 and 75 % ETo water application.

The leaf numbers obtained with 75% ETo at 8 WAT were statistically similar with those of 100 % ETo application depth.

Cultivar variations significantly affected number of leaves per plant in 2016 and 2017. Baby Mix Leaf generally produced plants with statistically higher number of leaves compared to the Great Lake and Slaai in both years.

Table 2: Effects of irrigation depths and mulch levels on plant height (cm) and number of leaves of lettuce at 6 and 8 WAT in 2016, 2017 and 2018

	Plant height						Leaf number					
	2016		2017		2018		2016		2017		2018	
Factors	6	8	6	8	6	8	6	8	6	8	6	8
Irrigation (I)												
50 % ET_o	6.5	8.9	8.7b	11.8b	8.6b	13.4	12.1	24.3	10.1b	15.4b	18.5	22.0
75 % ET_o	6.3	8.3	9.7ab	12.4ab	9.3ab	14.1	11.8	25.1	10.0b	7.2ab	19.5	23.7
100 % ET_o	6.1	8.3	10.2a	13.5a	10.7a	15.4	13.2	27.8	11.5a	19.4a	20.4	24.4
SE±	0.21	0.37	0.45	0.42	0.61	1.13	0.57	1.62	0.41	0.74	1.67	1.54
Cultivar (C)												
Great Lake	6.5	8.5	9.6	12.3	9.6	15.6	10.1c	19.5c	9.3b	15.9b	20.1	23.5
Slaai	5.9	8.6	9.0	12.6	9.4	13.9	12.4b	24.6b	11.3a	16.3b	17.4	22.6
Baby leaf Mix	6.5	8.4	10.	12.8	9.6	13.4	14.7a	33.1a	11.3a	19.9a	20.8	23.9
SE±	0.21	0.37	0.45	0.42	0.61	1.13	0.57	1.62	0.41	0.74	1.67	1.54
Mulch (M)												
No mulch	6.17	8.5	8.47b	11.1b	8.60	13.6	11.9	23.8	10.2	17.1	18.3	20.2b
5 t ha^{-1}	6.42	8.5	10.6a	14.0a	10.5	15.0	12.9	27.6	10.9	17.6	20.6	26.5a
SE±	0.170	0.30	0.365	0.34	0.49	0.92	0.47	1.24	0.34	0.60	1.32	1.28
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 /factor followed by same letter is statistically similar ($p>0.05$) using DMRT. NS: Not significant.

Mulching had significant effect on leaf number only at 8 WAT in 2018 season. Un-mulched plant significantly produced lower leaf number throughout the study periods.

Canopy spread (cm)

The response of lettuce cultivars to irrigation levels and mulch treatment on leaf canopy spread and stem diameter in 2016, 2017 and 2018 in 2017 and 2018 is shown on Table 3. Irrigation levels had significant difference on canopy spread only at 8 WAT in 2017 study periods only. Application of 100 % ETo water level produced plants with significantly wider canopy compare to plants irrigated at 50 and 75 % ETo.

Although, at 8 WAT plants that were irrigated with 75 and 100 % ETo recorded significantly similar canopies

Cultivar variation significantly affected canopy spread only in 2016 dry season, (Table 3). Baby Leaf Mix produced significantly narrower canopy compared to Lake and Baby Mix. However, Great Lake and Slaai statistically produced plants with similar canopies in 2016.

Mulching significantly influenced canopy spread on in 2017 and 2018 dry seasons. growing season. Mulching enhanced canopy of lettuce plants. Mulched plants significantly recorded wider canopies compared to un-mulched plants throughout the study periods of 2016 and 2017.

Table 3: Effects of irrigation depths and mulch levels on canopy spread and stem diameter of lettuce at 6 and 8 WAT in 2016, 2017 and 2018

	canopy spread (cm)						**stem diameter (cm)**					
	2016		2017		2018		2016		2017		2018	
Treatments	6	8	6	8	6	8	6	8	6	8	6	8
Irrigation (I)												
50 % ET_o	26.8	32.6	14.7	18.9b	25.0	29.3	5.8b	7.6b	5.5	7.2c	7.0	10.3b
75 % ET_o	26.6	31.3	15.4	21.9a	25.5	29.8	6.1b	8.1b	5.7	8.3b	7.3	10.8b
100 % ET_o	27.1	32.4	15.6	23.1a	25.6	30.4	6.8a	8.8a	5.7	9.6a	7.7	11.9a
SE±	0.56	0.61	0.47	0.84	1.38	0.87	0.21	0.23	0.17	0.32	0.24	0.33
Cultivar (C)												
Great Lake	26.9ab	32.1ab	16.1	22.1	25.6	31.2	6.0	7.8	6.0a	8.3	7.8a	11.6a
Slaai	27.8a	33.4a	14.7	21.4	25.3	29.1	6.3	8.4	5.5ab	8.2	7.2ab	11.0ab
Baby leaf Mix	25.7b	30.4b	15.0	20.4	25.2	29.1	6.4	8.3	5.3b	8.6	6.9b	10.4b
SE±	0.56	0.61	0.47	0.84	1.38	0.87	0.21	0.23	0.17	0.32	0.24	0.33
Mulch (M)												
No mulch	27.0	31.4	14.5b	19.9b	23.0b	27.4b	6.05	8.07	7.52b	8.34b	7.3	10.8
5 t ha^{-1}	26.6	32.8	16.0a	22.7a	27.8a	32.3a	6.42	8.23	9.23a	9.75a	7.3	11.1
SE±	0.46	0.50	0.38	0.69	1.13	0.71	0.170	0.184	0.263	0.239	0.20	0.27
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 /factor followed by same letter is statistically similar ($p>0.05$) using DMRT. NS: Not significant.

Stem diameter (cm)

A significant difference among the irrigation treatments was observed on the stem diameter except at 6 WAT in 2017 and 2018 seasons. It was observed that plants irrigated at 100 % ETo significantly produced widest stem per plant throughout the periods of study. In 2016 cropping season, as from 6 and 8 WAT plants that received 50 and 75 % ETo water application significantly produced plants with similar stems. The same trends were observed in 2018 cropping season. However, 1n 2017 at 8 WAT, plants irrigated with 100 % ETo significantly produced higher value (9.6) compared to the values (7.2 and 8.3) recorded with plants irrigated with 50 and 75 % ETo water application. Irrigation treatment at 50 % ET_o level recorded the least stem diameter throughout the period of experimentation.

Cultivar had significant effect on stem diameter at 6 WAT in 2017 and in 2018 cropping seasons. Great Lake produced significantly plants with widest (6.0cm) stem against 5.5 and 5.3cm by Slaai and Baby Leaf Mix at 6 WAT in 2017. In 2018, a similar trend was also observed at 6 and 8 WAT in 2018.

Mulching had significant effect on stem diameter in 2017 cropping season. Mulching enhanced stem diameter in 2017. At 6 and 8 WAT mulched plants significantly produced wider stem diameter (9.23 and9.75 cm) as against 7.52 and 8.34 cm that were produced by un-mulched plants at 6 and 8 WAT in 2017.

The effect of various treatments on root length and vegetable fresh weight per hectare for 2015/2016, 2016/2017and 2017/2018 irrigation season is shown in Table 4,

Root length (cm)

The response of lettuce cultivars to irrigation levels and mulch rates on root length in 2016, 2017 and 2018 is presented on Table 4. In 2016, significantly longer root length was recorded on plants that received 100 % ETo irrigation water application only at 8 WAT. In 2017, at 6 WAT significantly plants that received 75 and 100 % ETo produced similar root length. While in 2017, application of water at 50 % ETo significantly produced shortest (6.93 and 7.05 cm) compared to the values obtained with 75 and 100 % ETo (8 and 9 cm) at 6 and 8 WAT.

Cultivar variation did not show any significant effect on root length of lettuce throughout the sampling periods, except at 8 WAT in 2016 (Table 4). Baby Leaf Mix significantly produced plants with shorter roots compared to Great Lake and Slaai.

Mulching had significant effect on root length only in 2016 and 8 WAT in 2018 cropping seasons. Mulching resulted in the production of plants with significantly longer roots compared to the un-mulched plants at in 2016 and 8 WAT in 2018.

Table 4: Effects of irrigation depths and mulch levels on root length and vegetable yield of lettuce at 6 and 8 WAT in 2016, 2017 and 2018

	Root length (cm)						**Vegetable yield kg ha^{-1}**		
	2016		2017		2018				
Treatments	6	8	6	8	6	8	2016	2017	2018
Irrigation (I)									
50 % ET_o	6.70b	7.60b	6.93c	7.05c	8.49	8.75	72806b	66528c	75231b
75 % ET_o	7.78a	7.63b	8.68b	7.81b	8.74	9.38	78041b	75231b	79491ab
100 % ET_o	7.85a	8.50a	9.48a	8.91a	9.02	9.78	84536a	84120a	86019a
SE±	0.300	0.210	0.422	0.239	0.301	0.351	2175.9	1516.8	2952.5
Cultivar (C)									
Great Lake	7.21	8.23a	8.47	8.29	8.97	9.61	79284	78889a	82917
Slaai	7.92	8.17a	8.40	7.70	8.93	9.18	77141	74676ab	80741
Baby leaf Mix	7.20	7.33b	8.22	7.78	8.35	9.11	78958	72315b	77083
SE±	0.300	0.210	0.224	0.239	0.301	0.351	2975.9	1516.8	2952.5
Mulch (M)									
No mulch	7.18	7.87	7.60b	7.18b	8.45	8.79b	67823b	62222b	72654b
5 t ha^{-1}	7.71	7.94	9.12a	8.67a	9.05	9.81a	89099a	88364a	87840a
SE±	0.245	0.171	0.183	0.195	0.246	0.287	1776.6	1238.4	2410.7
Interaction									
I x C	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x M	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x M	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x C x M	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Vegetable yield kg ha^{-1}

Response of lettuce cultivar to irrigation levels and mulching in 2016, 2017 and 2018 is shown in Table 4. There were significant differences among irrigation depth in terms of fresh yield per hectare throughout the study periods. However, application 100 % ETo depth significantly resulted in higher fresh weight per hectare of lettuce. Increasing irrigation depth from 50 to 75 % ETo significantly produced plants with similar fresh weight ha^{-1} in 2016 and 2018. However, in 2017 50 % ETo irrigation depth produced plants that yielded significantly lower (66.5 t ha^{-1}) value than the values (75.2 and 84.1 t ha^{-1}) obtained from plants irrigated with 75 and 100 % ETo depth.

Cultivar variation had significant effect on fresh weight per hectare only in 2017 season. Great Lake produced significantly heavier plants that yielded significantly higher (78.7 t ha^{-1}) against 74.7 and 72.2 t ha^{-1} by Slaai and Baby Leaf Mix in 2017. However, Slaai and Baby Mix statistically produced plants with similar yield in the same year.

Mulch treatment had significant effect on fresh yield per hectare in 2017, 2018 and 2018 growing seasons. Throughout the sampling periods, mulching produced plants with significantly higher fresh yield than the un-mulched plants in 2016, 2017 and 2018 dry seasons.

Crop Water Use Efficiency (CWUE) and Irrigated Water Use Efficiency (IWUE)

The yield, IWUE and TWUE values of irrigated lettuce were summarized in Table 5 for the growing seasons. The total irrigation water applied during the experimental period and water use of lettuce were given for each irrigation treatment. Plots received irrigation water with mulch varying from a lower value of 349.1 mm in 50% ETo to a higher value of 380.3mm in 100 % ETo treatment. Seasonal evapotranspiration (SET) of lettuce varied from a lower value of 225.2mm to a higher value of 268.6mm, the lowest yield obtained was in 50% treatment without mulching was 59.7 t ha^{-1} compared to 75 and 100% ETo.

Table 5: 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}	83611.1	225.2	349.1	37.1	24.0
	I_{75}	90833.3	264.8	370.5	34.3	24.5
	I_{100}	108333.3	268.6	380.3	40.3	28.5
No-Mulch	I_{50}	59722.2	324.9	379.8	18.4	15.7
	I_{75}	60000.0	325.5	392.3	18.4	15.3
	I_{100}	70833.4	254.3	349.2	27.9	20.3

DISCUSSIONS

The present results had indicated that fresh vegetative lettuce received 75 and 100 % ET_o irrigation depth grew vigorously and produced the highest plant height, number of leaves, canopy spread, stem diameter, root length and vegetable yield per hectare throughout the study periods. The observation might be as a result of provision of water at full irrigation which provides optimum moisture to promote vegetative growth and stimulate the activities of micro-organisms and hence influencing the growth and yield greatly. The result is in line with the report of [33] who tested the effect of different irrigation levels (100%, 80% and 60% of evaporation of Class A pan) for lettuce plants and reported that 100% significantly increase number of leaves and marketable head weight. However, the plants grown in the 50% ETo irrigation deficit was the least recorded across the three years due to the scheduling of water supply to the plants. This negatively affects the growth and development of the plant. The plants pass through the harsh weather condition with increase in evapotranspiration.

The harvested fresh vegetative lettuce yields were significantly different from each other for the various irrigation treatments. This may be due to abundant moisture supply which enabled the crop to respond yield resource favourably which resulted in good growth. The results obtained from the present study is in contrast with results attained by [34] which was in a range of 12- 32t/ha. Similarly, [34] reported that the lettuce dry matter and fresh weight were linearly related to the total water use, leading to higher water use efficiency values for full irrigation.

Crop water use efficiency (CWUE) is generally defined as marketable yield divide by crop evapotranspiration (ETc), but economists and farmers are most concerned about the yield per unit of irrigation water applied [16]. The results of the crop water use showed that 100 % ETo irrigation depth recorded the highest crop water use efficiency for the period of experiments. The results suggested that 75 and 100 % ETo irrigation depth is economically productive when adopted by lettuce farmers in the northern part of Nigeria. However, the results obtained from the experiment were higher than the results recorded by [16] in Tunisia which were in a range of 14.5 – 34.3 kg ha^{-1}. This could be due to differences in geographical locations. The values obtained were different from those obtained by [35] and [36]. Differences between this study and previous studies may be due to different region, cultivars and cultivation periods.

CONCLUSION

Results from the present work show that combining irrigation deficit with mulch cover (rice straw mulch) that is in abundance with farmers, presents a sustainable strategy for lettuce production in the semi-arid areas of Kadawa in Kano State. Since there were only minor differences between growth characters of lettuce obtained from 75 and 100% ETo, it can be said that water application should be kept at 75% weekly reference evapotranspiration in this region with Great Lake cultivar and might be recommended to tolerate the negative effects of excess water application to the ecology and for a better water economy especially in arid regions of the world.

REFERENCES

1. Alhassan, A., Saddiq, M., Gashua, A. G. and Gwio-Kura, K. K. (2017). "Effects of Irrigation Scheduling and Soil Management on Maize (*Zea mays* L.) Yield in Guinea Savanna", Zone of Nigeria. *World Academy of Science, Engineering and Technology International Journal of Agricultural and Biosystems Engineering,* 11(6): Pp 439-443

2. Azad, B., Hassandokht, M. R. and Parvizi, K. (2015). "Effect of Mulch on Some Characteristics of Potato in Asadabad Hamedan", *International Journal of Agronomy and Agricultural Research,* 6 (3): 139-147.

3. Ayas, S. (2013). "The Effects of Different Regimes on Potato (*Solanum tuberosum* L. Hermes) Yield and Quality Characteristics under Unheated Greenhouse Conditions", *Bulgarian Journal of Agricultural Science,* 19: 87-95.

4. Zhang, Q., Wang, S., Li, L., Inoue, M., SXiang J., Qiu G. and Jin, W. (2014). "Effects of mulching and sub-surface irrigation on vine growth, berry sugar content and water use of grapevines", *Agricultural Water Management,* 143, 1-8.

5. Bunna, S., Sinath, P., Makara, O., Mitchell, J. and FuKai, S. (2011). "Effects of straw mulch on mungbean yield in rice fields with strongly compacted soils", *Field Crops Research*, 124(3): 295-301.

6. Laila, K. and Ali, M. (2011). "A study of some methods of waste management of rice through its impact on soil physical properties, N, P and K contents in maize yield and water use efficiency under different tillage systems", *Australian Journal of Basic and Applied Sciences,* 5(5): 1017-1034.

7. Kar, G. and Kumar, A. (2007). "Effects of irrigation and straw mulch on water use and tuber yield of potato in Eastern India", *Journal of Agriculture and Water Management,* 94 (1-3): 109-116.

8. Bafeel, S. O. and Moftah, A. E. (2008). "Physiological response of egg plants grown under different irrigation regimes to ant transplant treatments", *Saudi J. Biol. Sci.* 15(2): 259-267.

9. Fan, L., Roux, V., Dube, C. and Chalebois D. (2012). "Effect of mulching systems on fruit quality and photochemical composition of newly developed strawberry lines", *Agricultural and Food Science*, 21, 131-140.

10. Al-Rawahy, S. A., Dhuhli, H. S., Prathapar, H. A. and Abdelrahman, H. (2011). "Mulching material impact on yield, soil moisture and salinity in saline-irrigated sorghum plots", *International Journal of Agricultural Research*, 6 (1): 75-81.

11. Acharya, S. K., Shukla, Y. R. and Khatik, P. C. (2013). Effect of Water Regime on Growth and Yield of Lettuce (Lactuca Satıva L.). The Bioscan. *An International*

Quarterly Journal of Life Science, 8(1), 201-206.

12. Abdul-Ganiyu, S., Alhassan A. L. and Adongo T. A. (2015). "Effect of Different Water Application Schedules on the Growth and Yield of Loose Leaf Lettuce (*Lactuca sativa* var. crispa) at Golinga Irrigation Scheme in the Tolon District of Northern Region, Ghana", *Greener Journal of Agricultural Sciences*, 5(5): 159-166.

13. Williams, J. F., Robert, S. R., Hill. J. E., Scardacia, S. C. and Tibbits, G. (2007). Managing water for weed control in Rice. UC, *Department of Plant Science*. Retrieved 2007-03-14

14. Halil, K., Ismail, T., Zeki, G. and Sedat, K. (2016). "Effects of Different Irrigation Levels on Yield of Lettuce Grown in an Unheated Grenhouse". *Current Trends in Natural Sciences* (on-line), 5(9): 145-151.

15. Mader S. (2010). "Center pivot irrigation revolutionizes agriculture", *The Fence Post Magazine*. Retrieved June 6, 2012.

16. Nagaz, K., Mokh, F. E.I., Masmoudi, M. M. and Mechlia, N. B. (2013). "Soil salinity, yield and water productivity of lettuce under irrigation regimes with saline water in arid conditions of Tunisia", *International Journal of Agronomy and Plant Production*, 4 (5): 892-900. Available online at http:// www.ijappjournal.com.

17. Broner, I. (2005). "Irrigation Scheduling", Crop Series on Irrigation. Colorado State University Cooperative Extension. Publication no. 4.704. p 1274-280.

18. Khattab, M. M., Shaban, A. E., Hussein, I. A. and Elgammal, O. H. (2008). "Effect of irrigation, fertigation and organic manure on vegetative of Picual olive trees grown under Mid North Sinai conditions", *Egypt. J. of Appl. Sci*. 23(4B): 621-636.

19. Iniesta, F., Testi, L., Orgaz, F. and Villalobos, F. J. (2009). "The effects of regulated and continuous deficit irrigation on the water use, growth and yield of olive trees"*, Europea Journal of Agronomy,* 30(4): 258-265.

20. Mehanna, H. T., Stino, R.G., IkramSaad, E., and Gad El-Hak, A. H. (2012). "The influence of deficit irrigation on growth and Productivity of Manzanillo olive cultivar in desert land", *Journal of Horticultural Science & Ornamental plants,* 4 (2): 115-124.

21. Bilal Acar1, Mustafa Paksoy, Önder Türkmen and Musa Seymen (2008). Irrigation and nitrogen level affect lettuce yield in greenhouse condition. African Journal of Biotechnology Vol. 7 (24), pp. 4450-4453, 17 December, 2008 Available online at ttp://www.academicjournals.org/AJB. ISSN 1684–5315 © 2008 Academic Journals.

22. Shaheen A., Naeem, M. A., Jilani, G. and Shafiq, M. (2010). “Integrated soil management in eroded land augments the crop yield and water-use efficiency”, *Acta Agricultural. Science and Soil & Plant Science,* 60(3): 274 - 282.

23. FAOSTAT. (2013). Crops data for 2011. Food and Agricultural Organization of the United Nations. http://faostat3.fao.org, (accessed 21 Feb. 2013).

24. Zohany D., Hope, M., and Weiss, E. (2012). “Domestication of plants in the old world” the origin and spread of domesticated plants in *South West Asia, Europ and the Mediterranean Basin*. Oxford University Press. ISBN 0-19-954906-0.

25. Asaduzzaman, M. D., Shamima, S. and Arfan Ali, M. D. (2010). “Combined effect of mulch materials and organic manure on the growth and yield of Lettuce”, *American-Eurasian Journal of Agricultural and Environmental Sc*ience, 9 (5): 504-508.

26. Ananda, M. A. I. D. and Ahundeniya, W. M. K. B. W. (2012). Effect of different hydroponic systems and media on growth of lettuce (*Lactuca sativa*) under protected culture. *http: www.goviya.ik/agri-learning*, 146-154.

27. Masarirambi, M. T., Dlamini, P., Wahome, P. K. and Oseni, T. O. (2012). “Effects of chicken manure on growth, yield and quality of lettuce (Lactuca sativa L.) ‘Taina’ under a lath house in a semi-arid sub-tropical environment”, *American-Eurasian Journal of Agriculture and Environmental Science,* 12 (3): 399-406.

28. Bello, W. B. and Awwal, M., 2008, “Effects of Nitrogen, rate and timing of application on growth and yield of Beet root (*Beta vulgaris*)”, *African Journal of Biotechnolog,* 7 (15): 47-53.

29. Davey, M. R, Anthony, P., Van Hooff, P., Power, J. B. and Lowe, K. C. (2007). “Lettuce Transgenic Crops”, *Biotechnology in Agriculture and Forestry*. Volume 59. Springer. ISBN 978-0-684-80565-8.

30. Michael A. M. (2006). “*Irrigation: theory and practice*”, 2nd ed. New Delhi, Indi, Vikas Publishing House Pvt. Ltd., p. 768.

31. Igbadun, H. E. and Oiganji, E. (2012). “Crop Coefficients and yield response factors for onion (Allium cepa L.) under irrigation and mulch practice in Samaru, Nigeria”, In: *African Journal of Agricultural Research*, 7(36): 5137-5152.

32. Duncan, D. B. (1955). “Multiple ranges and Multiple “F” test *Bioetrics*, 11, 1-42.

33. Acar, B., Paksoy, M., Turkmen, O., and Seymen, M. (2008). “Irrigation and nitrogen level affect lettuce yield in greenhouse condition”, *African Journal. of Biotechnology* ,7(24): 4450-4453.

34. Ogbodo, E. N., Okorie, P. O. and Utobo, E. B. (2010). "Growth and Yield of Lettuce (*Lactuca sativa* L.) at Abakaliki Agro-Ecological Zone of Southeastern Nigeria", *World Journal of Agricultural Sciences,* 6 (2): 141-148.

35. Duman, S. (2007). "Erzurum Kosullarında Sonbahar Doneminde Yuksek Tunelde Farklı Dikim Zamanlarının Marulda Bitki
36. Gelismesi ve Verim Uzerine Etkisi",. Ataturk Universitesi, Fen Bilimleri Enstitüsü, Yuksek Lisans Tezi, 34 (in *Turkish press*).

37. Kaymak, N. (2007). "Marul (*Lactuca sativa* L.)'da Yabanci Ot Kontrolu için Kritik Periyodun Belirlenmesi", Ataturk Universitesi Fen Bilimleri Enstitüsü, Yukseklisans Tezi, 49s (*in Turkish press*).

Plate A: Great Lake

Plate B: Slaai

Plate C: Baby Mix Leaf Mix