Influence of Irrigation Regimes on the Growth and Yield Components of Lettuce (Lactuca Sativa L.)

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Abstract
Lettuce (Lactuca sativa L.) is one of the most important salad vegetable crop in the world due to its potential to return profit, nutritional value and production potential. The study analysed the response of different irrigation regimes on the growth and yield parameters of lettuce crop. The experiment was carried out on 48 m² plot in the waterworks area of Tamale Metropolis. Randomized Complete Block Design (factorial) with four treatments and four replications was adopted. Soils were sampled and analysed in the laboratory for FC and PWP. Irrigation regimes used include: 100 % AWC (A), 75 % AWC (B), 50 % AWC (C) and 25 % AWC (D). Data collected were subjected to ANOVA at 5 % significance level. Results from the analysis showed significant difference between treatments A and B, A and D, B and C, B and D and C and D for leaf area index. Plant height was also significant between all the blocks. Significant difference occurred between B and D, A and C, A and D, and B and C recorded significant difference in terms of stem girth. Further, root length showed statistical difference between B and D, A and C, A and D and B and C. Significant difference occurred between A and B, A and C, A and D, and B and C in terms of lettuce head weight. The number of leaves per plant was statistically significant between treatment A and B, A and C, A and D, and B and C. Irrigation regime A resulted in increased agronomic parameters, followed by B, C and D. Hence, farmers in the Waterworks vegetable farming area adopt 100 % AWC to boost lettuce production level.

Keywords: lettuce; growth and yield parameters; irrigation regimes
INTRODUCTION

Lettuce (*Lactuca sativa* L.) is the first cultivated salad crop and commercialized internationally (Abu-Ryyan *et al.* 2004). It is the most popular vegetable according to the highest consumption rate and economic importance throughout the World (Coelho *et al.* 2005). Lettuce is a native of Europe, Asia and Northern Africa and has been cultivated for over 5000 years. It grows best in a relatively cool season with monthly mean temperatures of 12.8ºC to 15.6 ºC with an average minimum of 7.2ºC and an average maximum of 24 ºC (Jevons 1995; Norman 1997). Lettuce can be grown under protected cultivation in green house or in the open field (Mathew & Kari Kari, 1990; Filho, 2009). Recently, lettuce is grown all over the world in places of different climatic and soil conditions. Lettuce is a rich source of antioxidants, vitamin A and C and photochemical which are anti-carcinogenic. It also provides some dietary fiber, carbohydrates, protein and a small amount of fat. Lettuce also provides calcium, iron and copper, with vitamins and mineral largely found in the leaf. Lettuce is usually consumed as a salad or shredded in a salad mix of onion, tomato, cheese and basil. In the market of tropical regions like Ghana, early maturity iceberg type lettuce with three prominent cultivars (Eden, trinity and great lakes) are mostly cultivated. The productivity and quality of these lettuces depend on the growing conditions and soil amendments. Moreover, the difference in minerals and vitamins of the various cultivars of lettuce might also be due to the genotypic difference since they are grown under the same environment (Ojetayo *et al.* 2011). Urban population is growing at an estimated annual rate of 4.1% compared with the overall population growth of 3% in Ghana (Ghana Statistical Service-GSS 2002). The upsurge in urban population in recent times coupled with high rate of unemployment and other socioeconomic factors has led to increase in utilization of urban land and water resources for several purposes including food production particularly of high value vegetables, which are needed to meet the urban diets and demand. The demand is not seasonal, necessitating year round production heavily depend on irrigation (Sonou 2001).

In Tamale, urban garden have become important sources of food crops especially vegetables, and this activity provides supplementary sources of income for city dwellers (Ghaniyu *et al.* 2002; Bediako *et al.* 2005). Urban farming provides employment and income for a chain of beneficiaries such as farmers, market sellers, suppliers of agricultural inputs, etc., and, therefore, contributes to Tamale’s urban economy (Obuobie *et al.* 2006). The seasonal rainfall fluctuates considerably on inter-annual and inter decadal timescale, due in part to variations in the movement and intensity of inter tropical convergence zone, and in the timing and the intensity of the west Arica monsoon (GFDRR 2011). Tamale has a relatively dry climate, with a single rainy season that begins in May and ends in October. Annual rainfall for Tamale varies between 900mm and 1100 mm, with a long term average
annual rainfall of 1078mm. Inter-annual variability of rainfall is up to 17% (GMA 2010). Vegetable production has become a major occupation for most farmers in Tamale. However, farmers use different water application efficiency for irrigation without any scientific standards which can affect their production in the waterworks. Therefore, it is imperative to assess different water use efficiencies at the waterworks. Many vegetable species are shallow-rooted and sensitive to mild water stress. In lettuce, where the harvested part of the plant is the photosynthetic leaf area, it is especially important to obtain optimal growth through the application of water and nitrogen (Gallardo et al. 1996). Farmers at waterworks (VRA irrigation site) use mechanized way of water application such as the use of pumping machine to flood their fields.

Crop responses to different water application have been used to determine irrigation strategies for optimal yield and maximum efficiency of water use for many crops N-form affected growth and yield of many vegetables (Gamiely et al. 1991). In furtherance, these farmers have placed more emphasis on improving water supply for crops, rather than on striving for full water control because they have no drainage channels at their fields which constantly retain water for more than necessary. Fertilizers due to flooding will be washed away. This brings ineffective distribution of irrigation water and hence, affects the water use efficiency. The main objective of this study is to analyse the influence of irrigation regimes on the growth and yield components of lettuce. The analyses have the possibility of enlightening water management practices to boost crop productivity in the area.
METHODOLOGY

Study area
Tamale Metropolis is located lies between latitude 9°16” and 9° 34” North and longitudes 0° 36” and 0° 57” (GSS 2010).

Figure 1. Location map of Tamale Metropolis (GSS 2010)
Tamale lies in the Guinea-savanna belt with only one rainy season from April/May to September/October, followed by a prolonged dry season. Maximum day temperature ranges from 33 °C - 42 °C while minimum night temperature ranges from 20 – 22 °C. Average relative humidity is 90 % during the day and 96 % in the night. (Emmanuel et al. 2006). The main soil types in the Tamale Metropolis are sandstone, gravel, mudstone and shale that have weathered into different soil grades. Due to seasonal erosion, soil types emanating from this phenomenon are sand, clay and laterite ochrosols (GSS 2014). The soils at Tamale are usually of low aggregate stability and are therefore limited by unfavorable pore size distribution, low infiltration and high susceptibility to surface sealing by rain water and soil erosion (Hauffe 1989). In some parts, the soil is underlain by mudstone, or are shallow soils underlain by 30 cm or more of lateritic hardpan (Bates 1962b). Percolation below this hardpan is practically zero, thereby making the area prone to shallow floods in the wet season.

Information obtained from the farmers made it clear that, the site became a vegetable farming area after the 1964 disaster, when then electricity production station built at that time got washed away by the dam which served as a source of water for Tamale. The heavy down pour during that year led to an increase in the volume of the dam water than its normal capacity leading to the collapse of the dam wall. Hundreds of houses including properties were destroyed displacing dwellers around the area. This situation compelled the
Government to relocate these people with compensational benefits. After this disaster, farmers around Gumbihini Town saw the need to make good use of the land by growing vegetables. Since the land belonged to the Government and no other person else, land acquisition became a first come first served system and hence, giving farmers who arrived early the opportunity over others to continually farm at the Waterworks area. The sources of water for the Waterworks area currently is mainly the gutter which takes it source from the old dam and other sewage water channel into the gutter. Some of the vegetables grown at the Waterworks farming area are: \textit{Lactuca sativa}, \textit{Brassera oleracea} and \textit{Amarantus cruentus}.

The two most considerable water application techniques are watering can irrigation and mechanized water pumping machines mode of irrigation. Waterworks, which is located in a suburb of Tamale called Gumbihini, is so named because of the existence of a dam that was built originally to provide pipe-born water for Tamale. The dam is no longer used for domestic water provisioning, thus giving the residence of the area around the dam the opportunity to use the water for irrigated vegetable production (Obuobie et al. 2006).

\textbf{Baseline study}

A baseline study was conducted to ascertain the source of water, types of crops cultivated and the watering regimes at the Waterworks area. Land/bed preparation. The land was totally cleared with the aid of a cutlass and all the debris were collected with the rake and disposed. Thereafter, the field measured with a measuring tape with a length 12 m and breadth 4 m respectively. The measured area was marked and pegged. Four beds with heights of 10 cm were prepared with their length and breadth 4 m and 2.5, and 3 m respectively as presented in Figure 2.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Experimental field layout}
\end{figure}
**Experimental design**

Randomized Complete Block Design (RCBD) was used for the experiment with 4 replications and treatments. The replications are the number of plants rows on the beds respectively whilst the treatments are the beds on which the replicates are found.

**Soil sampling and laboratory analysis**

Soil was sampled using the auger. The sampling was done by randomly scooping out the soil from two parts of each treatment at a depth of 15 cm respectively. The samples were carried in an ice chest to SARI for water analysis.

**Permanent wilting point**

Eight (8) holes are bored at the base of the drum so as to allow drainage the holes are covered with sieve clothes to prevent loss of soil. In order to present desired soil profile and characterize of each layer with that is profile dry soil was packed, according to bulk density and depth of each desired layer. After soil has been packed, drum was be watered to field capacity. An access tube will also be inserted so that soil moisture content can be monitored using a p2/6 profile probe for the duration of the experiment. When excess water drained from the drum, these seeds of sorghum will be sowed and later thinned to one at two weeks after emergence, seeding will be thinned to leave one per drum. Soil in drum will be maintained at 100% field capacity until pre-flowing stage. After which watering will be stopped and wilting is apparent curly in the morning (before 8:00 am), it is assumed that the plant is unable to extract water to verify, leaf sample will be collected and in a dark humid cool room overnight. If recovery is not reached by morning, final soil water measured is the permanent wilting point (PWP).

**Field capacity**

The field capacity of soil was determined by placing the pots with soil sample in tank containing water and saturating through the bottom. Pots were removed from the tank after saturation and covered with transparent polythene sheet to prevent evaporation. They were allowed to drain freely for 48 hours to achieve field capacity status. The amount of water at field capacity was calculated as the difference in the amount of water used for saturation less the amount freely drained after 48 hours. The FC was computed using equation 1.

\[
FC = \left[ \frac{(A-B)}{B} \right] \times 100 \% \quad [1]
\]

Where; FC, Field capacity (%); A, Weight of moist sample (g); B, Weight of dry sample at 105\(^{\circ}\) (g).

The available water content is the moisture held between field capacity and permanent wilting point. AWC was calculated using 2.

\[
AWC = (FC - WP) \times Z \quad [2]
\]

Where; AWC, Available water content; FC, Field capacity; WP, wilting point; Z, Root depth.
Planting material
The lettuce cultivar used for the experiment was Eden. Eden cultivar was chosen for the experiment because it is the commonly cultivated lettuce cultivar in the waterworks vegetable farming area. The seeds of the plant were obtained from Agriseed Company, a proficient agrochemical dealer in Tamale.

Planting, Nursing and Transplanting
Seeds of lettuce were raised in the nursery and transplanted in the field after three weeks. Healthy and strong seedlings were selected and transplanted to the field at 40cm by 30 cm plant density with a total of 44 plants per bed. Seeds were nursed on the 27th of April, 2016 and transplanted on the 17th of May, 2016.

Weed control and fertilization
Weeding was done 1WAP and continued at a week interval after data has been collected till the plant was matured.
Fertilization was done with only one type of fertilizer was used. This was the inorganic fertilizer. The inorganic fertilizer used was YARA N.P.K. 33:10 the rate of 40 g the inorganic fertilizer (N: P: K) was applied and incorporated into the soil a week after transplanting (WAT).

Irrigation regimes
Watering was done in terms of Available Water Content (AWC) on daily basis usually morning and evening from 6:00 am to 5:00 pm respectively. The treatments include; 100% of AWC (A), 75% of AWC (B), 50% of AWC (C) and 25% of AWC (D) were irrigated based on the available water content.

Measurement of growth and yield parameters
Plant height was measure with two lettuce plants each from a treatment was randomly picked and the height measured using a rule. The height of sampled lettuce plants was observed and recorded at 1 week interval. The length of the roots was measured by pulling out two lettuces randomly from each of the four treatments. A thread was placed along the longest root and transferred to the rule. The average value for the two lettuces was noted and recorded in 1 week interval. The leaf area was measured using a thread placed along the length and breadth of the leaf and recording their values. Random sampling was considered and measurement was taken every four days interval in all the treatments. The stem girth was measured with a thread wound round the stem and stretched afterwards. This information was transferred onto rule and the size was noted. The weight of lettuce head was measured after four weeks of the lettuce plants were harvested and samples were taken from each bed and weighted on an electronic balance. Two plants each from the treatments will randomly be collected after maturity and their leaves will be counted and averages will be noted.
Statistical analysis
The data collected was analyzed using EXCEL. Mean values of the treatments (100 %, 75 %, 50 % and 25 %) of the growth and yield parameters were separated using ANOVA at 5 % significant level.

RESULTS AND DISCUSSIONS

Leaf area index
The mean leaf area index were 0.81 m, 0.69 m, 0.60 m, 0.50 m for A, B, C and D respectively as depicted in Figure 4 below. The results of the analysis of variance showed that the effects of different water levels influenced leaf area index significantly between treatment A and B (0.203, p > 0.05), A and C (0.257, p > 0.05), A and D (0.051, p > 0.05), B and C (0.402, p >0.05), and C and D (0.115, p > 0.05). The level of significance might resulted in increasing the water level, as the plant grows, adequate amount of water is needed to carry out chemical activities such as cell division and as the cell divides multiple smaller cells are formed. The process of increasing the number of cells increases also the leaf area and hence the area index with respect to the water absorption. These analyses are in agreement with the results reported by Karam et al. (2002) and Bozkurt & Mansuroğlu (2011), who obtained higher head diameter at full irrigation treatment. It seems that water stress should be avoided during the period of head formation, the most critical period of lettuce for irrigation. However, treatment B and D was found not significant (0.029, p > 0.05).

Figure 3. Influence of irrigation regimes on Leaf Area Index (LAI)

From the results, it shows that even upon varying the water application, there was no significant difference, and this could be the result of biological condition such as climate change and even soil conditions the ability of the soil to hold water is a major factor. When a
particular soil fails to hold water for plant usage there may be water stress and this might not show any positive sign on the lettuce especially when it needs water at the development stage (Zhao et al. 2012). As presented in the above figure, the lettuce crop was harvested at 30 days after planting, otherwise the LAI would decrease due to loss of water from the crop. 

*Plant height*

The result for the mean values from the analysis were; 16.75 cm, 15.0 cm, 13.1 cm, 11.9 cm for A, B, C and D respectively as shown in Fig.4.2. The effects of watering on plant height showed a significant difference between treatments A and C (0.136, p > 0.05), A and D (0.103, p > 0.05), B and C (0.450, p > 0.05), B and D (0.222, p > 0.05), and finally C and D (0.116, p > 0.05).

![Figure 4. Influence of irrigation regimes on plant height](image)

Lettuce plant requires sufficient amount of water for growth because it is sensitive to any small amount of water, it begins to respond in accordance to the water intake and as the water increases, so as the plant increases most especially from the initial stage to maturity. During this period, life processes have to take place for instance photosynthesis where water will be transported from the soil through the stem to the leaves and various plant parts for chemical processes these activities might result in plant increment. Yazgan et al. (2008) reported that, the irrigation water level in lettuce had significant effects on plants height and obtained the highest plant height values from full irrigation levels. Kirnak et al. (2002) also reported that lettuce plant height increased significantly with increasing irrigation water
applied. However, there was no significant difference between A and B (0.022, p > 0.05). Lettuce is very sensitive to small amount of irrigable water and will increase as the water level increases, so will it decrease as the water decreases (Jonckheere et al. 2004). Thus water stress should be avoided in lettuce production because of heavily dependency on water.

**Stem girth**

The mean values were; 2.07 cm, 2.18 cm, 1.77 cm, 2.32 cm for A, B, C and D respectively as illustrated in Figure 4. The analysis of variance showed that there was statistical difference on the effects of watering regime on stem girth between treatment B and D (0.252, p > 0.05), A and C (0.124, p > 0.05), A and D (0.128, p > 0.05), B and C (0.100, p > 0.05).

![Figure 5. Influence of irrigation regimes on stem girth](image)

In plant cell where the cell sap is immersed in pure water, inward osmosis of water into the cell sap ensures. The gain of water results in the exertion of turgor pressure against the protoplasm, which in turn is transmitted to the cell wall. The pressure also prevails throughout the mass of solution within the cell. When the cell wall is elastic some expansion in the volume of the cell occurs as the result of osmotic pressure which may also increase stem girth. However, no significant differences were recorded between A and B (0.050, p > 0.05). These occurrences might be associated with water stress, when plants lacks water pressure begins to pile up at the root and this will be transmitted via the stem since there will be demand at the leaves zone for photosynthesis and other physiological activities this demand might cause shrinkage of the stem. Root length Mean values from the analyzed data were; 13.78 cm, 11.02 cm, 8.93 cm, 7.63 cm for treatment A, B, C, and D respectively (Figure 5). Results from the statistical analysis showed significant difference in terms of root length.
between treatment B and C (0.091, \( p > 0.05 \)), B and D (0.067, \( p > 0.05 \)), C and D (0.301, \( p > 0.05 \)). The result is consistent with that of Hochmuth & Howell (1983) from their experiment.

Figure 6. Influence of watering regime on root length

Whenever the water potential in the peripheral root is less than that of the soil water, movement of water from the soil into the root cells occurs. These occurrences might enable the roots to absorb some chemical element from the soil in the form of nutrients which may result in either increasing the length or the weight. The results is not in line with Karata (1995) which stated that mean root lengths and root extent also did not vary significantly with increasing water amounts. However there was no level of significance between A and B (0.019, \( p > 0.05 \)), A and C (0.018, \( p > 0.05 \)), A and D (0.028, \( p > 0.05 \)). However, the level of insignificance may be coupled with limited water supply. when the water supplied to plant lesser to its actual requirement stunted growth may occur however; over irrigation may also cause root rot (Jacnaksorn et al. 2004)

Weight of lettuce head

The average mean values were; 2.35 g, 1.65 g, 1.1 g, 0.55 g for treatment A, B, C and D respectively (Figure 7). The analysis of variance recovered significant difference between the treatments in terms of head weight of lettuce A and B (0.151, \( p > 0.05 \)), A and C (0.051, \( p > 0.05 \)), A and D (0.054, \( p > 0.05 \)) and BC (0.060, \( p > 0.05 \)).
Water is the most abundant constituent of all physiologically active plant cells. Leaves for example have water content which lies mostly within a range of 55-85% of their fresh weight. Lettuce crop is very sensitive to small amount of irrigation water this might have led to the increase in the amount water contained within the leaf. More so, the more you apply water the higher the leaves absorb the water and hence increasing the lettuce head weight. Our results disagrees with that of Acar et al. (2008) which states that there was no significant variation in head and marketable head weight in all irrigation levels.

**Number of leaves per plant**

The mean values from the analysis were; 13.5, 11.5, 9.5, 8.5 for Treatment A, B, C, and D respectively (Fig.4.5). The results of the statistical analysis showed significant between treatments A and B (0.613, p > 0.05), A and C (0.123, p > 0.05), A and D (0.523, p > 0.05), B and C (0.133, p > 0.05). Similarly, the results from a study by Haraguchi et al. (2003) showed are in agreement with results of this study.
In the case of number of leaves, decrease in irrigation level may result in reduction in mean leaf number per plant. However, increasing the level of irrigation might increase the number of leaves as a result of gradual progression in the growth stages, as the plant grows the leaves might also be increasing and as the leaves increases, weight also increases this means that the higher the leaves the heavier the lettuce head weight all things being equal. In contrast with the results, Acar et al. (2008) reported that different irrigation levels did not significantly affect the mean leaf number.

CONCLUSIONS
The results of the current study indicate that different amount of water application levels had significant effects on growth parameters and yield parameters of lettuce. The results showed that 100 % AWC resulted in increase and growth and yield parameters. However, 75 % AWC, 50 % AWC, 25 % AWC resulted in an increase in the growth and yield parameter but were below 100 % AWC. Farmers at the waterworks farming area in Tamale should adopt applying 100 % AWC to increase lettuce production levels in the area. Further study is required to determine the leaf dry weight and cost benefits of the lettuce crop.

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