Greener Journal of Agricultural Sciences

ISSN: 2276-7770 ICV: 6.15

Submission Date: 03/02/2015
Accepted: 09/02/2015
Published: 21/09/2015

DOI: http://doi.org/10.15580/GJAS.2015.5.020315028

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Greener Journal of Agricultural Sciences ISSN: 2276-7770 ICV: 6.15 Vol. 5 (5), pp. 159-166, September 2015.

Research Article (DOI http://doi.org/10.15580/GJAS.2015.5.020315028)

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ABSTRACT

To assess the effect of different water application schedules on the growth and yield of lettuce (*Lactuca sativa var. crispa*), a field experiment was carried out at Golinga Irrigation Site. Four treatments were laid out in a Randomized Complete Block Design in four replications. The treatments were; TRT_1 (adlib application by farmers), TRT_2 (100% of the daily ET_c applied only in the morning at each growth stage), TRT_3 (100% of the daily ET_c applied only in the evening at each growth stage) and TRT_4 (100% ETc split: 50% of the daily ETc applied in the morning and the other 50% applied in the evening at each growth stage). The daily crop water requirement (ET_c) of the crop was calculated for the four stages of growth using the CROPWAT software bearing in mind the area of each bed ($16m^2$). The data was analyzed using the Genstat Software. The results revealed that plants grown in the TRT_4 grew healthier and recorded the highest plant height (23.3cm), number of leaves (9), leaf spread (25.03cm), leaf area index (5.25), and fresh matter weight of leaf (43.0g), yield (28.3t/ha) and water productivity ($7.2kg/m^3$). Plants grown in TRT_3 recorded the least values for plant height (19.8cm), number of leaves (7), leaf spread (20.9cm), leaf area index (4.1), fresh matter weight of leaf (30.7g), yield (13.9t/ha) and water productivity ($3.5kg/m^3$). It is recommended that interested lettuce farmers could adopt TRT_4 water application schedule since it gave the highest values in all the parameters used for data collection.

Keywords: Different water application schedules, yield of lettuce, crop evapotranspiration (ETc), crop water productivity.

INTRODUCTION

Lettuce (*Lactuca sativa* L.*)* belongs to the sunflower family. It is an annual plant native to the Mediterranean area (Ryder, 1986).The amount of water available to agriculture is declining worldwide due to the rapid population growth and the greater occurrence of drought in recent years caused by climate change. Competing agricultural, municipal and industrial water usage will eventually threaten food security (World Bank, 2006; Nagaz *et al.,* 2013). Continued successful management of the limited amount of water available for agricultural uses depends upon better agronomic practices and enhanced understandings of water productivity, defined as the crop production per unit of water consumed (Jones, 2004; Nagaz *et al.,* 2013).

Sammis (1980) reported that one way to address the issue of water shortage is to change to more efficient irrigation methods, such as drip irrigation. Another way is through development of new irrigation scheduling techniques. Yazgan *et al.* (2008) also mentioned that scheduling water application is very critical to make the most efficient use of drip irrigation system, as excessive irrigation reduces yield, while inadequate irrigation causes water stress and reduces production.

Nagaz *et al.* (2013) reported that there are different approaches of irrigation scheduling which include measuring soil and plant parameters to determine when and how much water to apply. However, irrigation scheduling based soil water balance approach is the most reliable, and the results can be extended away from the research station to farmers. The soil water balance irrigation scheduling based on crop water requirements and soil characteristics results in varying water application and intervals, and then allows for applying irrigation water when needed during the growing season. Smith (1985) reported that accurate irrigation scheduling is only possible when water supply and irrigation amounts can be managed independently by farmer.

The most limiting and variable environmental factor affecting the productivity of plant is water (Roth and Field, 1994). Water is essential to the life and growth of crops. The availability of water in the soil depends on several factors which combined and known as water balance. According to Asano *et al.* (1982), not all the water in the soil is available for crop growth, part is unavailable due to physical properties of the soil. Adequate water is required for the sufficient development of crops to maximize final yield (Heinemann, 1994). Therefore with water often as a limiting factor especially in the Northern part of Ghana, it is necessary for farmers to have an idea of the crops water requirements of their crops in order to supply the right quantity of water to the crops and to conserve water for other domestic activities.

According to Broner (2005), irrigation scheduling is the decision of when and how much water to apply to a field. Its purpose is to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level. Irrigation scheduling saves water and energy. All irrigation scheduling procedures consist of monitoring indicators that determine the need for irrigation. The purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and the exact timing for application. The amount of water applied is determined by using a criterion to determine irrigation need and a strategy to prescribe how much water to apply in any situation (Broner, 2005). Nagaz *et al.* (2013) recorded lettuce yield of 42.6t/ha and 45.8 t/ha and water productivity values of 14kg/m^3 and 34.3 kg/m^3 in an experiment carried on the yield of lettuce under three different irrigation regimes in Tunisia. Ogbodo *et al.* (2010) also obtained fresh weight yield range of 12.33-32.31 t /ha in their study on growth and yield of lettuce in Nigeria.

The best use of water must be made for efficient crop production and higher yields. Therefore, agriculture under unfavourable climatic conditions and limited water resources cannot be profitably practiced unless on-farm water management techniques are designed to meet the present growing demands of water for increased food production (Oad *et al.*, 2001). This study was therefore sought to determine the effects of different crop water application schedules on the yield of lettuce at the scheme and to determine the crop water productivity.

MATERIALS AND METHODS

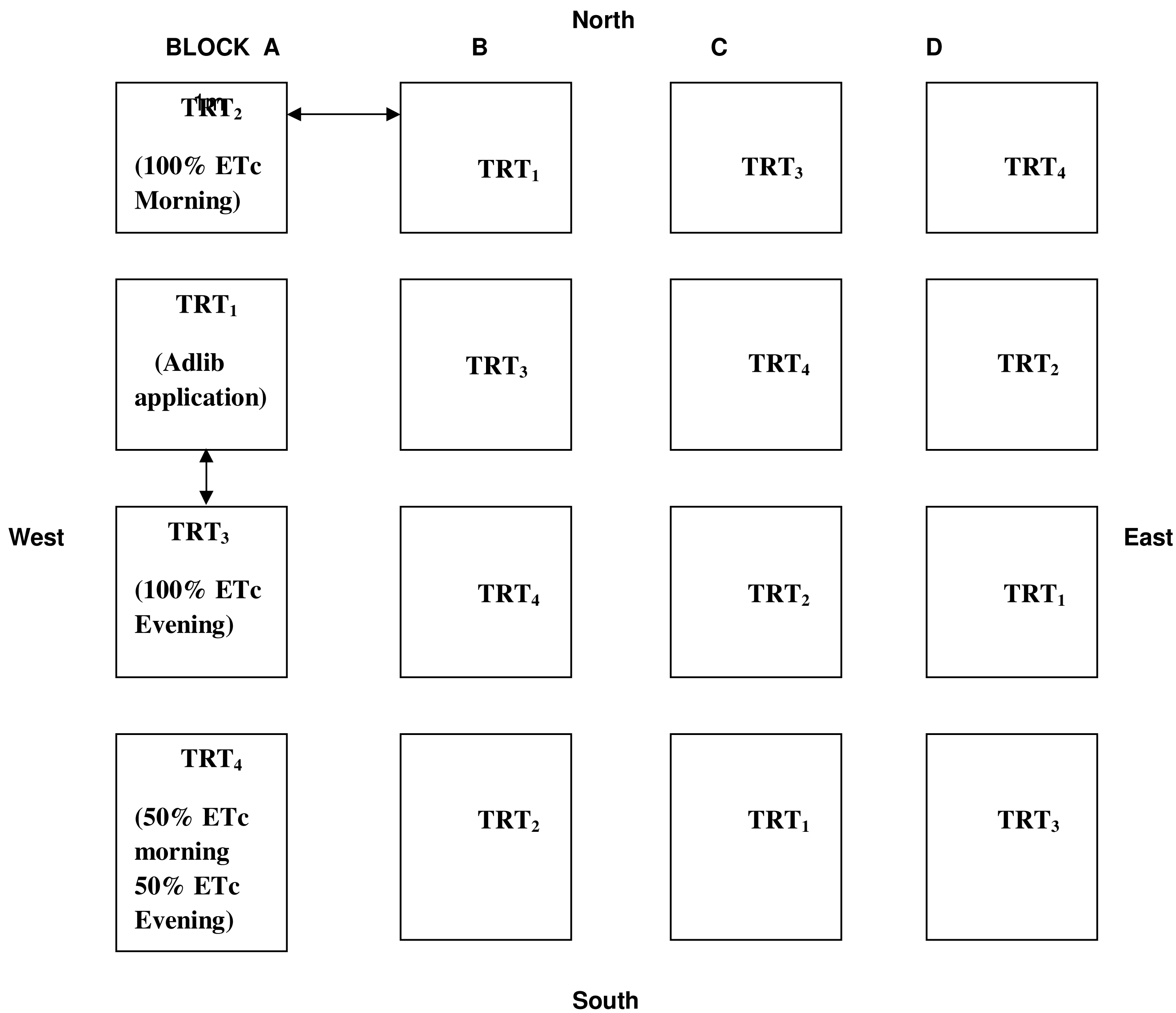
Description of the Study Location: The field experiment was carried out at the Golinga Irrigation Site in the Tolon district of Northern Region of Ghana. The site is located 14.5km south west of Tamale the regional capital and 12km from the University for Development Studies Nyankpala Campus. It lies on latitude N09.35845^o and longitude W000.95317^o. The study area has an average rainfall of 1060mm and average seventy-seven (77) rainy days in a year with 87% of the total annual occurring from May to October. The relative humidity ranges from 2% low in January to highest 82% in August. The wind speed is the lowest in November of 72km/day and highest in April of 225km/day. The sunshine duration is highest in November with 8.8hr/day and lowest in August of 4.9hr/day (SNC, 2010).The relief of the area is fairly flat and gentle slopping towards the reservoir. The watershed landscape pattern is mosaic and has a leutic system where it drains into the reservoir. Generally, the Golinga watershed is characterized by grasses with few scattered economic trees. The predominant soil types in the area are loamy sand and sandy loam.

Field Layout: The field experiment was carried in the dry season. The crop was planted on raised beds (2cm high), replicated four times and arranged in a randomized complete block design (RCBD). The size of the experimental field was 361 m^2 (19 m x 19 m). The size of each block was 76 m^2 (19 m x 4 m). Each block contained four plots, each measuring 16 m^2 (4 m x 4 m), giving a total of 16 plots. The experimental units were separated from one another by 1 m spacing, while the blocks were also separated by 1 m spacing. The Lettuce seeds used were sourced from the Garnoma Agro-Chemicals Limited, Tamale, Ghana. Four treatments were used for the experiment. The treatment included: TRT_1 (adlib application by farmers), TRT_2 (100% of the daily ET_c applied only in the morning at each growth stage), TRT_3 (100% of the daily ET_c applied only in the evening at each growth stage) and TRT_4 (100% ETc split: 50% of the daily ETc applied in the morning and the other 50% applied in the evening at each growth stage). The daily crop water requirement (ET_c) of the crop was calculated for the four stages of growth using the CROPWAT software bearing in mind the area of each bed (16m^2) and presented as; initial (66litres/day), development (93litres/day), mid-season (102litres/day) and late season (91litres/day).

Cultural Practices and Field Observations: The loose leaf lettuce variety was used. Seedlings were transplanted when the seedlings were three weeks old at a distance of 30cm between plants and 40cm between rows, giving a plant population of 130 stands per plot (bed). Fertilizer (Urea) was applied at the rate of 128g/plot by band method, at 14 days after transplanting. Weeding was carried out in the second and fourth week after transplanting by manual method using hoe to avoid crop-weed competition. Five plants were randomly selected in each plot and tagged for plant height, leaf area and number of leaves measurements. Plant height was measured as the vertical distance between the ground and the highest living part of the plant. Leaf area was determined by measuring the length and width of all the leaves on a plant with a simple ruler and the average leaf area of the five plants recorded as the leaf area. Number of leaves was measured by counting all the leaves on each plant and the mean of the five plants assumed as the number of leaves. Lambda supper 2.5ec was used at the rate of 50ml to 15l litres of water during 3rd week after transplanting for the control of the caterpillars. Harvesting was done in the 6th week after transplanting from a net plot of 2 m^2 in the center of the plots and converted to tons per hectare.

Data Collection and Analysis: Data were collected on plant height, leaf area index, number of leaves and fresh weight of leaves. The collected data were subjected to analysis of variance (ANOVA) using Genstat software at the least significant difference (LSD) of p<0.05 to compare the means..

Experimental field Layout



Crop Water Requirement of loose leaf lettuce

With the aid of the CROPWAT software, the crop water requirement of loose leaf lettuce calculated for the various growth stages. The data inputted were historic (1974-2010) monthly climatic data from Tamale synoptic station, soil physical properties of the irrigation scheme such as texture, field capacity, permanent wilting point and available water capacity as well as the infiltration capacity of the soils. Other inputs required by the model include the crop type, information on growth stages and their periods up to maturity, effective rooting depth and days to maturity.

Tables 1, 2 and 3 represent the summarized climate information and soil physical properties of the study area and the calculated crop water requirements of looseleaf lettuce respectively.

Table 1: Summary of long-term climatic observations (30) years (1974-2010) for Tamale

MONTH	RAINFALL	ETo	MAX. Temp.	MIN. Temp.	WIND RUN	RH	SUN SH.
	(mm)	(mm)	^{O}C	^{O}C	(km/day)	(%)	Hours
JAN	1.32	158.41	35.50	19.52	125.55	26.76	7.40
FEB	9.36	164.36	37.50	21.57	142.19	27.28	7.69
MAR	31.51	185.38	38.10	24.25	143.91	39.60	7.33
APR	79.12	198.90	36.70	31.89	224.68	59.28	7.47
MAY	122.46	165.85	34.40	24.36	147.57	68.18	7.85
JUN	141.55	134.40	32.00	23.05	125.10	77.02	7.18
JUL	167.86	118.11	29.70	22.65	115.81	81.09	5.74
AUG	191.52	112.84	30.00	22.38	99.40	81.73	4.86
SEP	206.96	117.30	31.10	22.22	74.55	81.37	6.07
OCT	89.97	134.54	33.20	22.36	72.39	75.45	7.88
NOV	7.16	136.80	35.80	21.09	76.77	57.16	8.79
DEC	3.78	165.23	35.30	19.32	153.33	39.25	8.05
Total/Mean	1052.57	1792.12	34.11	22.89	125.10	59.51	7.19

Table 2: Soil data for the experimental site at Golinga Irrigation Scheme (Lateral 2)

Horizon (0-30cm)	Golinga
% Sand	50.4
% Clay	11.04
% Silt	38.56
Texture	Loam
Bulk density (g/cm^3)	1.62
Average Infiltration rate (mm/h)	9.95
Saturation (volumetric %)	36.6 (31.3-41.9)
Field capacity (volumetric %)	20.7 (19.9-21.5)
Permanent wilting point (volumetric %)	4.61 (3.7-5.6)
Saturated hydraulic conductivity (cm/h)	2.7

Table 3: Crop water requirement of looseleaf lettuce

Month	Number of days	ETc (mm/day)	Etc(litre/day) A = $16m^2$	Total vol. of water applied in (litres)/month	Total vol. of water applied by farmer in (litres)/month
February	23	5.8	93	2139	3122
March	31	6.3	102	3162	3723
April	11	5.7	91	1001	1380
Total	**65**	**17.8**	**286**	**6302**	**8225**

RESULTS AND DISCUSSION

Table 4: The effect of different water application schedules on the growth and yield of looseleaf lettuce

Treatment	Plant Height (cm)	Number of leaves	Leaf spread (cm)	Leaf Area Index	Fresh Matter weight of leaf (g)	Fresh vegetative yield (t/ha)
TRT_1	22.7	9	22.1	5.1	34.5	20.9
TRT_2	23.0	9	23.0	5.1	38.1	24.2
TRT_3	19.8	8	20.8	4.1	30.7	13.9
TRT_4	23.3	9	25.0	5.3	43.0	28.3
$LSD_{(0.05)}$	4.9	2	2.0	2.0	26.8	3.1

Plant Height

The results (Table 4) showed that the treatments had not shown significant effect compared with the TRT_1 which was used as a control on the parameter measured. The results had indicated that, the plants grown in the TRT_4 grew healthier and produced the highest plant height (23.3cm) throughout the growth period. The observation might be as a result of providing water to the treatment any time it demands it which provides optimum moisture to promote vegetative growth and stimulate the activities of micro-organisms and hence influencing the height greatly. Rai and Yadax (2005) indicated that, lettuce requires well drained soils with adequate watering. The plant heights (Table 4) obtained from the experiment is significantly higher than the results obtained by Ogbodo *et al.* (2010) in Nigeria which was in a range of 9-16cm. This could be due to differences in geographical locations.

Number of leaves

The results (Table 4) showed that there is no significant difference between the control and the other treatments in the parameter measured. Notwithstanding the above statement, plants grown in the TRT_4 was recorded the highest average number of leaves. This could be as a result of providing water to the plants at the time it demands it. However, the plants grown in the TRT_3 was the least recorded 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 hash daily weather condition with increase in evapotranspirational pool. The results obtained from the experiment are significantly different from the results recorded by Ogbodo *et al.,* (2010) in Nigeria which was in a range of 12- 24. This could also be attributed to differences in geographical locations.

Leaf Spread

The results (Table 4) revealed that there is a significant difference between some treatment means. The plants grown in the TRT_4 (25.0cm) recorded the highest recorded mean leaf spread and therefore significantly different from TRT_1, TRT_2 and TRT_3 at $p < 0.05$. However, the least recorded was plants grown in the TRT_3. This increase in the leaf spread could be related to adequate supply of water to the plants since the surface of leaves most probably determine the amount of sunlight absorption of the leaves which invariably increases the photosynthetic activities of the crop and the amount of carbohydrate produced.

Leaf Area Index

The results (Table 4) showed no significant difference for average leaf area index at the end of the experiment. The leaf area index for the plants grown in the TRT_4 was the highest recorded despite the fact that the seepage could affect the growth and development of the plant. This could be as a result of supplying adequate water to the plant in both morning and evening to aid wet the soil after the daily hash condition. The results recorded are significantly different from the results obtained by Ogbodo *et al.* (2010) in Nigeria which was in a range of 2.1 – 3. This could also be attributable to differences in geographical locations.

Fresh Matter Weight of Leaf and Fresh Vegetative yield of lettuce

There was no significant difference between the treatments in terms fresh matter weight of leaf at $p < 0.05$ (Table 4), but the highest recorded average fresh weight is plant grown in the TRT_4. This could be as a result of split supply of water to the plants at anytime it demands it. This effect encouraged the plants to grown quicker which yielded more roughage and invariably contributed to the weight. However, the harvested fresh vegetative lettuce yields were significantly different from each other for the various treatments (Table 2). The fresh yield of lettuce harvested from TRT_4 (28.3t/ha) was significantly higher (p< 0.05) than the rest of the other treatments. TRT_3 yielded the least with a value of 13.9t/ha. The results obtained from the experiment agreed with the results attained by Ogbodo *et al.* (2010) in Nigeria which was in a range of 12- 32t/ha. However, the recorded fresh lettuce weight yield range of 13.9 – 28.3 t/ha fell below the world potential yield of 49.7 t/ha reported by Valenzuela *et al.* (1996). This comparably lower yield of the crop in the study area compared to this potential yield could have resulted from poor soil physical and chemical properties of the study site.

Crop Water Productivity

Crop water productivity (WP) is generally defined as marketable yield/ETc, but economists and farmers are most concerned about the yield per unit of irrigation water applied (Nagaz *et al.*, 2013). Thus, the WP was calculated as follow as WP (kg/m^3) = yield (kg/ha) divided by total irrigation water (m^3/ha) from transplanting to harvest; an irrigation of 81.2 mm applied before transplanting is not included in the total. The results of the crop water productivity (Table 5) showed that TRT_4 recorded the highest crop water productivity of (7.2 kg/m^3) followed by TRT_2 (6.1 kg/m^3), TRT_1 (3.49 kg/m^3) and the TRT_3 recorded the least crop water productivity of 3.5 kg/m^3. The results suggest that TRT_4 and TRT_2 are economically productive when adopted by lettuce farmers. However, the results obtained from the experiment were lower than the results recorded by Nagaz *et al.* (2013) in Tunisia which were in a range of 14.5 – 34.3 kg/m^3. This could be due to differences in geographical locations.

Table 5: Crop water productivity of looseleaf lettuce for the various treatments

Treatment	Total water use (m^3/ha)	Yield (kg/ha)	Productivity (kg/m^3)
TRT_1	5140.63	20900	4.1
TRT_2	3938.75	24200	6.1
TRT_3	3938.75	13900	3.5
TRT_4	39.38.75	28300	7.2

Plate 1: Lettuce crop four weeks after transplanting under TRT_4

Plate 2: Lettuce crop four weeks after transplanting under TRT_1

Plate 3: Lettuce crop four weeks after transplanting under TRT_2

CONCLUSION

The results from the experiment showed that lettuce yields were significantly influenced by the different irrigation schedules. Lettuce yield of TRT_4 (100% ETc split: 50% ETc morning and 50% ETc evening application) were significantly higher than the yields of TRT_3, TRT_1 and TRT_2 respectively. However, the different irrigation schedules had no significant effects ($p < 0.05$) on parameters including plant height, number of leaves and leaf area index though TRT_4 happened to record highest for all the above mentioned parameters. The water productivity for lettuce yield was also significantly affected by the different irrigation schedules. The highest value was obtained under TRT_4 even though the highest volume of irrigation water was used for TRT_1. The lowest value occurred under TRT_3. At the light of the results obtained from the experiment, it can be concluded that the TRT_4 treatment offers significant advantage for both lettuce yields and water productivity compared to the TRT_3, TRT_1 and TRT_2 in lettuce production. However, where time is a limiting factor, TRT_2 (100% ETc morning application only) could be used since it recorded the second highest values respect to yield and water productivity.

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Cite this Article:
Abdul-Ganiyu S, Alhassan AL, Adongo TA (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, http://doi.org/10.15580/GJAS.2015.5.020315028.