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EFFECT OF DIFFERENT WATER APPLICATION SCHEDULES ON THE GROWTH AND YIELD OF ONION (*Allium cepa* L.) AT GOLINGA IRRIGATION SCHEME IN THE TOLON DISTRICT OF NORTHERN REGION, GHANA

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ABSTRACT

In order to study the effect of different water application schedules on growth and yield of onion (Allium cepa L.), a field experiment was conducted at Golinga Irrigation Scheme. The experiment was arranged in a Randomized Complete Block Design (RCBD). Four treatments namely; **T1** (adlib application by farmers), **T2** (100% of the daily ET_c applied only in the morning at each growth stage), **T3** (100% of the daily ET_c applied only in the evening at each growth stage) and **T4** (50% of the daily ETc applied in the morning and the other 50% applied in the evening at each growth stage) were used for the study. Parameters studied on the crop were plant height, number of tillers, weight of fresh bulbs, weight of fresh leaves and weight of oven-dried leaves. The results of the experiment showed that bulb weight, plant height, and number of tillers were significantly affected by different water application schedules. **T4** produced the highest mean weight of fresh bulb of 150.2g (25t/ha) with water productivity of 5.45kg/m^3 followed by **T3** of 138.8g (23.1t/ha) and water productivity of 5.04kg/m^3 while **T2** recorded the least mean weight of fresh bulb of 96.2g (16t/ha). **T1** which served as control recorded the lowest water productivity of 2.65kg/m^3. Since bulb weight determines its quality, maximum economic yield can be achieved by using **T4** which produced the highest mean bulb weight at harvest. This suggests that, quality onion bulbs production could be achieved if a **T4** water application schedule is adopted by onion farmers. However, where time is a limiting factor, **T3** can be adopted since it followed T4 in terms bulb yield (23.1t/ha) and water productivity of 5.04kg/m^3.

Keywords: *Different water application schedules, yield of onion, crop evapotranspiration (ETc), crop water productivity*

1. INTRODUCTION

The onion (*Allium cepa* L.) belongs to the plant family of Alliaceae and is one of the earliest vegetable crops grown. Its origin was traced to different parts of Asia, namely Central Asiatic region, including North Pakistan, Afghanistan, and eastern USSR [26]; West Asia, extending to Palestine and India [5]; Middle and South-eastern Asia [12]; [20]. The use of onion is worldwide among all nationalities and cultures. It is available in most markets of the world in all seasons of the year. The leading producer countries include the United States, China, Spain, India and Japan whilst the major importers include the United Kingdom and West Germany [12]; [20]. Onion is used widely in Ghana and many parts of the world for flavouring and seasoning foods, as vegetable and for medication. Thus onions form an essential part of the daily diet, creating year round demand for [1].

Considering the production volume and importance, onion is seen as a major horticultural crop in many countries. During the last 25 years, continuous increase of onion acreage has been registered [9]; [18].Onion is ranked second in value in the list of cultivated vegetable crops and the area under its cultivation is 3.44million hectares and its total annual production in the world is 61.6 million tonnes [2].
Generally, onions are grown extensively throughout Ghana with commercial production occurring in the Northern, Upper East and Upper West regions. However, yields are rather low and highly variable compared to those of other countries in Africa and outside, although high levels of organic and inorganic fertilizers are used annually. Thus, while the local Bawku Red onion yields about 7 t/ha (below the average world yield of 12.4 t/ ha), yields of 10-20 t/ha of the exotic Early Texas Grano have been obtained in Ghana [15]; [1]. Up to 36 t/ha onion bulb yield has been reported in Botswana [13] and 25-35 t/ha from improved composite varieties in Nigeria [6]. Also, onion yields of 41.1t/ha, 36.7t/ha and 28.0t/ha have been recorded in Japan, the Netherlands and Egypt respectively [18]. [17] reported that the comparatively lower onion bulb yields in Ghana could be attributed to inappropriate agronomic practices, improper irrigation scheduling, pest and disease problems and lack of genetically-improved progagules. [18] also reported that in Serbia, onion is grown on 20,400 ha

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with an average yield of 6.21 t/ha. They lamented that this low average yield may be attributable to inadequate management practices, insufficient amount and unfavorable arrangement of precipitation in the growing season and inappropriate irrigation scheduling applied to onions grown from seed.

In arid and semiarid areas, irrigation may supply all or most of the crops water needs [19]. All crops require certain amount of water during each stage of development mainly their initial stage, crop development stage, mid-growing and maturity stage and will transpire water maximum rate when the soil water is at field capacity. But the amount, intensity, duration, frequency and distribution of rain needed to meet the actual water requirement of the crop to achieve full production potential is rarely realized in nature [25]. It is therefore the presence of optimum amount of water that will help crops achieve a stable interval balance and resistance to other sources of stress.

Agriculture currently consumes about 70% of the world's developed fresh water supplies. By improving the productivity of water used for agriculture by 40%, it is possible to reduce the amount of additional freshwater withdrawals needed to feed the world's growing population to zero [11]. Agriculture, particularly irrigated agriculture stands accused not only being the greatest water consumer but with the lowest net return per unit of water used [28]. Achieving greater efficiency of water use will be a primary challenge for the near future and will include the employment of techniques and practices that will deliver a more accurate supply of water to crops [23]. To develop and implement management practices by improving effective water use of plant, the understanding of crop water requirement, is crucial for selecting and planning crop mixtures especially under conditions of limited water.

The irrigation needs of onion is location specific and the amount of water required by this crop growth is not evenly spread over the growing season, but depend largely on a number of factors including the species, stages of development, soil properties and meteorological conditions.To achieve full production potential at a particular location with respect to water is therefore based on the estimation of evapotranspiration before irrigation is effected so as to meet the usable water capacity of the crop. This knowledge is not readily available to the local farmer practicing irrigation hence water is applied to crops on discretion by the farmer, which could result in over or under irrigation. Adequate water is required for the sufficient development of crops to maximize final yield [10]. [21] stated that the amount of water supplied to crops influences crop production; deficit as well as excess supply of water to crops results in general, in yield reduction. With regards to excess water supply it is mentioned that these practices may not only result in a yield decrease but may also on the term produce other negative effects such as leaching of nutrients, rise of ground water table, water logging, soil salinity, pollution of groundwater and increase hazard of related diseases such as malaria.

Under irrigation gives poor soil salinity control which leads to increased soil salinity with consequent build up of toxic salts on soil surface in areas with high evaporation. Over irrigation because of poor distribution uniformity or management wastes water chemicals, and may lead to water pollution [27]. Efficiency of irrigation water use is very necessary in order that limited water use can be optimally with less waste and more land irrigated consequently.
Onions are considered as shallow-rooted crop. [7] found that although the maximum root penetration was 0.76 m, most of the roots were in the top 0.18 m of soil, whereas only few roots were found below 0.31 m. Irrigation water that moves below 0.76 m is most likely not available to the onion crop. [18] reported that 90% of the root system of the onion plant was concentrated at the top 0.4 m of soil and only 2 - 3% of the total root length was recorded below 0.6 m depth, which indicates that very little water could be extracted from soil depths below 0.6 m.

According to [4], 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 [4].

Irrigation scheduling is one of the most important tools for developing best management practices for irrigated areas ([3]; [19]. If shortage of readily available soil water is eliminated and the technological and biological characteristics of the crop are taken into account, it is possible to achieve high and stable yields of irrigated onions, at the level of 40 t/ha or higher [19]. Many growers obtain much lower yields, primarily because of inadequate irrigation scheduling [14].

The main objective of this study was to evaluate the yield response of onion to different water application schedules and to compare the yield obtain from the different irrigation schedules to the farmer application rate so as to recommend to farmers an efficient and effective water application rate and schedule for onion crop.

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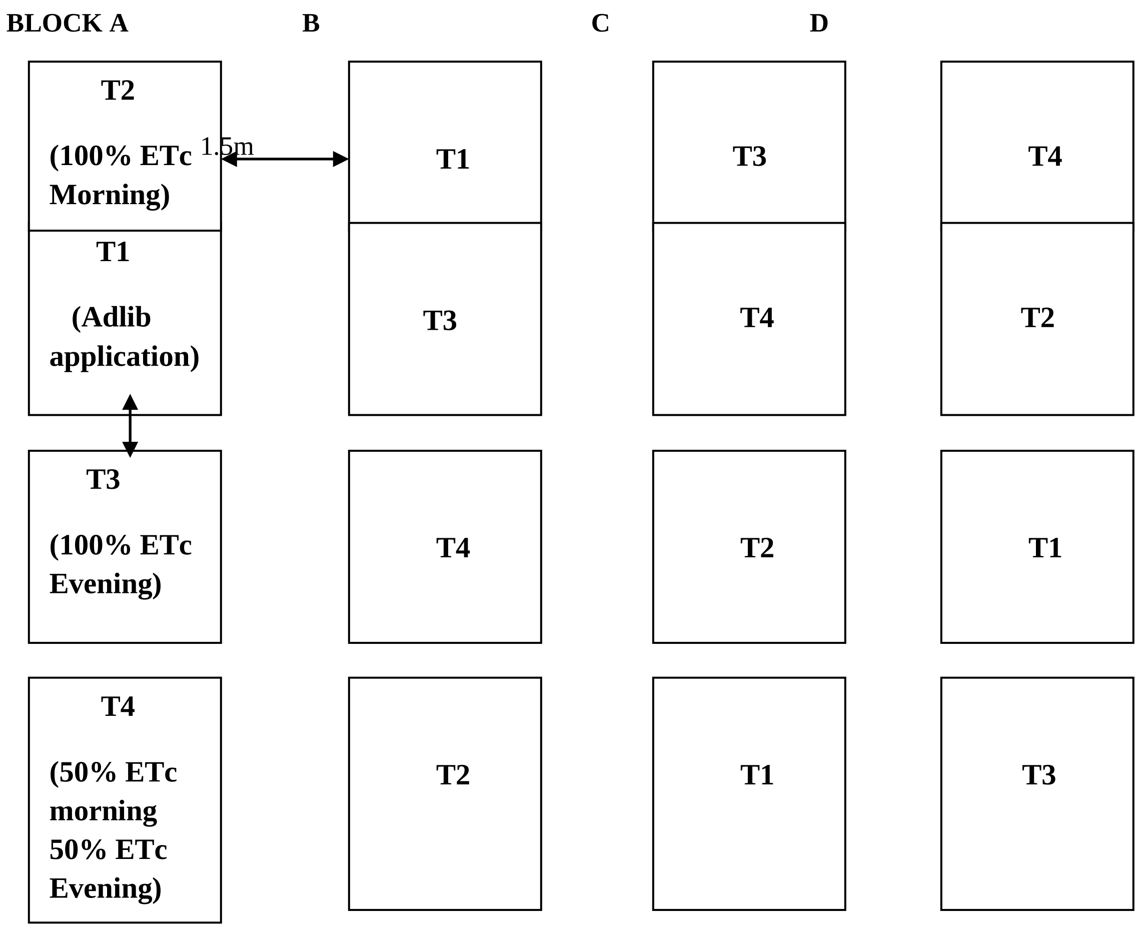
2. MATERIALS AND METHODS

The field experiment was conducted at the Golinga Irrigation Scheme in the Tolon district of Northern Region of Ghana. The scheme is located 14.5km south west of Tamale the regional capital and 12km from the UDS Nyankpala Campus. It lies on latitude N09.35845˚ and longitude W000.95317′. 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 [24].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.

The experiment was arranged in a Randomized Complete Block Design (RCBD). Four irrigation treatments in four replications were used. The treatment included: **T1** (adlib application by farmers), **T2** (100% of the daily ET_c applied only in the morning at each growth stage), **T3** (100% of the daily ET_c applied only in the evening at each growth stage) and **T4** (50% of the daily ETc applied in the morning and the other 50% applied in the evening at each growth stage) were used for the study. The daily crop water requirement (ET_c) of the crop was computed for the four stages of growth using the CROPWAT software bearing in mind the area of each plot ($9m^2$) and presented as; initial (30litres/day), development (42litres/day), mid-season (53litres/day) and late season (48litres/day).

Layout of the experimental field



The space between blocks and beds are 1.5m and 1m respectively. Each bed was measured 3m x 3m, given an area of $9m^2$. The total land area of the experimental field was $247.5m^2$

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Crop Water Requirement of Onion

With the aid of the CROPWAT software, the crop water requirement of onion 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 onion 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 (0-30)	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 onion at various growth stages

Month	Number of days	ETc (mm/day)	Etc(litres/day) Bed area = $9m^2$	Total vol. of water applied in (litres)/stage	Total vol. of water applied by farmer in (litres)/stage

February	14	3.3	30	420	670
March	31	4.6	42	1302	2038
April	30	6.1	53	1590	2210
May	17	5.4	48	816	1426
Total	**92**	**19.4**	**173**	**4128**	**6344**

Agronomic and cultural practices

The variety of onion used was the white variety. The beds were raised at 2cm high. Poultry dropping (16kg/bed) was incorporated into each plots and watered for 2 weeks before transplanting. The onion was transplanted in a distance of 30cm x 20cm, given a total of 150 plants per bed. Weeding was done in the 3rd, 6th and 8th week after transplanting. 15-15-15 NPK fertilizer was applied at a rate of 270g/bed in the 2nd week after transplanting. Sulphate of ammonia was applied at a rate of 150g/bed as side-dressing in the 4th week after transplanting, before bulbing started to promote good bulbing and increase yield. During the research, no pest or disease was found on the field. Harvesting was done when the leaves started to die off and fall to the ground (12th week after transplanting).

Data Collection and Analysis

Data was collected on height of plant, number of tillers, weight of fresh/oven-dried bulbs and weight of fresh/oven-dried leaves. The height of plant and number of tillers were monitored bi-weekly. The data collected was subjected to analysis of variance (ANOVA) using Genstat software. Treatment means were compared using the least significant difference (LSD) at 5%.

3. RESULTS AND DISCUSSION

Number of Tillers/Plant

The experiment showed that the treatments differed significantly ($p<0.05$) in terms of number of tillers (Table 4). Comparing T1 with T2 there is no significant difference. However, T3 and T4 showed statistical difference. T3 produced the highest number of tillers followed by T4. The obtained results for T1, T2, and T4 are significantly lower those reported by [22] in Egypt which was in a range of 6 – 9 leaves per plant. However, the performance of T3 (7 tillers/plant) fell with the range.

Table 4: Mean number of tillers of onion

Treatments	Mean no. of tillers/plant
T1(Adlib application by farmer)	4a
T2(100% ETc morning application only)	4a
T3(100% ETc evening application only)	7b
T4(50% ETc morning and 50% ETc evening application)	5c
L. S. D	0.4

Means in a column with the same letter are not significantly different.

Height of Plants

The treatment differed significantly ($p<0.05$) in terms of height plant comparing the various treatments with T1 as the control (Table 5). T2, T3 and T4 showed significant difference, with T4 recording the highest, followed by T3 and then T2. However, obtained results are significantly different from those reported by [22] in Egypt which was in a range of 44.00 – 56.43cm. This could be due to differences in geographical locations and the different rates and types of fertilizers applied on the crop.

Table 5: Mean plant height of onion

Treatment	Mean plants height (cm)
T1(Adlib application by farmers)	39.07a
T2(100% ETc morning application only)	41.86b
T3(100% ETc evening application only)	46.62c
T4(50% ETc morning and 50% ETc evening application)	48.34d
L.S.D	1.37

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Means within a column with different letters are significantly different

Yield and Quality of onion bulbs

As seen in Table 6, bulb weight was significantly (p<0.05) affected among T2, T3 and T4 when compared to T1. T4 produced the highest bulb weight than the rest of the treatments though not statistical different from T3. The weight of onion bulbs which serves as a function of bulb quality, thus, the higher the weight of the bulb, the more appealing it is to the customer was recorded in T4. The results obtained T3 (138.8g) and T4 (150.2g) are significantly higher than those recorded by [22] in Egypt which was in a range of 78.76 -133.94g. In terms of yield per hectare (t/ha), T2 and T3 did not indicate any statistical difference when compared to the T1. T2 yielded the lowest bulb weight and this could be due to high evapotranspiration during the day time. T4 recorded the highest value of 25t/ha and T3 with a value of 23.1t/ha. T1 and T2 recorded the least values of 18.7t/ha and 16t/ha respectively. The difference in yields under the various treatments indicate that appropriate irrigation scheduling with accurate crop water requirement can greatly influence yield. The T4 (25t/ha) is within the results of [6] who recorded 25 -35t/ha. However, the trend of the obtained results are significantly lower than those reported by [13] – 36t/ha and [18] – 41.1t/ha. Also, according to [8], a good bulb yield under irrigation is 35 to 45 ton/ha.

Table 6: Mean weight of fresh onion bulb (g)

Treatment	Mean weight of fresh bulb(g)	Yield per hectare (tones/ha)
T1	112.1ab	18.7
T2	96.2a	16
T3	138.8bc	23.1
T4	150.2c	25
L.S.D	34.07	

Means in a column bearing the same letter(s) are not significantly different

Plate 1: Freshly harvested onion

Plate 2: Air dried onion bulbs

Weight of fresh leaves

As can be seen in Table 7, no statistical difference was observed among the treatments at (p<0.05). However, T4 happened to show the highest mean weight (233.6g), followed by T2 (229.8g) with T3 (210.9g) recording the lowest value.

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Table 7: Mean weight of fresh leaves (g)

Treatment	Mean weight of fresh leaves(g)
T1(Adlib application by farmers)	213.2a
T2(100% ETc morning application only)	229.8a
T3(100% ETc evening application only)	210.9a
T4(50% ETc morning and 50% ETc evening application)	233.6a
L.S.D	38.85

Means in a column bearing the same letter(s) are not significantly different

Mean weight of dry leaves

No statistical difference was observed among the treatments at ($p<0.05$). However, T3 happened to show the highest mean weight (26.98g), followed by T4 (25.95g) with T2 (25.10g) recording the lowest value. T1has recorded 25.05g

Plate 3: Weighing fresh leaves of onion

Plate 4: Oven drying of onion leaves

Crop Water Productivity

Crop water productivity is the ratio of actual yield (kg/ha) to the total water use (m^3/ha). It was calculated for each treatment during the experiment. The results of the crop water productivity (Table 8) showed that T4 recorded the highest crop water productivity of (5.45 kg/m^3) followed by T3 (5.04 kg/m^3), T2 (3.49 kg/m^3) and the adlib water application the farmer recorded the least crop water productivity of 2.65 kg/m^3. The results suggest that T4 and T3 are economically productive when adopted by onion farmers. According to [8], the water utilization efficiency for harvested yield for bulbs containing 85 to 90 percent moisture is 8 to 10 kg/m^3. The results obtained from the experiment are, however; significantly lower than the FAO values. Also, the obtained results are however, significantly higher than those reported by [16] which was in a range of 1.9 – 2.4kg/m^3.

Table 8: Crop water productivity of onion for the various treatments

Treatment	Total water use (m^3/ha)	Yield (kg/ha)	Productivity (kg/m^3)
T1	7048.89	18700	2.65
T2	4586.67	16000	3.49
T3	4586.67	23100	5.04
T4	4586.67	25000	5.45

4. CONCLUSION

Based on the obtained results of the effect of different water application schedules on the growth and yield of onion, yield components and morphological characteristics of the onion crop, it was concluded that irrigation scheduling had significantly affected all the studied parameters, except for fresh weight of leaves. To achieve a high production potential of onion, appropriate soil moisture should be maintained during the entire growing season. High yields of bulbs in T4 (25t/ha) suggested that splitting the daily crop water requirement of onion into two, thus, 50% applied in the morning and the remaining 50% applied in the evening can maintain appropriate soil moisture during the entire growing season. T4 is therefore recommended for onion farmers to adopt if they want to achieve maximum yield and optimum utilization of irrigation water per acreage.

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