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Irrigation scheduling and water use efficiency on cabbage yield

Mexoese Nyatuame*, **Francis Ampiaw**, **Victor Owusu-Gyimah**, **Bingali Mabinde Ibrahim**

Ho Polytechnic, Agricultural Engineering Dept, Box 217, Volta Region, Ghana

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Abstract

Irrigation frequency is one of the most important factors in irrigation scheduling, and a proper irrigation frequency can establish moderate moist and oxygen conditions in the root zone throughout the crop growth period. This study was conducted to study the effect of scheduling irrigation on the water use efficiency and yield of cabbage. It was conducted on a cabbage farm within the Ho Municipality. The weights of harvested cabbage heads were recorded. Four raised beds were prepared with two replication labelled into various treatment (T1, T2, T3, and T4). Treatment 1 was irrigated every day, Treatment 2 irrigated three times in a week, Treatment 3 irrigated only once in a week and Treatment 4 was under control (No irrigation). Treatment 1 (T1) yielded the highest weight(kg) of cabbage head after harvesting and the lowest water use efficiency as compared to yields of treatment 2 and 3 with treatment 4 yielding the least in weight of cabbage heads. The relationship between yield and applied water will allow to improve the management of water resources under water scarcity.

* **Corresponding Author:** Mexoese Nyatuame ✉ doga_nyatuame@yahoo.com

Introduction

Water is the major limiting factor for crop diversification and production. More than 80% of water resources have been exploited for agricultural irrigation (Wang *et a*l., 2001). To cope with the water-shortage, it is necessary to adopt water saving agriculture counter measures as efficient use of irrigation water is becoming increasingly important.

Irrigation scheduling is the application of the right quantity or amount of water at the right time to the soil for plant growth. In actual fact the main essence of irrigation is to sometimes supplement natural rainfall in areas where the amount of rainfall is limited and erratic and this is referred to as supplemental irrigation. However, in desert areas where the soil is very fertile and can support crop productivity but there is very little or no rainfall at all, irrigation is therefore adopted. This type of irrigation is known as total irrigation (Michael, 2008). Inadequate irrigation application results in crop water stress and yield reduction. Excess irrigation application can result in pollution of water sources due to the loss of plant nutrients through leaching, runoff, and soil erosion.

Many investigators have concluded that irrigation scheduling can increase net farm income (Fardad and Golkar, 2002). The potential returns of irrigation scheduling are derived from three factors: increase irrigation efficiency, reduced cost of irrigation and opportunity cost of water (English *et a*l., 1990)

The main increase in food supplies has come from making efficient use of land already being farmed. More efficient crop production will help for instance better varieties; effective use of fertilizer, mechanization etc, but rainfall is still a limiting factor for a very large proportion of the earth surface, hence irrigation is of much essence in increasing crop output

Cabbage as a vegetable requires water throughout its growing season. Unfortunately, the amount and distribution of rainfall is seasonal and at times erratic. This problem has consequently led to the realization of the significance of irrigation in cabbage farming. There is an increasing demand for cabbage, hence it is considered as one of the most important economical vegetables. The aim of this study was to determine the effect of different irrigation schedules on the yield and water use efficiency of cabbage plant and to select the most suitable irrigation schedule for cabbage plant under field condition.

Materials and methods

Study Area

The experiment was conducted on a cabbage farm near Ghana Electricity Company's power house off Adaklu road in Ho, located on latitude 6.60° and longitude 0.47°, the regional capital of the Volta region of Ghana. Ho municipality is located within the southern half of the Volta Region. There are two main types of vegetation namely the moist deciduous forest which covers mostly the northern hilly portions of the municipality and the savanna wood land which is predominant in the southern portions and occupied about 3/5 of the vegetation zone (Ho Municipal Agricultural data, 2007). The average annual rainfall is about 1450mm, however, the rainfall is bi-modal characterized by major and minor seasons. The major season starts from March - June and the minor from September - November. The major soil type includes: The forest soils namely forest achrosols, forest lithosols and the combination of the two types. These are in the hilly and wetter northern portions of the municipality.

The savanna soils of tree grassland vegetation namely; the tropical black earths and tropical grey earths

Notwithstanding the main study area, the soil at the experimental sites is sandy-loam (Table 1). Common plants within the area are; *Imperata cylindrica, Panicum maximum* and *Yas africana*. The topography of the area is gentle with a uniform slope.

Materials Used and Land Preparation

The materials used for the experiment were: Cabbage seeds, Dutch hoe, Cutlass, Watering can, Measuring tape, Pegs & lines and Rake.

The land was cleared, tilled and levelled using cutlass, hoe and rake. Saw dust was spread on the land and burnt to kill any soil pathogens in the soil.

A 70kg of a month old well decomposed poultry manure was spread on the prepared land after tilling.

Table 1. Physical and chemicals properties of the soil at the experimental site.

Properties	Units	Soil (Ho series)
PH (acidity level)	1:1 H_2O	6.40
Total Nitrogen	%	0.50
Organic carbon	%	1.73
Sand	%	85.77
Silt	%	4.23
Clay	%	10.00
Total phosphorus (P)	mg/kg	20.53
Potassium (K)	cmol/kg	0.41
Sodium (Na)	cmol/kg	0.46
Calcium (ca)	cmol/kg	3.80
Magnesium (Mg)	cmol/kg	0.80
Effective cat-ion exchange capacity	cmol/kg	26.40

Experimental Design Used

Completely Randomized Design (CRD) with two (2) replications and four (4) treatments was used. The total area of plot was 42 m^2 and the field divided into eight (8) beds resulting in four (4) treatments and two (2) replications. Each plot (bed) measured 1 m x 2 m (Area = 2 m^2). The moisture content of various beds were determined using gravimetric method and recorded whilst the volume of water irrigated at different treatment level computed. The soil at the study site is called Ho series and the land is almost flat but it was further levelled and soil sample revealed homogeneity with composition of 85.77% of sand, 10% clay and 4.23% silt. Fertility level was equal; this was done by applying equal amount of manure. These actions were carried out to minimize experimental error. The manure was applied and incorporated into the soil by thorough mixing and allowed to pulverize and blend with the soil a week prior to transplanting of the cabbage from the nursery bed to the experimental plots. In the growing season, plant protection measurements and hoeing were completed as necessary. Plants were hoed in order to both break the soil crust and control weeds.

Field Layout and Irrigation Scheduling Systems

Total area of land used was 42 m^2. Four raised beds were prepared. One bed measures 1 m x 2 m. Each bed labelled (T1, T2, T3, T4), with two (2) replication (R1, R2)

The prepared four (4) raised bed were each labelled A, B, C, and D. The bed labelled "A" (T1) was irrigated daily, "B" (T2) was irrigated every three days, "C" (T3) was irrigated once every week and "D" (T4) was not under irrigation (Contol).

Data Collection

Data were collected on the following parameters:

Mean weight of cabbage head, Amount of water used for irrigation.

Soil Sampling and laboratory analysis

Surface soil (0-15 cm) was sampled using a soil auger. The bulk soil samples were brought to the laboratory, air dried and sieved with 2 mm sieve. The soil samples were kept in white polythene bags for chemical and physical analysis. The chemical and physical composition of the soil samples are presented in Table 1

Soil pH was measured in distilled water at soil to solution ratio of 1:2 using Suntex pH meter. Total carbon was determined using the wet oxidation method of Walkley and Black (1934). Total nitrogen in soil was determined using the Kjeldahl method (Jackson, 1958). Total P was determined using concentrated HNO_3-$HCLO_4$ to digest the soil samples until the solution appeared colourless. After cooling and filtration, ascorbic acid molybdate method of Watanabe and Olsen (1965) was used. Colour intensity was measured using the spectrophotometer at a wavelength of 712 nm. Particle size analysis was undertaken by completely digesting organic matter with H_2O_2 (1:1 soil: H_2O_2). 0.01 M calgon (sodium hexametaphosphate) solution was used to disperse the soil particles followed by 5 minutes mixing of suspension using a motor mixer. Hydrometer was used to determined silt at 5 minutes and clay fraction over a period of 5 hour.

Estimating the Saturation Capacity

According to Smith (1981), the saturation capacity was estimated using the following relationship:

$$\text{Moisture content (MC)} = \frac{(w_s - W_1)\,100\%}{W_S}$$

Where MC = moisture content in %

W_s= weight of wet' soil mass

W_1= weight of dry soil mass

Procedure for Estimating the Saturation Capacity

At field capacity, soil sample was taken from the field. The soil sample was well covered making sure the sample was not exposed to the air. The sample was then weighed after which it was oven dried at a temperature of 105°C for 24hrs to avoid burning the organic matter completely.

The sample was then allowed to cool and weighed again and recorded the moisture content (Mc) expressed as a percentage of the final dry weight. After oven drying the sample, it was allowed to cool and weighed again and recorded as follows:

Mass of container = 30.5 g

Mass of container + wet soil sample = 470.6 g

Mass of oven dried soil sample + container = 250.2 g

Therefore; Mass of wet soil = 470.6 -30.5 = 440.l g

Mass of dry soil = 250.2 - 30.5 = 219.7 g

Moisture content (Mc) = ((440.1-219.7)*100%)/440.1

Mc= 50% = (220.4*100%)/440.1

According to Michael (2008), the moisture content of sandy-loam soils should not be allowed to fall to 50% since this will mean plant exerting suction to extract moisture from the soil which can result into a significant reduction in crop yield.

Results

Estimation of Crop Water Requirement of Cabbage

Blanney-criddle method was used in the determination of crop evapotranspiration and reference evapotranspiration as well. ETc= Kc x ETo (mm/day), Where Kc is Crop co-efficient, ETo is Reference Evapotranspiration, Etc = Crop Evapotranspiration. Also ETo = P (0.46T + 8), Where p is 0.27 (mean monthly percentage day time hours which depends on the latitude) T = 28.5° (means monthly air temperature). Therefore; ETo = 027 (0.46 x 28.5° + 8) = 5.7mm/day.

Table 2. Determining ETc= (Kc x ETo) mm/day.

Growth Stages (Days)	Initial 20-30	Development 30-35	Mid-season 20-30	Late-season 10-20
Kc	0.45	0.75	1.02	0.95
ETo (mm/day)	5.7	5.7	5.7	5.7
ETc (mm/day)	2.57	4.28	5.81	5.42

Estimating the Volume of Water Applied In Each Month.

One watering can of water was estimated to cover a bed of 2 m² without much loss encountered. Volume of watering can (Vc) = 13.5 litres = 0.027 m³

This was the amount of water irrigated on a 2 m² bed.

Volume of Water Applied In May

Treatment I = 0.027 m³ x 5 (days) each week for 4 weeks = 0.0273 m³ x 20 = 0.5 m³

Treatment 2 = 0.027 m³ x 2 (days) each week for 4weeks = 0.027 m³ x 8 (days) = 0.216 m³

Treatment 3 = 0.027 m³ x I (day) each week for 4 weeks = 0.027 m³ x 4 = 0.1 08 m³

Treatment 4 = control.

The above method was employed in the calculations for the volume of water applied in June, July and August.

Table 3. Volume of water Applied in each Month (m³).

Treatment	May	June	July	August	Total
1	0.500	0.486	0.675	0.370	2.031
2	0.216	0.162	0.270	0.108	0.756
3	0.108	0.081	0.135	0.054	0.375
4	-	-	-	-	-

The Table 3 above revealed the quantity of water applied to the various treatments under examination for the different months during period of growth. It was evident from the table above that July‘s cabbage water requirement was the highest, followed by May, June and August respectively. It was estimated that the total volume of water that gave the maximum yield was 2.031 m³

Table 4 demonstrates the cabbage yield, mean yield and water use efficiency of the treatments. As seen from the table, treatment 1, which gave the highest cabbage yield, had the least water use efficiency (WUE).

The yield data of treatments were presented in the table above. Treatment 1 received the highest irrigation water and having the highest crop water consumption had the highest yield. The highest total yield was also obtained from treatment 1. The lowest total yield was also obtained from treatment 4 (control).

Table 4. Yield.

Treatment	R1 (kg)	R2 (kg)	Total yield (kg)	Mean yield (kg)	WUE (kg/m3)
1	32.740	32.860	65.600	32.80	16.149
2	26.890	26.750	53.640	26.82	35.476
3	21.940	22.100	44.040	22.02	58.720
4	18.850	18.550	37.400	18.700	-

Hypothesis

H_o =there is no differences in the yield of cabbage among the treatment (Y1=Y2=Y3=Y4)

H_A= there is differences in the yield of cabbage among the treatment (Y1 ≠ Y2 ≠ Y3 ≠ Y4)

The rejection region of the test-statistic (F) was set at α = 0.05 (5%) , F=0.05

The analysis of Variance (Table 5) showed significant differences among the four treatments. Therefore the null hypothesis is rejected and the alternate (H_A) fail to reject. The result showed that T1 recorded the highest value, followed by T2 and then T3 followed with T4 recording the lowest value.

The Table 6 above indicated that there was a significant difference between the treatments at the 0.05 level. The result and analysis indicated that the bed (i. e. Treatment I) with daily irrigation produced the maximum yield with respect to the weight of cabbage. The result indicated and confirmed that cabbage were very sensitive to water deficiency.

Discussion

Volume of Water Applied

The results showed significant differences in the volume of water applied in each month. The volume of watering can used for applying water to each treatment was the same except for treatment (4) which was the control (without irrigation /rain fed). Indications were that the treatment (T1) with daily irrigation had the highest volume of water for irrigation followed by Treatment (T2), which was irrigated in every two (2) days and finally Treatment (T3) was irrigated only once in a week. Treatment (T4) had no water supply as it was strictly under control. Due to this scheduling system, there was variation in the volume of water applied in each month. It was evident that the more water applied to the treatments the more cabbage yield was obtained (Table 3). Moreover, the more water applied to the treatments the higher quality cabbage head was obtained.

The less watered treatments formed more gloomy and crooked heads. As a result, it is obvious that right scheduling of irrigation is important not only to get optimum yield but also to get higher quality cabbage head. The result obtained was consistent with that of Himanshu *et al*., (2012), which averred that the marketable yield of cabbage increased with an increase in seasonal water applied and also the mean number of head per m² was influenced by irrigation levels. Guler and Ibrikci (2002) also corroborated that in their study carried out in Italy and Turkey; irrigation water increased the fruit number and based on this yield increased.

Table 5. Analysis of Variance (ANOVA).

		Sum of Squares	Df	Mean Square	F	Sig.
Yield of cabbage * Treatment levels	Between Groups	14.529	3	4.843	18.514	.000
	Within Groups	7.325	28	.262		
	Total	21.854	31			

Mean Weight of Cabbage Heads In Kilograms.

The results showed that T1 had the highest mean value of 32.800 kg with 2.031 m³ of water; also T2 recorded 22.020 kg with 0.375 m³ of water. This could be due to the fact that T2 and T3 had lower volume of water with T4 being without irrigation (i. e. control). There were significant positive correlation ($P<0.01$) between mean weight and irrigation water, between mean weight and crop water consumption and between mean weight and the yield. As Manini (1988) stated, irrigation water and crop water consumption increased the mean weight and this affected the yield.

The finding is also coherent with that of Sammis (1980), which stated that many vegetable species are shallow-rooted and sensitive to mild water stress.

When plants (crops) are under water stress, they channel their energy into survival first and production (fruition) second hence the yield of crops are impacted by water with other factors being constant.

Table 6. Dependent Variable: Yield of cabbage.

Treatment levels (I)	Treatment levels (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	T2	.74250*			.2187	1.2663
T1	T3	1.41250*	.25573	.000	.8887	1.9363
	T4	1.76250*	.25573	.000	1.2387	2.2863
	T1	-.74250*	.25573	.007	-1.2663	-.2187
T2	T3	.67000*	.25573	.014	.1462	1.1938
	T4	1.02000*	.25573	.000	.4962	1.5438
	T1	-1.41250*	.25573	.000	-1.9363	-.8887
T3	T2	-.67000*	.25573	.014	-1.1938	-.1462
	T4	.35000	.25573	.182	-.1738	.8738
	T1	-1.76250*	.25573	.000	-2.2863	-1.2387
T4	T2	-1.02000*	.25573	.000	-1.5438	-.4962
	T3	-.35000	.25573	.182	-.8738	.1738

*. The mean difference is significant at the 0.05 level

The volume of water applied to each bed could have been affected because an evaporation loss causes a further decrease in volume of water resulting in dry conditions. From the results, Treatment (T1) which had an appreciable volume of water left in the soil after evaporation recorded the highest mean weight of cabbage head. Therefore, the higher the volume of water applied the greater the yield obtained and vice versa since the optimum water requirement of cabbage is about 1500-1600 mm during its growth season.

Water Use Efficiency of Cabbage (WUE) kg/m^3)

With reference to the mean yield (weight) of the cabbage heads obtained and the total volume water applied, it was realized that the water use efficiency for T1 was 16.149 kg/m^3, and T2 was 35.476 kg/m^3, T3 was 58.720 kg/m^3 and that of T4 was not determined since no volume of water was applied (i. e. control). The water use efficiency (WUE) therefore varied significantly ($P \geq 0.05$) among different treatment and the increase and decrease in WUE under different treatments showed positive relationship with increase in cabbage weight. This indicates that the higher the yield obtained as a result of higher volume of water applied the lower the water use efficiency and vice versa.

The low WUE obtained could be attributed to high soil evaporation in relation to crop evapotranspiration. Therefore to increase the water use efficiency and still obtain the optimum yield, the crop should be irrigated in the evening since soil evaporation is minimal in the evening. Mulching of the soil could also be incorporated as cultural practice to minimise soil evaporation. Irrigation compensation was generally higher in treatments irrigated with high amount of water than those irrigated with low amount of water. This may be due to the fact that frequently watered plants used more water because they found it much more easily without suffering from water deficit and the water loss by radiation was much more in frequently watered treatments because of the irrigation water depth is shallower.

Conclusion

The overall results clearly revealed that in order to obtained optimum cabbage yield and also allocate limited water resources suitably, cabbage should be irrigated daily and in the evening. This means that in order to obtain higher yield in cabbage so as to achieve best weight of the heads, it is important that farmer's practice daily irrigation since cabbage requires an abundant and well-distributed water supply.

Any further research should compare the dry matter of the mean weight of cabbage heads for the various treatments. The cost of cabbage heads and the cost of water where the supply must be paid for should be compared to ascertain whether it is worthwhile irrigating.

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