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THE RESPONSE OF GREENHOUSE TOMATO (EVA) TO DIFFERENT WATER REGIMES IN THE FOREST-SAVANNA TRANSITION ZONE OF GHANA

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ABSTRACT

In Indonesia, rabbits have developed as small-scale businesses in tourist areas in the form of The study sought to find out the effective water regime for Eva tomato with respect to the 10.2% increase in mean Municipal decadal reference evapotranspiration between 1980 and 2009. Five treatments of drip fertigated irrigation regimes of 80 %, 100 %, 120 %, 140 % and 160 % with four replications of crop evapotranspiration (ETc), estimated from mean decadal monthly reference evapotranspiration estimated by the Meteorological Service Agency from 30 years data by Penman–Monteith (PM) method. The crop factors and growth stages were taken from FAO repository. Tomato (Lycopersiconesculentum, Eva variety) plants were grown in Chromic Luvisol in a poly-net greenhouse tunnel with dimension 15m x 8m (Amiran). T0,the 100% water regime produced the highest fruit size and weight followed by T1(80 % water regime). However, there was no significant difference between 80%, 100 % and the 120 % in both fruit size and weight ($p < 0.05$). In terms of growth (plant height) T4 (160 % regime) recorded the highest followed by T0(100 % regime). Results from the study shows that irrigating at 100% ETC will produce heaviest and largest fruits of highest quality of Eva tomato. However, under scarce water irrigation could be done at 80% ETC, saving about 20% water to obtain economic yields.

Keywords: Drought length, Actual evapotranspiration, Reference Evapotranspiration, Crop evapotranspiration

1. INTRODUCTION

The growing water crises coupled with sustainable use of water has become a serious concern. In many parts of the world, water is gradually becoming a scarce commodity [1]. With the rapid growth in population, industrialization and urbanization efficient use of water within the agricultural systems has become increasingly important [2].

In many developing countries, such as Ghana, the nutritional needs of the rapidly growing population have increased in the last decade and will continue to increase. In an attempt to ensure higher agricultural productivity per unit volume of water resources, per unit area of land, irrigation has been adopted[3]. However, it has been reported that agriculture through irrigation alone accounts for 70% of fresh water withdrawals across the globe [4]. Thus water use efficiency (WUE) can be optimized by the adoption of more efficient irrigation practices [5].

Tomato, one of the most important horticultural crops, is a high water demanding crop, and thus requires irrigation throughout the growing season in arid, semiarid areas and the forest-savannah transition zone of Ghana, where rainfalls from May to August are becoming unreliable in quantity and frequency. Field studies show that the crop needs soil moisture during the entire season in order to produce the optimum amount of high-quality fruit [6] (Snyder et al., 2000). The application of deficit irrigation strategies to this crop may greatly contribute to save irrigation water [7]. Since tomato is one crop in which consumers demand more varieties of higher quality, strategies focused on increasing fruit quality continue to be of great interest [8].

The use of Greenhouse technology in the production of horticultural crops has attracted a great deal of attention in recent years. The use of this technology has been accelerated by the need to provide fresh and quality produce throughout the year in addition to optimizing water use in a varying climatic conditions [9]. Besides creating and maintaining a controlled environment which fosters optimum crop production, greenhouse farming increases irrigation water use efficiency and produces yields that are about five to ten times greater than in the field [10].

In order to ensure sustainable and profitable production of horticultural crops under greenhouse in a warming climate, water must be applied in adequate amounts and at appropriate times [11]. The situation therefore calls water saving strategies to ensure adequate supply of water through irrigation. As a potential water saving strategy, it has been estimated that better irrigation scheduling and use of drip irrigation in row crops may save about 20% of the water consumption [12]. Scheduling water application, on the other hand, 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 [13].

Generally, there is an increase in the mean decadal daily drying capacity of the study area (Mampong Ashanti) by 10.2 % [14]. This is making it difficult for soils to retain sufficient moisture throughout the growth period for vegetables to benefit more from fertilizer and other inputs. The soil in the greenhouse, more or less, experiences the drying trend of the outside environment through the 2.0 m high mesh around the greenhouse. This will, certainly, not create any significant difference in the daily crop-water requirement for crops in the greenhouse.

Greenhouse tomato has become popular in Ghana nowadays. One of the main reasons is because many people are becoming aware that the technology is far more profitable with less drudgery and economic risk and the fruit produced are of higher quality and wholesome compared to that from traditional farming. Again the possibility of producing organic produce is very high. Also there is dwindling trend in water supply for the traditional farming as demand is exceeding supply.

Thus the study sought to establish the optimum water regime for the highest size and weight of Eva tomatoes in 10.2 % increase in the territorial reference evapotranspiration.

2. MATERIALS AND METHODS

2.1Experimental Site

The experiment was carried out at the College of Agriculture Education (CAGRIC), University of Education, Winneba’s, Multi-purpose Nursery, 62.0 km North of Kumasi, Ghana (0.05o

1.30o W 6.55o 7.30o N). The climate of the study site is Transition of the forest and the savannah zones with rainfall becoming erratic and unreliable. Rainfall ranges between 1270 mm and 1524 mm per annum whiles mean monthly temperatures range from 25o C to 32oC per month [15]. The soils within the site were sandy loam with good infiltration rates.

2.2 Experimental set up

The experiment was carried out in a mini greenhouse tunnel with dimension 15 m x 8 m. Beds with dimension 12 m x 0.3 m were made and sub-divided into four blocks of 3 m x 0.3 m. The distance between the drip lines was 1.0 m with 0.3 m between plants. Equal quantities of dry compost (10 kg) of cattle dung was thoroughly incorporated into each bed. The experimental design used was the Complete Randomized Design (CRD) with five treatments and four replicates. Treatments applied were 80% regime (T1), 100 % regime (T0), 120 % regime (T2), 140 % regime (T3) and 160 % regime (T4) of daily crop ETC estimated fromthe local, Municipal, mean monthly reference evapotranspiration. Eva tomato seeds, sown in plastic nursery trays, were transplanted at 21 days after germination. The crop coefficients, and the period of growth stages used were obtained from [16] and the estimated crop water requirement at the various growth stages are shown in Table 1.

Table 1: Reference and 100% Crop Evapotranspiration and Irrigation Schedule

Parameter	Days	Kc	ETc (mmd^{-1})							
			Apri	May	Jun	Jul	Jul	Aug	Aug	Sept
Period			27^{th}-30^{th}	1^{st}–31^{st}	1^{st} -30^{th}	1^{st} –5^{th}	6^{th} -31^{st}	1^{st} -14^{th}	15^{th} -31^{th}	1^{st} – 9^{th}
ETo (mm)			3.85	3.48	2.91	2.45	2.45	2.34	2.34	2.68
Initial stage	30	0.45	1.733	2.61						
Development stage	40	0.75			2.18	1.84				
Mid stage	40	1.15					2.83	2.69		
Late stage	25	0.80							1.87	2.14

2.3 Reference Evapotranspiration for the study area

The mean daily reference evapotranspiration for the study as published by [14] from 30 year data (1980-2009) is presented in Table 1. At the time of the study the drying capacity of the atmosphere has increased by 10.2 % as actual evapotranspiration.

2.4 Soil and water test

Composite soil samples were taken from the surface (1.0-15.0 and 15-30 cm) from the greenhouse soil before the study, and analyzed at the Soil Research Institute, Kwadaso, Kumasi.

2.5 Calibration of system and scheduling

The irrigation setup was made up of 1,000 litre capacity fertigation tank mounted 2.0 m above ground. The set up was calibrated by determining its mean dripping rate (litres per min).

The irrigation time was determined using equation (2) for the various ETcs at the growth stages using the mean (calibrated) dripping rate of the system. From the ETcs of the various growth stages and their periods the irrigation was scheduled with the help of a calendar and followed. Crop evapotranspiration (ETc) was calculated using equation (1). ETC was determined using a 30 year (1980-2009) mean monthly ETo of the local area (Municipal) from equation (1). The irrigation time for each growth stage was determined by equation (2):ETC = ETo x KC(1)

Where ETC = crop water requirement (mm)

ETo = Reference evapotranspiration (mm)

KC = crop factor(dimensionless)

Irrigation time (mins): (ETc (mm))/(Drippng rate (mm/Min)) (2)

The mean daily Reference Evapotranspiration (ETo) of the months (April to September) for the area were estimated from monthly data from 1980 to 2009 obtained from Ghana Meteorological Service Agency. The KC for the various growth stages were taken from [16].

2.6 Uniformity coefficient and Coefficient of Variation

Two of the four widely-used parameters for measuring emitter discharge uniformity were used. They are: Coefficient of variation (CV) and Uniformity coefficient (UC).Coefficient of variation, CV, was calculated using the equation: CV = (s/q) *100 (3).

Where s represents the standard deviation of emitter flow rates, and q is the mean emitter flow rate.

Uniformity coefficient, UC, as defined by [17] and modified to reflect a percentage, was calculated using the equation:

$$UC = 100 \left|1 - \frac{\frac{1}{n}\sum_{i=1}^{n}\left[q_i - \bar{q}\right]}{\bar{q}}\right| \quad (4)$$

Where n represents the number of emitters evaluated.

2.7 Harvesting and Data collection

Three parameters; plant growth rate, fruit weight and size were measured and analysed using ANOVA and the means separated by LSD at P < 0.05 using Genstat.

3. RESULTS AND DISCUSSIONS

3.1 Greenhouse soil conditions and system calibration

Results from the greenhouse soil sample showed soil was non-saline (EC ranged from 1.91 to 2.12 dS m-1), non-calcareous (CaCO3 ranged from 23 to 30%), sandy-clay in texture and with pH ranging from 6.3 to 7.7. The borehole water had EC, pH and sodium adsorption ratio (SAR) of 3.2dS m-1, 7.08 and 6.94 respectively.

The emitters of the drip irrigation system were calibrated as 0.00771 Litres per minute and used to estimate the irrigation times for the ETces at the various growth stages for fertigation.

Table 2: Mean Temperature Range (oC)

Factor	Temperature (ºC)	
	Inside Greenhouse	Outside Greenhouse
Night	26.5-29.0	29.0-30.5
Day	28.0 – 37.5	28.5-43.5

Tomato temperature tolerance for extreme heat or cold snaps is of extreme importance to the development of blossoms and subsequent fruit set. Blossom drop occurs in the spring if daytime temperatures are warm but night temperatures drop below 13oC (55oF) [18] (Amy, 2018). The period of the study, April to September, exhibits high temperatures (day and night). The day temperatures soared over 32oC (90oF) (Table 2) with nights recording over 24oC (76oF) in the green house; the tomato plant suffered some damage to immature fruit and or loss of flowers. Also, (when) the night's temperatures were too warm, and according to [18] Army (2018) the pollen grains of the tomato flower begins to burst above 26oC, thwarting pollination, and hencepoor fruit setting. This is true when the air is saturated with relative humidity as the green house did not have vents. The mean night and day time temperatures range in the greenhouse were respectively 2oC and 9oC. The temperature records are the reasons for lower number of fruits per plant observed in the house.

3.2 Uniformity Parameters

The Coefficient of variation (CV) 7.47 % and the Uniformity coefficient was 98.24 %. The uniformity coefficient (UC) and the Coefficient of variation are good since they agree with [19] Braltset al., (1987) with value of UC greater than 95% and the CV less than 20.0 %.

Figure 1 presents the effect of the water regimes on mean plant growth rate. The Eva tomato plants that received 160% water regime (T4) showed the highest plant height throughout the first four weeks after transplanting with 32.62 cm by the 4th week after planting. It could also be observed that the growth rate increased with increasing level of irrigation water. That is, increasing the water levels improves vegetative growth. This is supported by [21] that, increase in irrigation depth above 80% of ETc increased crop growth rate (CGR). Therefore, an increase in depth of irrigation above 80 % of ETc ensures adequate moisture for nutrients transport, plant cell turgidity and promotes higher water energy consumption for growth.

Effect of water regime on growth of plants

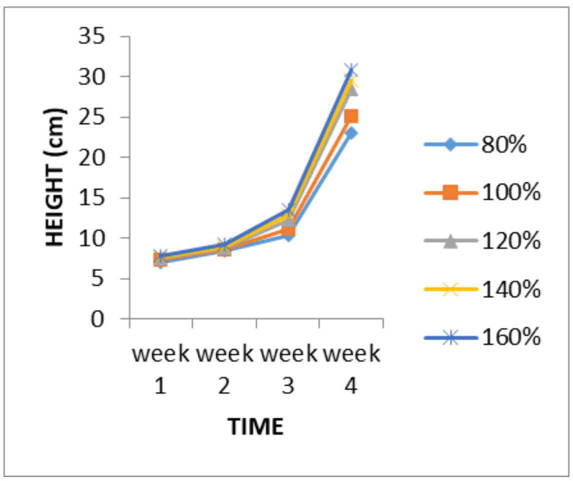

Fig 1: Mean plant height

The least growth rate was recorded by 80.0% (T1) treatment which gave 24.73 cm at the same period. There was significant difference ($p < 0.05$) in growth rates when T4 and T3 are compared to T1.

Effect of water regime on fruit weight

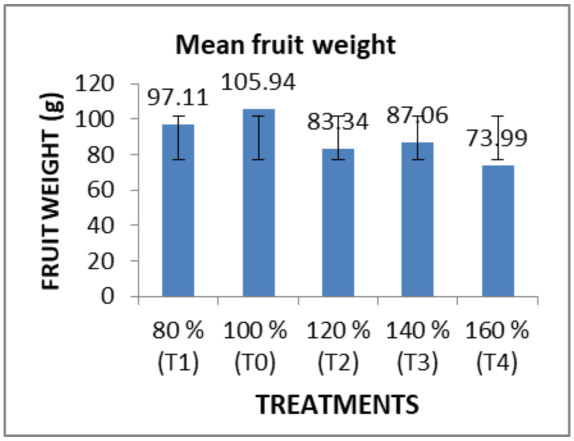

Fig. 2 Mean fruit weight

From the graph(Fig 3), T0 (100% ETc) gave the highest fruit weight of 105.94 g followed by the 80 % ETc (97.11 g) and the least weight recorded by the 160% ETcregime (73.99 g)(T4). Statistically, the treatment means indicated no significant difference ($p<0.05$).

Statistically, the increment of the irrigated water to 120%, 140% and 160% of the ETc had no significant effect on the fruit weight of Eva.

The 20.0% incremental interval above the 100% could be considered as over irrigation. The performance of the 80.0 % (T1) application agrees with [22] assertion that, a 20% reduction in the crop water requirement does not significantly reduce yield. According to them a 30% or more reduction in ETc will however have significant negative effect on both growth and yield of tomato. At the new ETc of the study area which is an increase by 10.2 % [14] (Koteiet al., 2013) the 100.0 % ETc estimated from the 30 year climate data could be used as climate change adaptation measure for higher fruit weights in the area. However, farmers could irrigate at the 80.0% ETc with some mulching materials to save 20.0% of irrigation water and reduce input cost.

Effect of water regime on mean fruit size

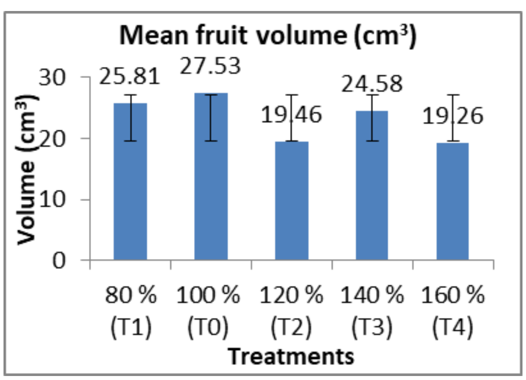

Fig 3: Mean fruit volume

T1 (100%) recorded the highest fruit size of 27.53 cm3 followed by the 80.0 % ETc (T3) (25.81 cm3) and the least by the 160.0% (T4) (19.26 cm3). There was no significant difference between the treatment means ($p < 0.05$). Therefore, the application of the 100% water requirement in the warmer climate could be adopted for higher fruit weight and size. Again, where mulching materials are readily and cheaply available 80.0% of the water required in the warmer climate could be applied for Eva tomato in the Mampong-Ashanti Municipal area as climate change mitigation strategy. This is in consonance with [22] Alaouiet al. (2015), that increasing irrigation water or frequency above the optimum doesn't significantly affect fruit size.

The mean night temperatures in the greenhouse (27.5oC), during the study period, were higher than the annual mean (26.8oC) for the 30 years data [14] (Koteiet al., 2013) by 2.61 %. According to [14] Koteiet al. (2013), the drying capacity of the air in the study area has increased by 10.2% in 2000-2009 decade. According to [23] FAO (2008), these increments negatively affect potential yield and water productivity of crops in the long term, especially vegetables. These could have been the reason for the lower figures recorded in weight and size of Eva tomato.

4. CONCLUSION

The study sought to find out the effective water regime varied around the estimated requirement (100%) for Eva tomatoes from the new mean Municipal's reference evapotranspiration for the period April to September. The study has so far shown that for Eva tomato grown under greenhouse conditions, without vents, in Chromic Luvisol, from the current climate variables at the study area, about 20% of irrigated water can be saved by irrigating at 80.0% of the new Municipal water requirement estimated for the area for optimum fruit weight and size by mulching the soil. More importantly the study has confirmed that increasing or decreasing Eva water requirement estimated from the current climate conditions by 20.0% does not significantly affect fruit weight and size.

Following the results obtained, the following recommendations were made:

1.Tomato producers in the study area should be educated and supported to avoid over irrigation and under irrigation to save precious water for expansion of irrigated agriculture.

2.In the absence of sufficient water for Eva irrigation in the greenhouse, especially in the Forest-Savannah Transition zone, 80% of the water requirement (ETc) could be employed under controlled greenhouse conditions for high weight and size.

3.All green houses in the study area must have adequate vents to regulate the greenhouse humuduty.

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