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Effect of Deficit Irrigation on Yield and Quality of Eggplant

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***Abstract*— *The aim of the study was to determine the effect of deficit irrigation on yield and quality of eggplant. Eggplant cultivated under different irrigation treatment. The treatment imposed included, treatment 1 (100ETc: full irrigation), treatment 2 (90ETc: 10% reduction of full irrigation), treatment 3 (80ETc: 20% reduction of full irrigation), treatment 4 (70ETc: 30% reduction of full irrigation). Eggplant cultivated under different irrigation treatment and were harvested and analyzed for total yield, fruit shape, pH of the fruit, moisture content, protein, carbohydrate, phosphorus. Deficit irrigation had significant effect on the protein content, carbohydrate content and fruit moisture. Results of the study showed that deficit irrigation had no significant effect on phosphorus and fruit shape. Also, deficit irrigation reduced disease incidence in eggplants while ensuring an improvement in fruit firmness and the overall marketable yield. The study concludes that a reduction of 10% ETc in the cultivation of eggplant would produce optimum and quality fruits thereby saving irrigation water.*
***Keywords*— Deficit irrigation, Water Use Efficiency, Yield, Eggplant.**

I. INTRODUCTION

Eggplant (*Solanum melongena L.)* is a short-lived perennial herb that belongs to the family Solanaceae. It is grown as an annual plant and is one of the consumed fruit vegetables in tropical Africa; probably the third after tomato and onion, and before okra (Grubben and Denton, 2004). Although excessive rainfall affects both vegetative growth and flower formation, the plant is well adapted to both wet and dry season cultivation. In West Africa the eggplant fruits are eaten raw, cooked or fried with spices in stews, or dried and pound as condiments (Fayemi, 1999). Eggplant is rich in essential vitamins and minerals. It contains 89.0g water, 1.4g protein, 1.0 fat, 8.0g carbohydrate, 1.5g cellulose, 105mg vitamin C and 1.6mg iron 130mg calcium (Ramain, 2001). In particular, eggplant is a good source of calcium, phosphorus and iron salts for bone and blood cell formation in the body (Schippers, 2000; Romain, 2001). According to Fereres and Soriano (2007), water scarcity has become a global problem. As cities grow and populations increases, the problem worsens since needs for water increase in households, industry and agriculture. This affects both the yield and quality of fruits and vegetables. Inability of farmers to determine the correct amount of water required by crops and adoption to the necessary irrigation practices during the growing season is one of the major challenges in vegetable production in Ghana. Studies have shown that eggplant can give a fruit yield of 0.5 kg to 8 kg per plant depending on the cultivar and growing conditions (Lester and Seck, 2004). Under rain fed, this translates to fruit yields varying from 5 to 8 ton/ha, while under optimal irrigation, potential fruit yield vary from 12 to 20 ton/ha. Currently, potential fruit of improved cultivars vary from 50 to 80 ton/ha (Lester and Seck, 2004). According to Norman (1992), the local egg plant can give an average yield of about 35-40 fruits per plant weighing between 0.9-1kg per plant. The aubergine types produce 5-10 fruits per plant depending on the cultivar and as the number of fruits produced increases, the size of the fruits decrease. (Tindall, 1992) also reported that 8-14 fruits per plant may be harvested with fruit size varying from 0.25-0.4kg per fruit with a yield of 2-5 t ha^{-1}. Without irrigation yield of about 5-8 t ha^{-1} can be obtained while with irrigation 12-20 t ha^{-1} can be obtained depending on the cultivar. Conventionally, irrigation is applied to avoid reduction in crop production due to water deficits (Fereres and Soriano, 2007). For commercial farmers, irrigation is applied to allow production of cultivated crops that will produce a satisfactory economic yield (Pereira *et al*. 2012). Crops are much supplied with sufficient water so that the crops can transpire and meet their full ET requirements throughout the growing seasons. Under conditions of water scarcity, the water available for farmers is normally below the maximum ET needs of the plants. Farmers are then forced to make decisions to concentrate on the limited water over a smaller land area or to irrigate the total area with levels below the full ET requirement. Irrigation application below the full ET requirement is termed as deficit irrigation. Deficit irrigation field studies normally derive production functions that can be used to predict yield depending on the amount of irrigation applied or the amount of water used by the crop (ETc) other than water, yield and quality of the crop is affected by several other factors some of which are unpredictable such as climate, incidences of pests and diseases and several agronomic factors (English and Roja, 1996). Therefore the production function will only be an estimate of the true relationships. Application of deficit irrigation in crop production is an approach to save water in areas of water shortage and longer drought during production period so as to maximize water productivity. Regulated deficit irrigation saves substantial amount of irrigation water and increase water use efficiency (Kirda, 2002). It is therefore important to use irrigation technique that suit to the local environmental condition and also with capability to improve yield and quality when complemented with good management practices, with the capacity to limit scarce resource wastage and require few inputs (Darko *et al*., 2016; Imtiyaz *et al*., 2000). Most of the agricultural production in Ghana is by smallholders who rely on seasonal rainfall that is unpredictable and sporadic. The onset of the climate change, insufficient rainfall and occasional uncontrollable floods results in frequent crop failures which are having a serious effect on the livelihood of the population. As a result, the population is extremely poor and food insecurity threatens every year. Inability of famers to determine the correct amount of water required by the crop and adoption to the necessary irrigation practices during the growing season is also another major challenge in vegetable production in Ghana. Thus application of deficit irrigation in eggplant production is an approach to save water in areas of water shortage and longer drought during the production period. By extension, this has left questions into the minds of many as to whether deficit irrigation has any effect on the yield and quality of crops. Hence, the study seeks to investigate the effect of deficit irrigation on the yield and quality of eggplant as well as water use efficiency.

II. MATERIAL & METHODS

Study area

The study was carried out at the School of Agriculture Teaching and Research Farm, University of Cape Coast. The study area experiences two rainy seasons namely the major season which starts from May and ends in July and a minor season that starts around September and ends around mid November to give the dry harmattan season that runs through to the end of March in the subsequent year. The area is characterized by an annual temperature range of 23.2-33.2 ºC with an annual mean of 27.6 °C and a relative humidity range of 81.3-84.4% (Owusu-Sekyere *et al*., 2011). The soil is described as sandy clayey loam of Benya series, a member of Edina Benya Udu compound association. Weeds were cleared to the ground level and allowed to dry. Pegging was done to demarcate the bed size. The hoe was used to loosen the soil to a maximum depth and with the peg and line; equal beds of 2.0m × 2.0m were prepared. The main cultural practices carried out included weeding, earthen up and stirring. These practices were carried out to ensure the optimal growth of the plant.

Experimental design and layout

The experimental design used in this study was Randomized Complete Block Design there were four (4) treatments with three (3) replications. The treatment were T1: 100%ETc; T2: 90%ETc; T3: 80%ETc and T4: 70%ETc. Egg plant seeds was nursed the healthy seedlings were transplanted unto prepared beds. All the plants comprising the treatment combination were given equal volume of water (500ml) for eight days to ensure uniformity among the seedlings before the various treatments were administered. A two day irrigation interval was employed. The volume of water applied to each treatment was obtained by the computation of crop evapotranspiration using the pan evaporation method. The amount of water applied represent 100%, 90%, 80% and 70%ETc. These water treatments were maintained for entire growing season of the eggplant crop. The stages are the developmental stage, the mid-season stage and the late season stage. The class A evaporation pan and a rain gauge installed at the teaching and research farm unit of the university of cape coast were used to record the amount of rainfall and the evaporative power of the atmosphere. The daily reduction in the pan water level with reference to the initial level noted the previous day was measured as the day's evaporation loss and then multiplied by the pan coefficient (kp) which is 0.7; the reference crop evaporation was obtained.

The reference crop evaporation was computed using the formulae

$ET_0 = K_p \times E_p$ (1)

Where;

ETo= reference crop evapotranspiration

Kp= pan coefficient

Ep= pan evaporation

Crop Evapotranspiration was computed using the formula

$ETc = ET_0 \times K_c$ (2)

Where

ETo = Reference evapotranspiration

Kc = Crop evapotranspiration

Data Collection

Data was collected on based on plant height, leaf area, average fruit weight, total yield, fruit shape, pH of the fruit, moisture content, protein, carbohydrate, phosphorus.

Plant Height

The plant height at the end of the initial stage, vegetative growth stage and final stage (fruiting) were measured using a tape measure. The data obtained were then summed up and their mean height was calculated for each treatment.

Leaf area

The longest length along the petiole line and the widest breath across the leaf of the eggplant were recorded by using a 30cm capacity roll up rule with a graduation of 10cm. A factor of 0.75 was multiplied by the product of the length and breadth to arrive at the leaf area according to Brown and Covey (1966).

Average fruit weight

Measurement of the mass of each treatment after harvesting was carried out using the electronic balance. Mean fruit mass was calculated for each treatment.

pH determination

The pH of the beverage was determined by the using a digital pH meter after calibrating with buffer solutions of pH 4.0 and 7.0 respectively. The beverage sample was then put in a 100 ml beaker, and thoroughly stirred. The electrode of pH meter was then immersed in and direct reading taken after the reading stabilized.

Determination of protein

The moisture content was determined using the oven drying method and Protein (%) was determined by first knowing the N(%) using Equation 3 below and computing it into Equation 4

$$N (\%) = \frac{(T-B) \times M \times 14.007 \times 100}{\text{Sample weight (mg)}} \quad (3)$$

Where M = Molality of Acid; S = Sample titre value; B = Blank titre value

Protein = N (%) × 6.25 (4)

Determination of carbohydrate

$$\text{Soluble carbohydrates (\%)} = \frac{C\text{ (mg)} \times \text{extract volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample wt (g)}} \quad (5)$$

Where C = carbohydrate concentration from the calibration graph

Statistical analysis

Data collected was subjected to the analysis of variance (ANOVA) procedure using Genstat software statistical to investigate whether there were statistical differences in the parameters studied. Comparison of means will be done using Tukey Test at a probability level of 0.05.

III. RESULTS AND DISCUSSION

Eggplant growth and yield response to deficit application

Plant height

Analysis of variance on the effect of deficit irrigation on plant height (Figure 1) showed significant difference among the treatments, indicating that, at 24 days after transplanting, the height of plants which received 100% ETc (14.36 cm) was not significantly different from those that received 90% ETc (13.31 cm), but was significantly different from egg plants that receive 80% ETc (12.06 cm) and 70% ETc (10.29cm). A similar pattern was obtained for plant heights recorded at 41 DAT and 69 DAT. At 24 DAT, 41 DAT and 69 DAT there was no significant difference between egg plants that received 100% ETc and 90% ETc, a similar observation was made between egg plants that received 80% ETc and 70% ETc. This is in line with the findings of Owusu-Sekyere and Andoh (2010) who stated that after 69 DAT the highest plant height recorded from plant that received 100% ETc is not significantly different from the plant that received 90%ETc, while the lowest plant height recorded from plant that received treatment 70% ETc is not significantly different from the plant that received 80%ETc. Bilibio *et al*., (2013) reported that eggplant was more sensitive to water deficit and that plant height showed growth inversely proportional to soil water stress. This experiment has demonstrated that reducing a crops evapotranspiration beyond a certain reach would have a significant impact on the height of egg plants. The least plant height could be attributed to the non-availability of adequate moisture, which has a significant impact on the vegetative growth of egg plants. Water is a major component of plant cells and is the medium in which biological process such as photosynthesis

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occurs, without adequate moisture, photosynthetic rate of a plant is reduced. Reduced photosynthesis results in a retrogression of plant growth especially plant height. Since photosynthesis required for plant growth is not available or when available are present in smaller quantities. Also, plant under stress experiences difficulty in absorbing essential nutrients because transpiration which is linked with the roles of minerals salt absorbing, cooling and general effect on growth and development is negatively affected (Berrie and Berie, 1990).

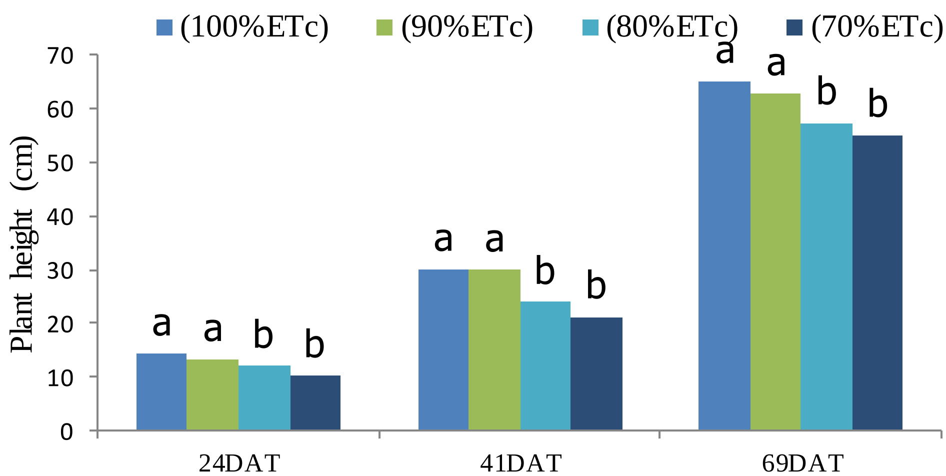

Fig.1: Effect of deficit irrigation on the plant height of eggplant

Leaf area

The effect of deficit irrigation on leaf area of eggplant is presented in (Figure 2). At 24 days after transplanting there was no significant difference between the mean leaf area of egg plants which received 100%ETc (29.67 cm^2) and 90% ETc (28.77 cm^2), a similar observation was made at 41 DAT and 69 DAT. However mean leaf area of egg plants that received 100% ETc (40.68 cm^2) and 90% ETc (39.74 cm^2) was significantly different from the mean leaf area of egg plants that received 80% ETc (37.37cm^2) and 70% ETc (35.82cm^2), a similar observation was made at 41 DAT and 69 DAT. Mean leaf area of egg plants that received 80% crop water requirement was significantly different from egg plants that received 70% crop evapotranspiration at 24 DAT, 41 DAT and 69DAT. After 69 DAT the lowest leaf area reordered was 44.42 cm^2, which was observed in plants that received 70% crop evapotranspiration. Owusu-Sekyere and Andoh, (2010) reported that they found the leaf area of egg plants reduced as the ETc of the plants was reduced. Egg plants that received the least ETc recorded the lowest leaf area. This could be attributed to the absence of adequate moisture, which has a major effect on the photosynthetic rate of the plants, hence it vegetative growth. Water alters a variety of biochemical and physiological processes ranging from photosynthesis to protein synthesis and solute accumulation (Hu and Schmidhalter, 1998). Photosynthesis is the process in which plants combine water, carbon dioxide and light to produce carbohydrate for energy; chemical limitations due to a reduction in critical photosynthetic components such as water negatively have impact on plant growth. When these happen, leaf growth will be affected more since they are not able to compensate for moisture stress as compared to other parts of the plants such as the root.

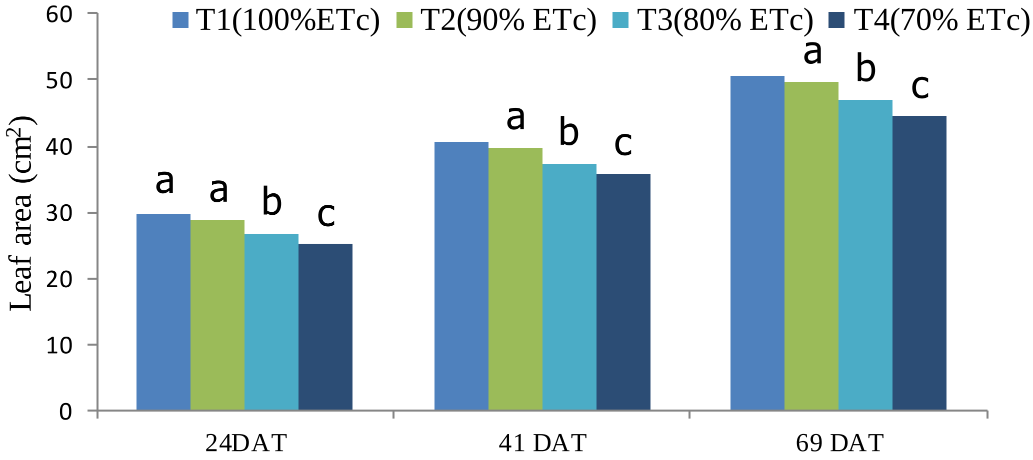

Fig.2: The effect of deficit irrigation on the leaf area of eggplant

Average fruit weight

Effect of deficit irrigation on the average fruit weight of eggplant is presented in Figure 3. Analysis of variance of the effect of different crop evapotranspiration on mean fruit weight showed significant difference among the mean fruit weight of egg plants which received 100%ETc (47.32 g), 90% ETc (45.93 g), 80% ETc (41.8 g) and 70% ETc (38.71 g). Research on eggplant also suggests that water stress limits fleshy fruit water accumulation but does not affect carbon partitioning to the fruit (Mitchell *et al*. 1991). Serhat (2017) reported that eggplant yield; length was significantly influenced by irrigation water level. The lowest average fruit weight was observed in eggplant exposed to the least irrigation amount that is 70% ETc. Diaz-Perez and Eaton (2015) reported that fruit yield of eggplant was lowest at 33% ETc and there were little yield differences among irrigation rates higher than 33% ETc. Dermirel *et al*., (2014) reported that yield reductions of 18.16 % and 27.13 % observed under low and moderate water stress. The highest average fruit weight was observed in eggplant exposed to full irrigation amount (100% ETc). This is in line with the findings of Kirnak *et al*., (2002). They reported that 100% ETc treatment had the highest yield as well as the largest and the heaviest fruit.

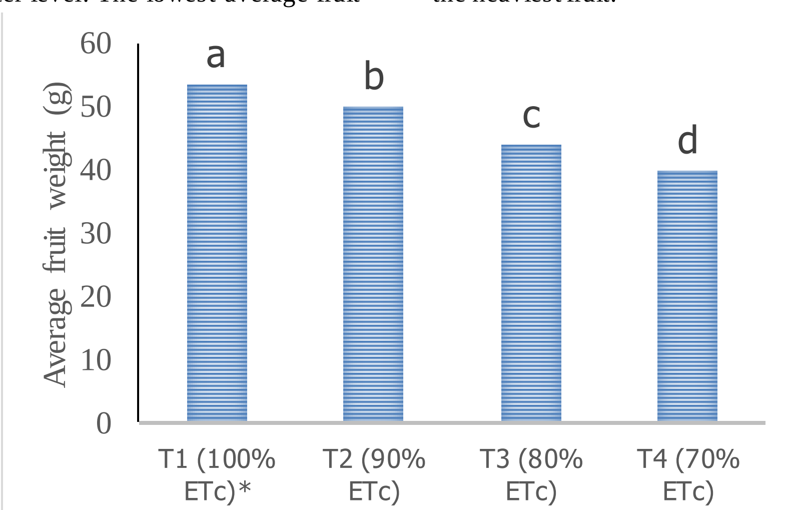

Fig.3: Effect of deficit irrigation on average fruit weight of eggplant.

Yield

Yield per tonnes of eggplant was significantly dependent on deficit irrigation (Figure 4). Analysis of variance of the effect of deficit irrigation on eggplant yield showed significant difference between the mean fruit weight of egg plants which received 100% ETc (4.0 MT), 90% ETc (3.8 MT) 80% ETc

(3.3 MT) and 70% ETc (3.0 MT). The highest yield was obtained from eggplant that received 100% ETc. This is in line with the findings of Serhat (2017), who reported that eggplant yield was significantly influenced by irrigation water level. The highest yield averaging 62 t ha^{-1} was obtained from eggplant that was given full irrigation amount. Although there was significant differences in the total yield of crops exposed to 90% ETc and 80% ETc was similar to that of 100% ETc. This is in tandem with earlier findings of Diaz-Perez and Eaton (2015) who suggested that eggplant may tolerate mild water stress, since plants irrigated at 20-30 % reduction of ETc produced fruit yields similar to those of plants irrigated at 100% ETc. Thus, there is a potential to save water by reducing current irrigation rates without negatively impacting fruit yields. Senyigit *et al.*, (2011) reported that the highest yield was obtained from full irrigation treatment and 10% reduction of full irrigation amount. The results of the study indicate that as the amount of irrigation water reduces total yield reduces. This could be attributed to the fact that water stress causes a reduction in the fruit number with decreasing soil water, this is further explained that lower soil moisture could result in pollen and stigma dehydration as well as unnecessary elongation of the flower's style which could result in up to 50% reduction in fruit setting and final fruit yield.

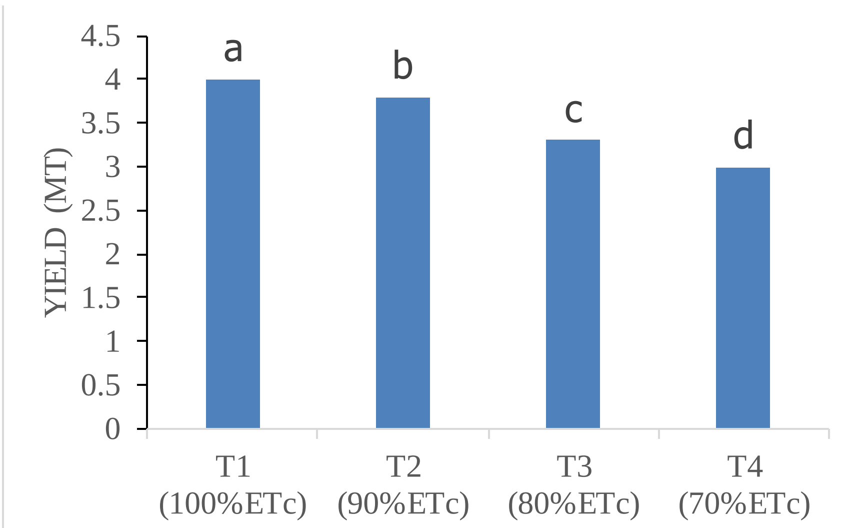

Fig.4: Effect of deficit irrigation on yield of eggplant

Effect of deficit irrigation on the quality of eggplant fruit.
Quality of eggplant fruits
Protein

The application of deficit irrigation instigated significant variation in the protein content of eggplant fruit (Table 1).

Table 1: Effect of deficit irrigation on the quality of eggplant fruit

Treatment	Protein (%)	Carbohydrate (%)	Phosphorus(ug/g)	pH	Fruit shape	Moisture (%)
100% ETc	17.4a	13.57a	3296a	5.5a	2286a	94.3a
90% Etc	19.3b	14.45a	3273a	5.5a	2777a	91.7b
80% Etc	15.6c	11.65b	3249a	5.6a	2759a	90.5c
70% Etc	15.6c	17.52c	3150a	5.6a	2571a	89.6d
L.S.D	0.40	0.967	208.2	0.02	625.6	0.92

The study portrayed that treatment 2 has the highest protein content of 19.34%, which was significantly different from the remaining treatments. Also treatment 4 had the least amount of protein content of 15.57% which was not significantly different from T3 with 15.63%. Present study indicate that eggplant fruit contains rich amount of vitamins and minerals of which protein is 1.4g according Romain (2001). This indicates that effect of water stress on eggplant had significant effect on the protein content of the fruit.

Carbohydrate and Phosphorous

The application of deficit irrigation instigated significant variation in the carbohydrate content of garden eggs as observed in Table 1. The study showed that treatment 4 (crops to which 70% ETc) has the highest carbohydrate content of 17.52%, which was significantly different from the other treatments. There was no significant difference between treatment1 (100% ETc) and treatment 2 (90%ETc) with 13.57% and 14.45% respectively.

The amount of phosphorus content in egg plant as a result of deficit irrigation is presented in (Table 1). There was high phosphorus content in treatment 1 (100%ETc) with 3296µg/g, followed by treatment 2 (90%ETc) with 3273µg/g, treatment 3 (80%ETc) with 3249µg/g, treatment 4 (70%ETc) with 3150µg/g in that order. The amount of phosphorus decreases with decrease in the ETc. There was no significant difference between the four treatments. The results of the study showed that, water stress of deficit irrigation had no significant effect with the phosphorus content of the eggplant. According to Fayemi *et al*., (1999), Phosphorus and Iron salts are used for bone and blood cell formation in the body, as well as a reasonable source of vitamin A(Carotene), Vitamin B-complex and vitamin C, all essential for good health and from the results of our study a decrease in ETc had no effect on the amount of phosphorus content in egg plant.

pH

The effect of deficit irrigation on the pH of eggplant fruits is presented in Table 1. pH measures the total acidity or alkalinity is an important factor in vegetable and fruit production as this relates to fruit quality.

The experiment discovered that, pH of eggplant fruit decreases with increasing water stress. Highest value of pH was as a result of high moisture content at the various treatments. This result is in line with the findings of Marouelli *et al*., (2007) who established that water supply restriction during either fruit development or maturation growth stages promoted a significant increase in fruit acidity. The results obtained as well confirm that of (Rouphael *et al*., 2008) who also illustrated that water stress can improve quality characteristics of fruits, pH inclusive. When crops are irrigated with less water, the plant regulate certain metabolic activities, such as osmotic adjustment in sink organs, to increase the sucrose and organic acid transformation rate and amount, consequently more assimilates shift to the fruits, thus improving the acid content. This implied that fruits from plants treated with less water had low pH values which would lead to an improvement in the flavour of the eggplant fruit.

Moisture Content

The results of moisture content of eggplant fruits with respect to deficit irrigation is presented in Table 1. Generally, it can be observed that as ETc reduces the moisture content of fruit decreases. Analysis of variance revealed that the variation in the moisture content of eggplant fruit after imposing deficit irrigation was statistically different. Bhattarai and Midmore (2002) noted that dry matter was highest for deficit irrigation treatments. Wahb-Allah *et al*. (2014) stated that water stress treatment significantly improve all fruit quality attributes in terms of fruit dry weight. The positive effect regarding water stress on eggplant fruit quality traits can be explained by a reduction in water accumulation in fruit. (Patanè *et al*., 2011). The moisture content of eggplant fruit is inversely proportional to its firmness. Hence the lower the moisture content, the higher the firmness. Since the moisture content of the eggplant fruits decreases as the crop water requirement is reduced, it is obvious that the eggplants plants that received a lesser crop water requirement would produce fruits with the least moisture content.

Fruit shape

The effect of deficit irrigation on the pH of eggplant fruits is presented in Table 1. Fruit shape measures the total length and width as an important factor in vegetable and fruit production as this relates to fruit quality. The experiment discovered that, fruit shape of eggplant fruit remain the same even with increasing or decreasing water stress. When the crop water requirement of crops is reduced it makes the fruits hardy and increases firmness, thus reducing the susceptibility of the fruits to diseases.

Effect of deficit irrigation on water use efficiency of the eggplant.

Results of data on water use efficiency (WUE) of eggplant as a result of deficit irrigation is presented in Table 2.

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Table 2: Effect of deficit irrigation on the water use efficiency of eggplant

Treatment	WUE (g/mm)
T1	2.012a
T2	2.517b
T3	3.237c
T4	3.372c
L.S.D	0.1600

It indicates that the highest water use efficiency was exhibited by crops that received 70% ETc (3.372 g/mm) and was significantly higher than crops that received 100% ETc (2.012 g/mm) and 90% ETc (2.517 g/mm), however it was not significantly different from crops that received 80% ETc (3.327 g/mm). This is in line with the findings of Serhat (2017) who reported that the highest WUE was observed in eggplants exposed to 75% ETc. It can be observed in Table 2 that the lowest water use efficiency (2.012 g/mm) was exhibited by crops that received 100% ETc. This agrees to earlier research done by Senyigit *et al*., (2011). They reported that the lowest WUE values of eggplant were calculated in the treatment to which the highest irrigation water was applied. Their findings indicated that WUE decreased with the increasing irrigation water and ET. Generally, it can also be observed that as the eggplants were exposed to water stress, the water use efficiency of eggplants increased. The lowest amount of water applied (70% ETc) recorded the highest WUE value, whereas the highest amount of water applied (100% ETc) resulted in the lowest WUE values in that order. The phenomena where by water stressed plants gives the higher WUE indicates that as the crops are exposed to water stress there is high dry matter accumulation in the fruit. According to Birhanu and Tilahun (2010) this observation can be attributed to the fact that as total plant biomass decreases with water stress level, fruit dry matter increased, hence there is an increase in water use efficiency when water stress level increases.

IV. CONCLUSION

Production continue to increase and the prospects for increase in vegetable all year round will possibly come mostly from irrigation and amendment of the soil fertility status as rainfall is unpredictable and the soil is of low fertility. Research in irrigation water management for efficient use of water by crops will contribute to crop improvements. From the study, it can be concluded that, 90% crop water requirement or water-use efficiency is the best application for eggplant in a water scarce environment. Also, decreasing deficit irrigation level from T3 to T4 Water-Use Efficiency can yield to compensate marketable losses. The study showed that increasing or decreasing deficit irrigation level in eggplant production had no significant effect on the fruit pH, fruit shape and the phosphorus content of the fruit but brought about significant differences in carbohydrate content of garden eggs for the various treatments.

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