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CROP COEFFICIENT (Kc), WATER REQUIREMENT AND THE EFFECT OF DEFICIT IRRIGATION ON TOMATO IN THE COASTAL SAVANNAH ZONE OF GHANA

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ABSTRACT
This study was conducted under a rain shelter to determine the crop coefficient, water requirement and the effect of deficit irrigation on the development and yield of tomato. Completely Randomized Design (CRD) was used with three replications. There were four (4) different water treatments, namely: 100% of water requirement (T_1), 90% of water requirement (T_2), 80% water requirement (T_3) and 70% water requirement (T_4). The seasonal water requirement of tomato was found to be 302.98mm, while the Kc was also between 0.62-1.61. Generally, the parameters studied were in the order T1= T2> T3> T4. The utilization of NPK from the start to the end of the experiment was in the order: for Nitrogen is T1> T2> T3> T4 and Phosphorus and Potassium were similar in the order T1> T2> T3= T4. These suggest that 10-15% reduction of ETc of tomato will have no significant difference in growth and development while reduction of above 20% will have a negative effect on growth of tomato.

KEYWORDS: tomatoes, crop coefficient (Kc), water requirement, deficit irrigation, performance.

INTRODUCTION
Tomato (*Lycopersicon esculentum* Mill) is an important vegetable crop grown worldwide for both fresh and processing markets (Opiyo and Ying, 2005). In terms of acreage, it is the largest vegetable crop grown worldwide (Ho, 1996). The fruit is cultivated where climatic conditions are favourable and the seasonal water requirement is 300-600 mm (Schwah *et al*., 1993). Water plays a crucial role in determining the yield of tomato. However, it is most likely that a water scarcity period will have to be faced in the not too distant future. The unpredictable rainfall and increasing competition for water resources will compel the adoption of irrigation strategies in Africa. Deficit irrigation could allow saving of water and still maintain satisfactory yields or production levels (Topcu *et al*., 2007). Under this strategy, crops are deliberately allowed to sustain some degree of water deficit and yield reduction.

Deficit irrigation is irrigating the root-zone with less water than required for evapotranspiration (Zegbe-Dominguez *et al*., 2003). However, deficit irrigation for most vegetables such as tomato has been extensively studied, but with contrasting results (Dorji *et al*., 2005). For example, Zegbe-Dominguez *et al* (2003) revealed that tomato dry mass yield did not decrease under deficit irrigation compared to full irrigation, besides making a 50% saving in water and approximately 200% increase in irrigation water use efficiency and relevant fruit quality attributes improved.

In Ghana, tomato is cultivated in most parts of the country though majority comes from the Northern region. The fruits are extensively used in most homes, and this makes the crop a very important part of most Ghanaian dishes. However during the lean season, Ghana imports tomatoes from other parts of the world. This is because farmers are afraid of low yields due to scarcity of water during the lean season. Moreover there is no information to help farmers manage this scarce resource called water during drought in order to optimize yields in the lean season where prices increase. It is against this background that deficit irrigation of tomatoes is being investigated in this study to supply relevant information or data to enable farmers make concrete decisions on water supply during the lean season for optimum yield, availability and high income.

Furthermore to calculate tomato's crop evapotranspiration (ETc), there is the need to multiply the crop co-efficient (Kc) by the reference evapotranspiration (ETo). However, over the years, Kc is selected from literature to be 1.15 for both the developmental and mid-season stages. But Allen *et al*., (1998) reported Kc values of 1.15 and 0.70-0.90 for both the mid-season and late season stages respectively. Therefore, there is the need to determine the Kc for tomato grown in Ghana at the different developmental stages for accurate estimation of crop evapotranspiration (ETc). The study thus seeks to determine the Kc for the various growth stages and also investigate the effect of deficit irrigation on the growth and yield of tomato.

MATERIALS AND METHOD
Study area
The study was conducted at the School of Agriculture Teaching and Research Farm, University of Cape Coast. The temperature and relative humidity of the study area were 24-33 ^{o}C and 78-94 % respectively (Teye, 2010) while the soil type and annual rainfall are sandy-clay loam and 650-1100 mm respectively (Boamah, 2009).

Experimental design and procedure
In this study, tomato plants were grown in containers and placed under a rain shelter. Completely Randomised Design (CRD) with three (3) replications (R_1-R_3) and four

(4) treatments (T_1-T_4, five samples per treatment) was used. In all there were sixty (60) treatment combinations.

Planting

Tomato seeds were nursed and the healthy seedlings were transplanted into the container under the rain shed after 30 days in the nursery bed. All the sixty plants comprising the treatment combination were given equal level of water application for five days to ensure uniformity among the seedlings before the various treatments were administered.

Irrigation

A two day irrigation interval was employed. The volume of water applied to each treatment was obtained by the computation of weight loss by each container with the plants of the treatment.

Growth stages

In this experiment, three growth stages were used, namely initial stage, vegetative growth stage and final stage (fruiting). Treatments were then given at these various stages.

Treatments

At the end of every two days, crop water requirement (CWR) was determined for each treatment and the corresponding volume or amount of water was given. These were: T_1=100% of CWR, T_2= 90% of CWR, T_3=80% of CWR, and T_4=70% of CWR.

Data collection

The following data were collected during the research i.e. leaf area, plant height, number of fruits per plant, soil analysis, fruit weight, crop co-efficient (Kc) and fruit size etc.

Leaf area

The longest length along the petiole line and the widest breath across the leaf of the tomato plant were recorded by using a rule. A factor of 0.75 was multiplied by the product of the length and breadth to arrive at the leaf area.

Plant height

Plant height for each plant was determined by measuring the length of the plant from the base to the apex of the plant.

Yield Components

- Number of fruits per plant

The number of fruits per plant was determined by counting the number of fruits from each treatment.

- Fruit Size

A calliper was used to measure the major diameter of the fruit from each treatment for the size.

- Fruit weight

An electronic balance (0.001g sensitivity) was used to weigh each fruit from the various treatment combinations.

Determination of crop co-efficient (Kc), Crop evapotranspiration (ETc) and reference evapotranspiration.

The crop water requirement (ETc) is defined as the depth or amount of water needed to meet the water loss through evapotranspiration and it is given by:

ETc = ETo x Kc -- (3)

The crop coefficient for the three growth stages were determined by the formula (Allen *et al*., 1998), $Kc = \frac{ETc}{ETo}$ ....(4)

Where:
ETc = Crop Evapotranspiration
ETo = Reference Evapotranspiration and
Kc = Crop co-efficient

Reference crop Evapotranspiration was also calculated by the formula:

ETo = Ep x Kp...(5)

Where:
Ep = Pan evaporation, that is depth of water lost from the evaporation pan
Kp = Pan co-efficient which is 0.7 (Allen *et al*., 1998).

Soil analysis

Nitrogen (N), Phosphorus (P), Potassium (K) levels were determined for the soil used before and after the experiment using standard laboratory protocol or procedure (Rowell, 1994). The soil samples used were taken from the nursery bags and were thoroughly mixed together. The samples were then divided into four and two opposite quadrants were taken out. This was repeated until a substantial amount was obtained. The soil sample was then dried for four days after which it was ground and analysed for the above mentioned nutrients.

Statistical analysis

The results were subjected to the analysis of variance (ANOVA) procedure using GenStat statistical soft-ware to investigate whether there were statistical differences in the parameters studied. Mean comparisons were done using Duncan's Multiple Range Test at a probability level of 0.05 for separation of means (Russel, 1990).

RESULTS AND DISCUSSION

Leaf area

From Table 1, the leaf area for the various treatments showed no significant differences at 5% between them 25 days after transplanting, though variations or differences were observed in the order of T1> T2> T3> T4. This was not different from the observation made by Owusu-Sekyere and Dadzie (2009). Furthermore, at the end of 65 days after transplanting there were significant differences between the various treatments applied. The table shows that T1 had the highest mean leaf area while the least was T4. This could be due to water stress and could be said that reduction of moisture reduces the rate of leaf expansion as a mechanism to obviate the effect of moisture stress and this is supported by Norman *et al*., (1995).

Plant height

From Table 2, the plant height observed from the various treatments applied showed no significant differences 25 days after transplanting. This could be due to the availability of moisture required for the initial development at the early stage. However 65 days after transplanting, there were significant differences observed; T_1 was not significantly different from T_2 but was significantly different from T_3 & T_4 while T_2 & T_3 was significantly different from T4 but there were no significant differences between them. According to Rahman *et al* (1999) water stress results in reduction in growth of most growth parameters in plants.

TABLE 1: Mean leaf area of treatments at various growth stages

Treatments	Leaf area (cm^2) Initial stage	Leaf area(cm^2) 25days after transplanting	Leaf area (cm^2) 65 days after transplanting
T_1 = 100% of ETc	6.3	21.45a	42.99a
T_2 = 90% of ETc	6.2	20.05a	36.41ab
T_3 = 80% of ETc	6.5	17.47a	32.09b
T_4 = 70% of ETc	6.6	16.36a	26.85c
LSD $_{0.05}$			

TABLE 2: Plant height for treatment at various growth stages

Treatments	Plant height 15 days after planting (cm)	Plant height 30 days after planting (cm)	Plant height 65 days after planting (cm)
T_1 = 100% of ETc	28.55	42.50a	52.10a
T_2 = 90% of ETc	25.50	37.50b	44.50b
T_3 = 80% of ETc	27.89	41.50a	46.00b
T_4 = 70% of ETc	25.00	35.84b	44.00b
CV	14.32%	16.94%	21.81%

Yield (Number of fruits, Fruit diameter & Fruit weight)

The yield data taken from the studies can be seen in Table 3. For the mean number of fruits treatment T_1 had the highest and it was significantly different from T_3 & T_4 though not significantly different from T_2 at probability level of 5%. It could therefore be said that a slight reduction of water requirement of Tomato does not significantly affect the number of fruits formed. However, above 10% water stress affects number of fruit. Satch *et al*., (1983) and Norman *et al*., (1995) stated that the number of fruits decreases under water stress.

For fruit diameter, differences existed between the treatments applied. However T_1 & T_2 showed no significant differences while T_3 & T_4 also showed no significant difference while T_1 & T_2 were significantly different from T_3 & T_4. It could be said that for a significant reduction of fruit diameter to be seen, there must be more than 10% reduction of water requirement.

Tomato plant under T_1 treatment had the highest fruit weight and this was significantly different from T_2, T_3, and T_4 while T_3 and T_4 were not significantly different from each other. Hence the fruit weights were in the order T_1> T_2> T_3> T_4. This order suggests that availability of the right amount of water enhances the development and final yield of tomato as reduction imposes stress thus making the plants unable to efficiently make use of available nutrients for growth and yield.

TABLE 3: Yield parameters for the various treatments

Treatments	Mean number of fruits	Major diameter of fruit (mm)	Mean fruit weight (g)
T_1 = 100% of Etc	10.33a	40.78a	39.24a
T_2 = 90% of Etc	8.66ab	39.83ab	30.16b
T_3 = 80% of Etc	5.65bc	37.15b	22.43c
T_4 = 70% of Etc	3.71c	26.25b	17.13c
CV	14.53%	18.29%	21.24%

TABLE 4: Mean Kc, ETo and ETc (100%) at various growth stages

Growth stages	Kc	ETo (mm)	ETc (mm)
Initial	0.62	75.98	47.12
Developmental	1.61	48.13	77.48
Mid-season	1.23	85.59	105.27
Late-season	0.92	79.47	73.11
Total			302.98

Crop co-efficient (Kc), Reference Evapotranspiration and Crop Evapotranspiration

From Table 4, the seasonal Kc value for tomato grown in the coastal savannah zone of Ghana was found to be between 0.62-1.61. This was not different from Kc values reported by Allen *et al*., (1998). Also the developmental stage had the highest Kc value of 1.61 and according to Doorenbos and Kassam, (1979) the Kc value for this stage is the highest as compared to the other stages. Furthermore, the seasonal ET or water requirement for tomato was found to be 302.98 mm and was within the range reported by Silva and Maroucelli, (1996) which was 300mm to 400mm. The range takes into account crop characteristics, time of planting and general climatic conditions (Doorenbos and Pruitt, 1977).

NPK levels in the soil before and after the experiment for the treatments applied

Figure 1 shows the NPK levels in the soil before the experiment and after the experiment for the four treatments imposed. It was generally observed that NPK levels declined over the experimental period. At the end of the experiment, Nitrogen decline in the order of T1> T2> T3> T4 while a similar trend was revealed by Potassium and Phosphorus in the order of T1> T2> T3= T4. This general trend, which is a decline in uptake of nutrient as moisture stress increases, was not different from the observation made by Hegde and Srinivas (1990) for Tomato grown in different levels of soil matrix potential and Nitrogen applied.

Soil analysis

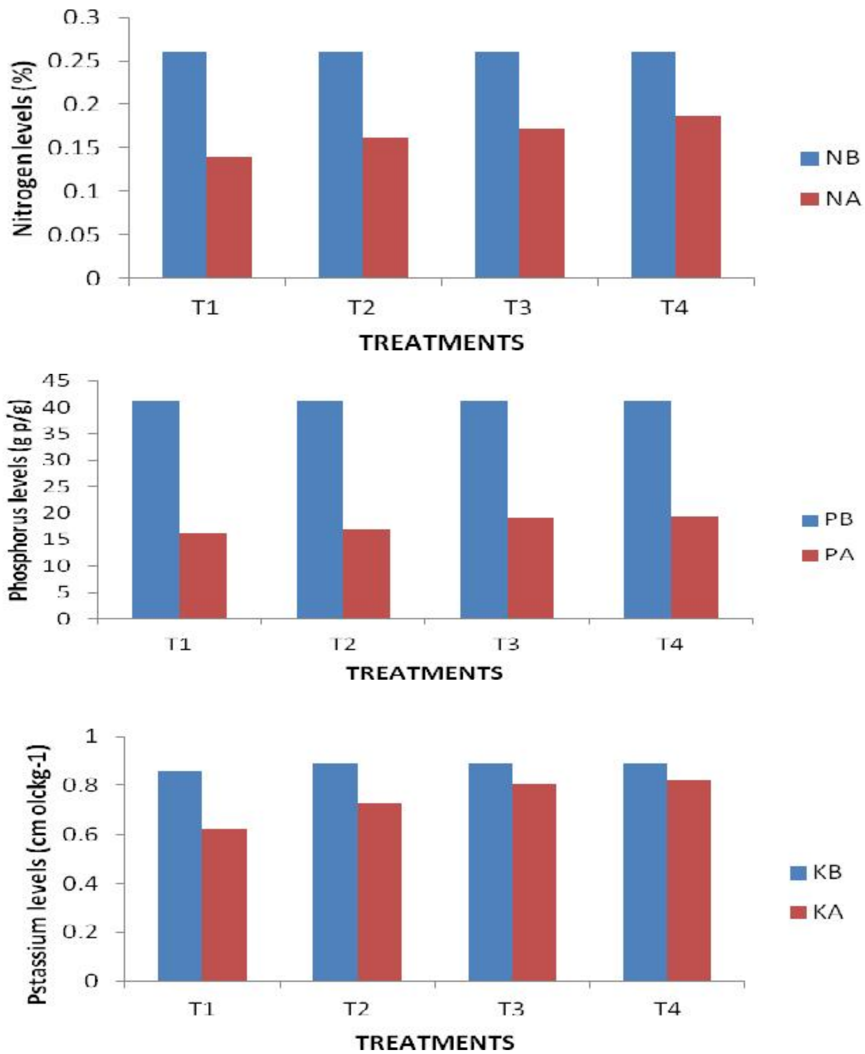

FIGURE 1: NPK levels in the various treatments before (B) and after the experiment (A)

CONCLUSION

The results show that deficit irrigation is feasible. However, to a large extent when water given is below 80% ETc, it negatively affects growth, development and total yield or profitability of tomato production in the coastal savannah zone of Ghana.

From this experiment it can be concluded that a 10-15% reduction in the amount or volume of water required while all other things been equal could be the best condition for tomato production if water economics is to be practiced to improve net profit of production.

The water requirement for tomato in the coastal savannah zone of Ghana was found to be 302.98mm while the corresponding Kc values are between 0.62 and 1.61

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