Estimation of Water Requirement of Early and Late Season Tomato (Lycopersicon Esculentum Mill) in Calabar, Southeast Nigeria.

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ABSTRACT

The estimation of water requirements of early and late season tomato was conducted based on 10 years meteorological data at Calabar typical of the humid tropical zone, using the Penman’s equation. Results showed that the seasonal crop evapotranspiration (ETo) value for early season tomato (March – July) was 60.8mm/day, while that of late season (September – December) was 73.6mm/day. The result showed that the water requirement for the late season was 2.0% higher than the early season tomato. However, water deficit tended to be greater in flowering than at yield formation. The calculated monthly crop coefficient (Kc/month) values for early season and late season tomato (the initial, crop development, and late season stages) were the same. The Kc values increased from low value at a time of crop emergence to a maximum value during the period when the crop reached full development, and declined thereafter when the crop matured. These results are discussed in light of estimation of water requirement of early and late season of tomato in Calabar.

KEY WORDS: Water Requirement, Tomato, Season.

INTRODUCTION

Tomato (Lycopersicon esculentum, mill) which is perhaps the most important crop in the world (Phene, 1989) and also an important constituent of the daily diet of most Nigerians is not grown commercially in Southern Nigeria. According to FAO (1980) estimates, Nigeria produces about 600,000 metric tones of tomato fruits annually, with the northern savanna zones as the main production centre.

The factors which limit large scale tomato production in the humid tropical lowlands of Nigeria can be traced to inadequate information on the production of most Nigerians is not grown commercially in Southern Nigeria. According to FAO (1980) estimates, Nigeria produces about 600,000 metric tones of tomato fruits annually, with the northern savanna zones as the main production centre.

The factors which limit large scale tomato production in the humid tropical lowlands of Nigeria can be traced to inadequate information on the production of the crop. Others include high relative humidity (51-87%), temperatures (20-33°C) and high rainfall, which are experienced during the late season of tomato in Calabar.

Water shortage during early flowering reduces the number of fruits and its deficit during yield formation period leads to small fruits and low yield (Raemaekers, 2001, Degras, 2005). In effect, more water supply to the crop and adequate nutrients are required at these growth stages. Ridge (1991) reported that water forms over 90% by weight of plant tissues hence, plant cells are water dependent and the water deficit. The implication is that the demand for water by crops must be met by water in the soil via the root system, and that the amount of water stored in the soil must be equal to the loss of water by evapotranspiration. The fact that tomato requires adequate amount of water means there is much need to determine the exact water requirements for both seasons as to reasonably know the best management option for greater economic returns to the farmer.

The objectives of the study were to determine crop water requirements and indicate the months with water deficit.

MATERIALS AND METHODS

The study was conducted at Calabar which lies within latitude 4º37’N and 4º41’N and longitude 8º 9’E and 8º12’E (White 1964). The humid forest zone of Nigeria. The annual rainfall in Calabar ranges from 1900mm to 2200mm, bimodally distributed with peaks in July and September. The soil is sandy clay loam (Course textured) and classified as an coastal plan soil. (Njoku et al 2001).

The study was based on 10 years (1997-2007) meteorological data collected from the Nigerian Airport Authority meteorological station, Calabar – Cross River State.

The meteorological data are presented in Table 1 and 2 and were used for the computation of the reference or potential crop evapotranspiration (ETo). Reference crop evapotranspiration (ETo) is defined as the rate of evaporation of an extended surface of 15-18cm tall green cover, actively growing, completely shading the ground and not short of water (FAO 1986). It therefore represents the climatic evaporation demand and tends to predict the effect of climate on crop.
reference crop evapotranspiration (ETo) was therefore calculated based on Penman’s equation. This equation is one of the empirical formulae that uses climatic data such as temperature, relative humidity, total wind speed and actual sunshine duration to estimate crop water requirements (FAO 1986). The Penman’s equation is stated thus:

\[ \text{ETo} = C \left[ W \times \text{Rn} + \left(1 - w\right) \times f \left(u\right) \times (e_a - e_d) \right] \tag{1} \]

Where \(e_a - e_d\) = vapour pressure deficit (mbar)
\(F\) = wind function (km/day)
\(W\) = temperature and altitude depended factor (\(T\) in °C, altitude in M)
\(C\) = adjustment factor for the ratio \(U\) (day/night)
\(\text{Rn}\) = total net radiation in mm/day

\(\text{ETa} = S_a \times \left[ 1 - \frac{1 - P}{1 - p} \right] \times \text{ETM} \quad \text{t} \quad \frac{1}{1 - p} \tag{3} \]

For late season stage 25 days
\(T = 25\) days
\(\text{ETa} = 140 (0.7) [20 - (4.4) (25) + 0.4]\)
25 \( (1-0.4) 140 (0.7) 1-0.4\)
= 3.92 [20 – 1.9 + 0.67]
= 73.6mm/day.

To calculate the total actual water requirement for same crop.
Water requirement \(\text{ETm} = \text{Kc, ETa}\)
\(\text{ETa} = C \times (W.Rs)\) 2006 climate data
\(C = 0.98, W = 0.76; Rs = 2.13\)
\(\text{ETa} = 0.98 [0.76 \times 2.13]; \text{Kc} = 0.76\) (Table 1b)
= 1.6mm/day

Water requirement \(\text{ETm} = 0.76 \times 1.6\)
= 1.3mm/period.

To indicate the months with moisture deficit for tomato
Moisture deficit is greater in yield formation than vegetative stage i.e. flowering > yield formation > vegetative moisture deficit for the month.

Crop Dev. Stage > mid season stage
Mid season stage > late season stage
Late season stage > initial stage

RESULTS AND DISCUSSION

Table 1a shows the meteorological data of Calabar in which daily reference crop evaporation ETa varied from 2.91 to 5.89 mm/day with a mean of 4.43 mm/day while the monthly ETa varied from 98.73 to 163.42 mm/month with a mean of 127.6 mm/month (Table 1b). The ETa values were higher in the drier months of January to April but lower in the wetter months of July and August. Similar results were reported by Chukwu (1999), Chukwu and Igbokwe (2001), Iren and Osodeke (2006).

The calculated monthly crop coefficient (Kc/month) values for the early season and late season tomato from the initial, crop development, mid and late season stages were the same (Table 2), and the reported trend is similar to earlier results (FAO, 1986; Messian, 1992) in which Kc values increased from a low value at time of crop emergence to a maximum value during the period when the crop reached full development, and then declines as the crop matures (FAO, 1986).

Crop evapotranspiration (ETcrop) refers to conditions when water is adequate for unrestricted growth and development.
Crop evapotranspiration (ETm or ETcrop) water determined as:

\(\text{ETcrop} = \text{ETa} \times \text{Kc} \ldots \tag{2} \)

The Kc value at each of the growth stages was calculated to monthly Kc as:

\(\text{Kc/month} = \frac{\text{Kc growth stage} \times N}{30} \ldots \tag{3} \)

Where \(N\) = number of days growth lasted in a month and each month was assumed to have 30 days.

Monthly crop evapotranspiration (ETcrop/months) was obtained as a product of ETa and Kc/month.
Seasonal ETcrop values were calculated by summing the monthly values.

To calculate actual evapotranspiration for each of the growth stages, apply:

\(\text{ETa} = \frac{S_a \times D}{t} \left[ 1 - \frac{\left(1 - P\right)e - \text{ETM} t + P}{S_a \times D} \right] \frac{1}{1 - p} \tag{3} \)

\(\text{ETa}\) is the actual evapotranspiration for the initial growth stage: 30 days parameters
\(\text{ETm} = 4.4\text{mm/day}\)
\(S_a = 140\text{mm}\)
\(T = 30\) days (initial stage)
\(P = 0.4\)
\(D = 0.7\)

For crop development stage 40 days
\(T = 40\) days
\(\text{ETa} = 140 (0.7) [20 - (4.4) 40 + 0.4]\)
40 \( (1-0.4) 140 (0.7) 1-0.4\)
= 2.45 [20 – 2.99 + 0.670]
= 43.32mm/day

For late season stage 25 days
\(T = 25\) days
\(\text{ETa} = 140 (0.7) [20 - 4.4 (25) + 0.4]\)
25 \( (1-0.4) 140 (0.7) 1-0.4\)
= 3.92 [20 – 1.9 + 0.67]
= 73.6mm/day.

The calculated monthly crop coefficient (Kc/month) values for the early season and late season tomato from the initial, crop development, mid and late season stages were the same (Table 2), and the reported trend is similar to earlier results (FAO, 1986; Messian, 1992) in which Kc values increased from a low value at time of crop emergence to a maximum value during the period when the crop reached full development, and thereafter declined when the crop matured. The highest Kc values were recorded in the month of May and June (0.83 and 0.98) for early season and October and November (0.83 and 0.98) for the late season tomato. Interestingly, these months coincided with the productive and maturity stages of growth in...
tomato and are found to be the most active growth stage (FAO, 1986; Phene, 1989, Thompson, 1996; Quinn, 2000). The result also showed that the water requirement for the late season tomato was 2.0% high than the early season tomato. Indeed, the effective rainfall tended to be higher than the water requirement for tomato throughout the growth period of the early season, indicating that water deficit will not be a problem for the good performance of the crop earlier in the season (Cobley and Steele, 1976; Noggle and Fritz, 1992; Reameakers, 2001). The results justified the selection of Calabar, Cross River State, Nigeria as an ideal place for the cultivation of tomato, for greater economic returns to the farmer.

CONCLUSION

The implication of these findings is that Calabar area of Southeast Nigeria crop water requirement ET\textsubscript{crop} for tomato would be higher during the late season than other periods. Water deficit is greater in yield formation later in the season than early in the season. The reproduction and maturity periods tended to be later in the season in which more rain was expected and higher moisture regime was attained.

| Months | Total Rainfall (mm) | Air Temp. (C) | Relative Humidity | Mean Total | Sunshine | Mean day | Mean night | U day |
|--------|---------------------|---------------|------------------|------------|----------|------------|------------|-------|
|        | Max | Min | Mean | Max | Min | Mean | wind | hours | wind | hours | wind | hours | wind |
| Jan.   | 49.4 | 36  | 21   | 28.5 | 67 | 42  | 54.5 | 84.53 | 5.8  | 18.14 | 5.36 | 4.88 |
| Feb.   | 3.8  | 38  | 23   | 30.5 | 78 | 48  | 63.0 | 96.68 | 6.5  | 18.18 | 9.38 | 9.34 |
| Mar.   | 47.6 | 35  | 24   | 29.5 | 89 | 79  | 84.0 | 112.51| 6.2  | 21.06 | 12.15| 2.85 |
| April  | 152.4| 34  | 25   | 29.5 | 90 | 73  | 81.5 | 124.22| 5.3  | 18.17 | 10.11| 3.66 |
| May    | 425.2| 32  | 24   | 28.0 | 94 | 76  | 85.0 | 118.15| 4.1  | 20.36 | 13.52| 2.52 |
| Jun.   | 191.6| 31  | 24   | 27.5 | 96 | 75  | 89.0 | 114.18| 3.3  | 18.25 | 12.10| 2.18 |
| Jul.   | 256.4| 29  | 24   | 26.5 | 95 | 84  | 90.5 | 121.25| 2.8  | 19.43 | 10.48| 2.03 |
| Aug.   | 510.1| 28  | 24   | 26.0 | 94 | 87  | 89.5 | 120.36| 3.4  | 19.74 | 9.37 | 1.98 |
| Sept.  | 518.9| 30  | 23   | 26.5 | 95 | 84  | 89.5 | 119.48| 3.7  | 18.05 | 8.92 | 2.93 |
| Oct.   | 525.8| 32  | 23   | 27.5 | 96 | 83  | 87.5 | 108.10| 4.8  | 17.55 | 9.71 | 2.58 |
| Nov.   | 32.4 | 33  | 23   | 28.0 | 94 | 81  | 98.19 | 8.5  | 16.32 | 8.24 | 2.96 |
| Dec.   | 36.2 | 33  | 23   | 28.0 | 93 | 72  | 82.5 | 94.47 | 7.8  | 17.24 | 9.02 | 2.95 |
| Total  | 2749.8| 3911.0| 281.0| 333.0 | 1081.0| 884.0 | 897.0 | 1309.41| 60.2 | 218.49 | 118.36| 40.46 |
| Mean   | 229.15| 32.58| 23.4| 28.0 | 90.08| 73.7 | 74.8 | 109.12| 5.0  | 18.20 | 9.86 | 3.37 |

Max = Maximum     Mix = Minimum

| Months | ET\textsubscript{o} mm/day | ET\textsubscript{o} mm/month |
|--------|-----------------------------|-----------------------------|
| Jan.   | 5.12                        | 141.13                      |
| Feb.   | 5.71                        | 138.17                      |
| Mar.   | 5.89                        | 162.42                      |
| April  | 4.47                        | 156.05                      |
| May    | 4.69                        | 149.35                      |
| Jun.   | 4.53                        | 114.71                      |
| Jul.   | 2.91                        | 98.34                       |
| Aug.   | 3.87                        | 98.73                       |
| Sept.  | 4.19                        | 102.51                      |
| Oct.   | 3.97                        | 119.01                      |
| Nov.   | 3.98                        | 129.30                      |
| Dec.   | 3.92                        | 121.14                      |
| Total  | 53.24                       | 153                         |
| Mean   | 4.43                        | 127.6                       |

ET\textsubscript{o} = Reference crop evapotranspiration.
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**Table 2: Monthly crop coefficient (Kc/month) for the early season and late season tomato**

| Months       | ETo (mm/month) | KC/month |
|--------------|----------------|----------|
| March        | 159.18         | 0.08     |
| April        | 137.43         | 0.72     |
| May          | 118.86         | 0.83     |
| June         | 99.74          | 0.98     |
| July         | 95.32          | 0.67     |

**LATE SEASON TOMATO**

| Months       | ETo (mm/month) | KC/month |
|--------------|----------------|----------|
| August       | 89.17          | 0.08     |
| September    | 98.10          | 0.72     |
| October      | 110.45         | 0.83     |
| November     | 121.63         | 0.98     |
| December     | 118.87         | 0.67     |

ETo = Reference crop evaporation, Kc = crop coefficient.

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