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DETERMINATION OF CROP COEFFICIENTS OF THREE VARIETIES OF TOMATOES

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Abstract
The careful planning of water use is of primary importance in any irrigation system, as water applied at wrong time or in excess of what is needed only become a waste and additional overall cost to farmers. The Crop coefficient and crop water use of three varieties of tomatoes (cherry, Roma and Jubilee) are determined in this study. Tomatoes was planted at the Demonstration farm of Kwara State Ministry of Agriculture and Natural Resources, Oyun, Ilorin, Kwara State, Nigeria between the months of December 2011 and April 2012. The crop water use was determined by water budget method while, the reference evapotranspiration was estimated using Blaney-Criddle model. The result shown that Cherry tomato among other varieties has the highest crop evapotranspiration with crop coefficient of 1.56. The mean monthly reference evapotranspiration value for the three varieties of tomatoes is 512.82mm/day. Therefore, accurate prediction of crop water use is the key to develop efficient irrigation management practices making it imperative to develop crop coefficient (K_c) for a specific crop.

Keywords: D*etermination, crop coefficient and varieties of tomatoes*

Introduction

All field crops need soil water, air and light (sunshine) to grow. The soil gives stability to the plants; it also stores the water and nutrients which the plants can take up through their roots. The sunlight provides the energy which is necessary for plant growth; the air allows the plants to breathe, without water crops cannot grow. Too much water is not good for many crops. If there is too much rainfall, the soil will be full of water and there will not be enough air. Excess water must be removed (Brouwer and Heibloem, 1986).

The primary reason for irrigating crop is to supplement available water from natural sources of water, such as rainfall, dew and groundwater which seeps into the root zone. Irrigation is needed in area where water from natural sources is adequate for crop production during part of the year or is sufficient in several years. The amount and timing of irrigation depends on several climatic, soils, and crop factors. The determination of crop coefficient (species factor) and evapotranspiration (E_a) are important for estimating irrigation water requirement in order to have better irrigation scheduling and water management (FAO, 2009).

To develop an effective irrigation management strategy, it is important to estimate crop water use and crop coefficient (K_c) which is essential for the estimation of water use. It helps in determining the water requirement of the crops according to their growth stages and environmental factors. If crop coefficient (K_c) is known for a given crop, then crop evapotranspiration (ET_c), can be calculated from Reference Evapotranspiration (ET_o). Studies have found that crop coefficient (K_c) for the same crop may vary from place to place based on factors such as climate and soil evaporation. Kang *et al*, (2003), emphasized the need to develop regional crop coefficient (K_c) for accurate estimation of water use under specific climate condition.

This study is therefore focused on the determination of crop coefficients and water requirement of three varieties of tomatoes for optimum planning of irrigation systems and management in the study area.

Evapotranspiration (ET)

Evaporation and transpiration are the two most important processes governing removal of water from the land and plant stomata into the atmosphere in vapour form. These processes occur simultaneously and are hard to distinguish from each other (Allen *et al.*, 1998).

Reference Evapotranspiration (ET_o)

According to Allen *et al.,* (1998), reference evapotranspiration (ET_o) can be defined as the rate of evaporation form an hypothetical reference crop with an assured crop height of 0.12m, a fixed surface resistance of 70sec/m and an albedo of 0.23 closely resembling the evapotranspiration from an extensive surface of green grass of uniform height, actively growing well, watered and completely shading the ground (Shukla *et al.,* 2007).

In this research Blaney-Criddle model was used to compute reference evapotranspiration;

$$ETo = P\ (0.46\ Tmean + 8) \qquad (1)$$

Where;

ET_o = reference evapotranspiration, mm/day

T_{mean} = mean daily temperature, ^0C

P = mean daily percentage of total annual day time hours.

Source: Michael, 1978.

The mean daily percentage (p) of annual day time hours for the latitude of Ilorin, the study area ($8^0$19' N) is given in table 1.

Table 1: Mean daily percentage (P) of annual day time hours for the study area

Month	P	Month	P
January	0.25	July	0.30
February	0.26	August	0.29
March	0.27	September	0.28
April	0.28	October	0.26
May	0.29	November	0.25
June	0.30	December	0.25

Sources: Brouwer and Heibloem, (1986)

Table 2 shows the mean monthly temperature of the study area used along with Blaney-Criddle equation to obtain reference evapotranspiration.

Table 2: Mean monthly temperature (T_{mean}) of the study area (1993-2002)

Month	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Dec	30.25	25.75	29.4	30.00	29.1	29.35	29.42	30.50	29.40	30.50
Jan	34.00	29.75	28.7	27.80	31.7	31.5	30.4	30.25	30.35	30.40
Feb	32.53	31.29	31.60	32.85	30.25	32.65	30.68	30.25	31.40	32.45
Mar	32.oo	32.54	32.10	32.85	31.6	31.55	31.28	33.8	32.55	31.60
Apr	29.75	31.75	31.7	29.40	30.4	31.75	30.27	31.5	29.80	30.50

Source: NCAM, 2012

Crop Evapotranspiration (ET_c)

The actual crop water use depends on climatic factors, crop type and crop growth stage while reference evapotranspiration(ET_o) provides the climate influence on crop water use, the effects of crop type and management is addressed by crop evapotranspiration (ET_c). Factor affecting crop evapotranspiration (ET_c) such as ground cover, canopy properties and aerodynamic resistance for crop are different from the factors affecting reference crop (grass or alfalfa). The characteristics that distinguish field crops from the reference crop are integrated into crop factor or crop coefficient (K_c) (Allen *et al.,* (1998).

Crop coefficient was used to determine the actual water use for crop in conjunction with reference evapotranspiration (ET_o) as given in equation 2.

$$ETc = Kc\ x\ ETo \qquad (2)$$

Where,

ET_c = Crop Evapotranspiration (mm/day)

K_c = Crop Coefficient

ET_o = Reference Evapotranspiration (mm/day)

Source: Shukla *et al.,* 2007.

Crop Coefficient

Doorenbos and Pruitt (1977) prepared a comprehensive list of crop coefficient (K_c) for various crops under different climatic conditions by compiling results from different studies. However crop coefficient (K_c) for crop may vary from one place to another, depending on factors such as climate, soil, crop type, crop variety and irrigation methods. Researchers have emphasized the need for regional calibration of crop coefficient (K_c) under a given, climatic conditions (Kang *et al.,* 2003).

Growth Stages of Tomatoes

The various growth stages of tomatoes with stage lengths are presented in the table 3

Table 3: Growth stages of tomatoes

Stage	Development Stage	Stage Length, Days
0	Establishment	25-35
1	Vegetative	20-25
2	Flowering	20-30
3	Yield formation	20-30
4	Ripening	15-20
Total		**100 – 140 days**

Source: (FAO, 2009)

Varieties of Tomatoes

There are many varieties of tomatoes, but varieties considered in this study are:

(1) Cherry Tomato: Cherry tomato is a small variety of tomato that has been cultivated since at least the early 1800s and though to have originated in Peru and Northern Chile. Cherry tomato ranges in size of a golf ball, and can range from being spherical to slightly oblong in shape.

(2) Roma Tomato: The tomato is a meaty, egg or pears-shapes tomato that is available in red and yellow. It has few seeds and is a good canning and Sauce tomato. Roma tomatoes are also known as Italian tomatoes, or Italian plum tomatoes. Roma tomatoes are grown in the United State, Mexico Australia, and Great Britain.

(3) Jubilee Tomatoes: This vigorous growing variety produces a big crop with little space and effort. The delicious fruit are excellent for Salads canning, juice and less acidic than the red tomatoes. This variety grows to 5 to 6 feet high and the highest quality fruits will be produced on plants that are staked and pruned. This tomato is a tropical origin and likes warm weather.

Cultural Practice of Tomatoes

The following are among the cultural practices of tomato production:

(1) Nutrient Management: Tomato Plant should be fertilized with organic (animal manure and/or chemical fertilizer to produce high yields (Hansan *et al.,* 2001).

(2) Water Management: Tomato is more sensitive immediately after transplanting and during fruit development and least sensitive during vegetative growth because indeterminate varieties flower and form fruit continuously; they are always sensitive to water deficits. The water requirement for maximum production of tomatoes varies between 400-800mm/season depending on climate and length of growing period (Brouwer and Heibloem, 1986).

(3) Staking: Staking of tomatoes plant with bamboo poles, wood stakes, or other material provides support and keeps the fruit and foliage off the ground. Staking can increase fruit yield and size, reduce fruit rot, and ease spraying and harvesting (Hansan, *et al.,* 2001).

(4) Pruning: Pruning improves air circulation within the canopy, which reduces foliar diseases, and facilitates spraying and harvesting. Indeterminate varieties should always be pruned so that they do not produce too much vegetative growth (Hansan *et al.,* 2001).

Location of the Study Area

The study area lies between latitude 8^0 to 30^0N and longitude 4^0 to 35^0 E. It is a transitional zone between the climate of southern Nigeria and the semi and Sudan savanna of the northern Nigeria part of the country. The experiment was conducted at demonstration farm of the Kwara State Ministry of Agriculture and Natural Resources at Oyun, Ilorin, Kwara State, Nigeria.

Field Preparation and Layout

A land of 5m x 4.5m was ploughed, harrowed and divided into six blocks laid along the general slope of the field in order to ensure as much homogenous soil condition as possible. Each block was divided in to 2 rows basins, the basins were 0.3m apart and each row of basins was irrigated.

Physical and Chemical Properties of the Experimental Soil

Soil samples were taken in each row basin at 0-10 cm and 10-20cm depths using soil auger. These soil samples were taken to the laboratory for both physical and chemical properties analyses and the results were shown in table 4 and 5, respectively.

Table 4: Physical properties of the experimental soil

Depth (cm)	Field Capacity (%)	Bulk density (g/cm^3)	Clay (%)	Silt (%)	Sand (%)	Texture class
0-10	30. 31	1. 91	6	20	74	Loamy sand
10-20	26-21	1-79	10	18	72	Loamy sand

Table 5: Chemical properties of the experimental soil

Parameter	0- 10cm	10-20cm
P^H m. water	6. 3	5. 6
%Potassium Chloride	5. 1	4. 6
% organize carbon	0. 81	1. 39
% total Nitrogen	1. 96	3. 38
Available (phosphorus ppm)	0. 68	0. 67
EXCHANGEABLE BASES (mol kg-1) of soil:		
Ca++(cgnol kg- i)	0. 66	0. 99
Mg++(cmol kg-1)	0. 19	0. 19
K+ (cmol kg-1)	1. 56	1. 65
Na+(cmol g-1)	0. 04	0.06
Exchange bale acidity CEC (%)	6. 80	8. 20

The basins were seeded of the three varieties of tomatoes (cherry, Roma and Jubilee) on the 20th December, 2011, by broadcasting method. A pre-planting irrigation was done two day before planting, to give a wet soil regime and enhanced seed germination. After three week of planting, tomato plants were transplanted to the experiment plot. After 26 days of transplanting, weeding operation was done and thereafter, no weed was found growing within the basin for some weeks. Fertilizer was applied (urea) four weeks after transplanting and chemical (Insecticide) was applied to prevent nematodes and also poultry waste was applied in order to increase the growth of the tomatoes. Table 6 showed the growth stages and length of growth stages of tomato plants in the study area.

Table 6: The description of growth stages and length of growth stages

S/N	Growth stage	Length of growth stages (day)
1.	Germination and seeding	10days
2.	Established(inures)	25days
3.	Vegetative	30- 25days
4.	Flowering	65days
5.	Yield formation	95days
6.	Ripening	111days

Irrigation Method and Water Application

Irrigation was by basin method in which a basin to be irrigated was open at a point by breaking the basin embankment and water was allowed in until the basin was adequately ponded, after which the basin was closed by replacing the soil taken out of the embankment.

Soil Moisture Determination

Soil moisture was measured during the irrigation season for each treatment by collecting soil samples for soil moisture determination two days after irrigation and just before the next irrigation. Soil samples were collected from a soil depth of 0-20cm at an incremental depth of 20cm in two replications for each treatment using an auger and the samples were oven dried at 900C for 24hours to determine the soil moisture content. The different in moisture content between the two sampling periods was regarded as the moisture use (evapotranspiration) by the crop for that period in line with the water budget method; it was assumed that drainage was negligible after the soil has attained the field capacity.

Net Irrigation Requirement

The soil in the study area is sandy loam from the textural classification chart. The net irrigation requirement for the available water capacity for sandy loam soil was taken to be 1.2mm/cm of soil water in accordance with table 7, which was then multiplied by 20cm the depth of soil layer to get 24mm. The ranges in available water capacity and intake rate for various soil textures are presented in table 7.

Table 7: Available water capacity for various soil textures

Soil texture	Available Water capacity (mm) of water/cm of soil	Intake Rate (mm/hr)
Sands	0.5-0.8	12 - 20
Loam sand	0.7-1.0	7 - 12
Sandy loam	0.9 - 1.3	7 - 12
Loam	1.3- 1.7	7 -12
Sandy loam	1.4 - 1.7	4 - 7
Sandy clay loam	1.5 - 1.8	4 - 7
Clay loam	1.5 - 1.8	4 - 7
Clay	1.5 -1.7	2 – 5

Source: Tan, 1990.

Gross Irrigation Requirement (GIR)

The gross irrigation requirement was obtained by dividing the net irrigation requirement by irrigation system efficiency (E). The efficiency for a basin system in a sandy loam soil is 65% (Sharma and Sharma, 2007). Thus;

$$GIR = \frac{24}{65}\, x\, 100 \ = 36.9\text{mm}$$

Area of each basin = 2 x 1 = 2 m^2

GIR for each basin = Area of each basin x net depth of irrigation

= 2 x 36.9 = 74mm

= 2 *x* 1 *x* 36.9/100

= 0.27 m^3 (For 100% of ET) = 270 liters

Required duration of irrigation = 270/24 =11.25 sec*ond*

2.9 Determination of Crop Coefficient

The crop coefficient was determined for each of the three varieties of tomatoes as a ratio of crop evapotranspiration (ET_c) to reference evapotranspiration (ET_o). Thus;

$$Kc = \frac{\text{ETc}}{\text{ETo}}$$

(5) **Results and discussion**

The results of the analyses were presented as follows:

Result of Reference Evapotranspiration (ET_o)

The results of reference evapotranspiration of tomatoes were shown in table 8.

Table 8: Reference evapotranspiration of tomatoes

Month	T mean	P	ET_o (mm/day)	No of days with crop/month	Total ET_o/month (mm)
Dec.	28.87	0.25	5.31	-	-
Jan.	30.49	0.25	5.05	9	49.50
Feb.	31.60	0.26	5.86	29	169.94
March	32.19	0.27	6.16	31	190.96
April	30-68	0.28	6.19	18	111.42

Table 8 shows the result of references evapotranspiration (ET_o) of the three varieties of tomatoes. From the result, it is revealed that there was no reference evapotranspiration (ET_o) value in the month of December because the crops were in the nursery stage and no measurement was taken. The results also revealed that highest reference evapotranspiration (ET_o) occurred in the month of March with the value of 190.96mm which is the flowering stage. This stage corresponds to the growth stage in which an adequate water use for tomato is most critical (Singh, 2010).

Results of Crop Evapotranspiration (ET_c)

The results of crop evapotranspiration (ET_c) of the three varieties of tomatoes were presented in table 9. The results shown that Cherry has the highest value of crop evapotranspiration (ET_c) while, the Jubilee has the lowest value of crop evapotranspiration (ET_c) in the study.

Table 9: Crop evapotranspiration (ET_c) measured on the experimental plots of the three varieties of tomatoes

Growth stage	I	II	III and IV	Seasonal ET(mm)
Treatment	Days After	Planting (mm)		
	24-47	48-74	75-111	24-111
C_1	279.2	357.2	179.7	816.1
C_2	257.7	344.9	172.6	816.1
R_1	230.5	317.5	175.8	775.2
R_2	227.9	302.4	168.1	698-8
J_1	212.3	260.7	144.2	617.0
J_2	226-9	244-6	136-6	608-10

C = Cherry Tomatoes, R = Roma Tomatoes, J= Jubilee Tomatoes

Tomatoes Yield Obtained from the Experimental Plot

Table 10: Yield result of the three varieties of tomatoes

Treatment	ET_c (mm/day)	Yield (g) m^2 A	Yield (g/m^2)	Yield (t/ha)
C_1	816.1	1201	600.5	6.01
C_2	775.2	1106	553.0	5.53
R_1	723.8	1011	505.5	5.06
R_2	698.4	975	487.5	4.88
J_1	617.20	847	423.5	4.24
J_2	608.10	862	431.0	4.31

The result shown that cherry tomato had the highest yield valves while jubilee tomatoes had the lowest yield values.

Crop Yield, Crop Evapotranspiration (ET_c) and Reference Evapotranspiration (ET_o)

Results of crop yield of the three varieties, crop evapotranspiration (ET_c) and reference evapotranspiration (ET_o) were presented in table 11
.

Table 11: Crop yield, crop evapotranspiration (ET_c) and reference evapotranspiration (ET_o)

Treatment	ET_o (mm/day)	ET_c (mm/day)	Yield (t/ha)
C_1	521.82	816.1	6. 01
C_2	521.82	775.2	5.5.3
R_1	521.82	723.8	5.06
R_2	521.82	698.4	4.88
J_1	521.82	617.20	4.24
J_2	521.82	608.10	4.31

The results revealed that there is a difference between the crop evapotranspiration (Water budget method) and reference evapotranspiration (Blaney-Criddle method).

Crop Coefficients of Three Varieties of Tomatoes

The crop coefficients of the three varieties of tomatoes as determined were presented in table 12.

Table 12: Crop coefficients (K_c) of the three varieties of tomatoes

Treatment	ET_c (mm/day)	ET_o (mm/day)	K_c
C_1	816.1	521.82	1.56
C_2	775.2	521.82	1.49
R_1	723.8	521.82	1.39
R_2	698.4	521.82	1.34
J_1	617.20	521.82	1.18
J_2	608.10	521.82	1.17

Conclusions

The study was carried out from December to April 3, 2012 on a field located at the demonstration farm of Kwara State Ministry of Agriculture and Natural Resources, Ilorin, Nigeria to determine of crop coefficient of three varieties of tomatoes (Cherry, Roma and Jubilee). The result showed that Cherry had the highest value of crop evapotranspiration (ET_c) while the Jubilee has the lowest value of crop evapotranspiration (ET_c). The result also showed that tomatoes crop would need more water during the flowering stage.

Recommendations

It is recommended for farmers intending to grow tomato that before planting seeds on the seed beds, the seed should be spread evenly and foreign particles should be removed. Also the seed should be treated and Apron is recommended in order to reduce soil borne disease and pest.

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