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Effects of drip irrigation frequency and depth on soil hydro-physical properties of a tomato field

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ABSTRACT: *A major challenge facing vegetable crop production globally is water scarcity. There is need to encourage tomato production in the Southern parts of Nigeria, particularly during the period of scarcity to bridge the production deficit gap, increase availability and improve the supply, the main objective of this study is to determine effect of irrigation frequency and depth of a tomato field on soil hydro-physical properties. The study was conducted at the drip irrigation research plot of Agricultural Engineering Department of Ladoke Akintola University of Technology, Ogbomoso, Nigeria. The experiment was a two factor experiment. The factors were frequency of water application [7 days (F_1), 5 days (F_2) and 3 days (F_3)], as the main plot and depth of application as subplots. The depth of application was taken as 100, 75 and 50% of the crop water need (ETc) designated as D_1, D_2 and D_3 respectively. The experimental layout is a randomized complete block design (RCBD) with three replicates. Thus, the experiment was arranged in a 3 x 3 x 3 experiment with an area of each plot being $4m^2$.*

KEYWORDS: *irrigation frequency and depth, soil hydro-physical properties, tomato field*

I. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is one of the most important vegetables grown in the world, and it's cultivated in both tropic and temperate zones for fresh and processed products (Opiyo and Ying, 2005). The general popularity and health benefits associated with this vegetable crop make it one of the most commercially viable of all agricultural commodities (Agarwal and Rao, 2000)). Tomatoes are consumed fresh, cooked or processed into various products and it is composed mainly of water (approximately 90%), soluble and insoluble solids (5-7%), citric and other organic acids, and vitamins and minerals (Pedro and Ferreira, 2007). Ripe tomatoes are also known to have a high content of the antioxidant lycopene and carotene, which plays important roles in the prevention of certain forms of cancer (Agarwal and Rao, 2000; Pedro and Ferreira, 2007). Cultivation of this high yielding, short duration crop is increasing worldwide. It is grown in different parts of the world where the annual rainfall ranges between 300- 600mm (Schwab *et al.*, 1993). Approximately 160 million tons of tomato is produced annually on 4.7 million hectares (FAOSTAT, 2011). However, earlier reports (Okunoya, 1996 and FAO, 2008) indicated that Africa produces about 79% of the total world production of tomato, and Egypt is the leading producer of the crop with an annual production of (1.51 million metric tons with a cultivated area of 254, 430 hectares per annum) which amount to about 65% of the total world production while Nigeria features as the second to Egypt in terms of production with 0.25 million metric tons per annum. In Nigeria, almost all the parts of the country produce tomato but it is predominantly produced in the North, particularly during the dry season via irrigation (Ramalan, 1994). Observably during the months of November to March, tomato is very scarce in the Southwestern parts of the country and the product has to be transported from the North. However, due to long distance and its high perish ability, the products become very scarce and expensive (Okunoya, 1996). Despite the importance of tomato in the nutrition of people, its production is very low as most farmers depend mainly on natural fertility of the soil and in addition invest considerable labour in land preparation and weed control, so as to achieve a reasonable yield. This is in contrast to the situation in developed countries where considerable inputs such as fertilizers, pesticides and irrigation are used (Akemo *et al.,* 2000). A major challenge facing agricultural production globally which also serves as the main causes of shortage of tomato and other vegetable crops production is water scarcity. This is a critical constraint to farming in many parts of the world. With regards to agriculture, the World Bank targets food production and irrigation water management as an increasing global issue that is fostering a growing debate. It was stated that arid regions frequently suffer from physical water scarcity and this occurs where water seems abundant but where resources are over- committed. This can happen where there is over development of hydraulic infrastructure, usually for irrigation (Broner and Schneekloth 2003). The physical water scarcity and economic scarcity according to

Broner and Schneekloth, (2003), is usually caused by an environmental degradation, declining of groundwater and by a lack of investment in water or insufficient human capacity to satisfy the demand for its use. Therefore, there is need to encourage tomato production in the Southern parts of Nigeria, particularly during the period of scarcity to bridge the production deficit gap, increase availability and improve the supply.

II. MATERIALS AND METHODS

2.1 Materials

The materials used for the research include soil core samplers, hand trowel, sieve mesh, pressure plates, core cutter, digital weighing balance, constant head permeameter, metal cylinders, flexible measuring tape, vernier caliper, AccuPAR LP-80 ceptometer and digital camera.

2.2 Description of the Study Areas

The study area is the drip irrigation research plot of Agricultural Engineering Department of Ladoke Akintola University of Technology, Ogbomoso. Ogbomoso lies between Longitudes $4^o\ 10^1$ and 4^o14^1 E of the Greenwich Meridian and Latitudes $8^o\ 08^1$ and $10^o\ 10^1$N of the Equator. The climatic condition of Ogbomoso is mostly influenced by the North east and southwest trade wind with a maximum temperature of 33^oC and a minimum temperature of 28^oC. It is sometimes cold with drying effect which normally starts from November to March while the later is warm and very moist which is between the months of April and October (Olaniyi *et al.*, 2009). The relative humidity of this area is about 74% all year round except in the month of December to February where relative humidity is low when the dry wind blows from the north Olaniyi (2009). The average annual rainfall is about 1000 mm. The soil type is general broad alfisol. The soil in this area had been used in the past for maize cropping and later lies fallow until the period it is used for this experiment and that makes the soil to be highly rich in organic contents.

2.3 Experimental Design, Plot Layout and Management

The experiment was a two factor experiment. The factors were frequency of water application [7 days (F_1), 5 days (F_2) and 3 days (F_3)] and depth of application (100, 75 and 50% of the crop water need (ETc) designated as D_1, D_2 and D_3 respectively). The experimental layout is a randomized complete block design (RCBD) with three replicates. Thus, the experiment was arranged in a 3x3x3 experiment with an area of each plot being $4m^2$ as shown in Figure 3.1.

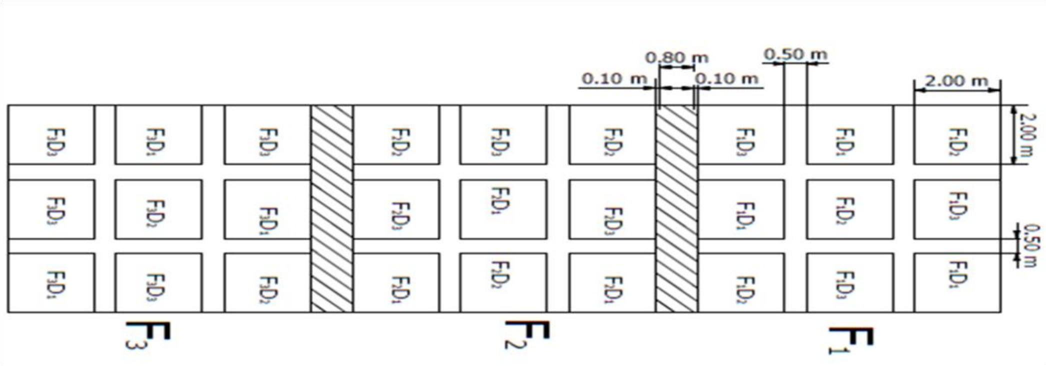

Figure 3.1: Experimental Field Layout of Irrigation Scheduling According to Frequencies and Depth of Applications

2.4 Irrigation Scheduling

The irrigation scheduling was determined as a function of ET_c. Three depths of application (D_1, D_2 and D_3) were used as 100% ET_c, 75% ET_c and 50% ET_c (ET_c, 0.75 ET_c and $0.5ET_c$). Three frequencies (F_1, F_2 and F_3) were used at every 7, 5, and 3 days respectively. The depths of application and frequencies were arranged according to 3 x 3 x 3 RCBD. The volume of application for the desired depth was determined by multiplying the depth by the crop area as

$$a_v = d_i \times a_c \quad (1)$$

Where: a_v is the volume of application (m^3 or L), d_i is the irrigation depth (m) and a_c is the crop area (m^2)

The drippers were calibrated to have a discharge $4L/h$. The time required for applying the desired volume was calculated using the relation

$$t = \frac{a_v}{d} \quad (2)$$

Where: t is the time required (hr), d is the discharge (L/hr)

Each sub-plot is 2 x 2 square meters which contained 15 stands of tomato at 0.5m spacing within row and 1m between rows. The three main plots were separated from the other by a space of 1 m. It is located in the savanna zone of area 187.5 m^2. Weeding of the plots was done manually at four (4) weeks interval. The first weeding was done four weeks after transplanting (WATP). Fertilizer application was done according to the standard recommended dosage for tomato using N.P.K (15-15-15) at the rate of 10g/0.26m^2 at the crop initial stage growth.

2.5 Preliminary Soil Investigation

Undisturbed and disturbed soil samples were collected from two alternating edges of the experimental site. The undisturbed samples were collected by digging soil profile of about 1x1x1m at the two edges. Soil core samplers of diameter 58 mm and height 40 mm was used to collect the samples at the depths of 0-5, 5-10, 10-20 and 20-30cm. The collected samples were kept in separate black polythene bags to prevent moisture loss before transporting to the laboratory. Disturbed samples were collected at the same depths with the aid of a hand trowel. The samples was air-dried at 105^{o}C for 48 hours and sieved with a 2 mm sieve mesh.
out the experiment are as detailed below.

2.6 Planting of tomato

Tomato seeds were planted on a nursery bed. The seedling was nursed for about four weeks after they were transplanted to the field. The seedlings were planted at a spacing of 0.5m within row and 1m between rows. This implies that each 2 x 2 m sub–plot had 15 tomato stands. Each tomato stands occupied an average area of 0.33 m^2.

2.7 Determination of Soil Hydro-physical Properties

The initial soil hydro-physical properties of the experimental site were determined. The undisturbed soil samples was used to determine the soil field capacity (FC) and permanent wilting point (PWP) using pressure plates. The FC and PWP was used to calculate the soil available water (AW) as

$$AW = FC - PWP. \quad (3)$$

The physical properties that were determined from the undisturbed soil samples include; Bulk density, saturated hydraulic conductivity, total porosity, macro-porosity, micro-porosity, field capacity, permanent wilting point, available water, soil organic carbon and water holding capacity.

i. Bulk Density (BD): The bulk density of the soil was calculated by determining the mass of soil and volume of core cutter. The soil samples were collected from the field at different locations after which the samples collected was transferred to the laboratory in order to know the weight of the soil and core cutter using a digital weighing balance (0.001g).

The bulk density (ρ_b), given by the equation

$$\rho_b = \frac{M_s}{V_t} \quad (4)$$

Where: ρ_b is the bulk density, (gcm^{-3}), M_s is the mass of soil (g), V_t is the total soil volume (cm^3)

ii. Saturated Hydraulic Conductivity (Ksat): The saturated hydraulic conductivity (K_{sat}) was determined using the constant–head permeameter, using undisturbed soil samples collected in metal cylinders after saturation by capillary in a water bath for 48 hours. The determination of K_{sat} was performed by collecting and measuring the amount of water that percolates through the soil sample under a constant hydraulic head of 3cm in water column according to methodology described by Pedro and Ferreira (2007). From the data, K_{sat} was calculated according to the equation:

$$k_{sat} = \frac{Q.L}{A.H.t} \quad (5)$$

Where: K_{sat} is the hydraulic conductivity in (cm/hr), Q is the volume of water that flow through the soil column in a given time (cm^3), L is the length of the soil column (cm), H is the water head above the soil column (cm), A is the area of soil column (cm^2) and t is the time (hr).

iii. Total Porosity, Macro-porosity and Micro-porosity (Pt, Ma and Mi): the total porosity (P_t) corresponds to the volumetric water content at saturation; micro-porosity (M_i) is the volumetric water content at 6 kP_a water tension while macro-porosity (M_a) is the difference between the total porosity and micro-porosity

$M_a = P_t - M_i$ (6)

iv. Field Capacity, Permanent Wilting Point and Available Water (Fc, PWP and AW): the field capacity was determined and the water content at FC corresponds to the volumetric water content - at 10 kP_a water tensions while the permanent wilting point is the moisture content at 1500 kP_a and the available water was determined by finding the difference between the FC and the PWP.

The available water (AW) in each soil layer was computed as:

$$AW = FC - PWP \quad (7)$$

Where: *FC* is the moisture content at field capacity, ($cm^3\ cm^{-3}$), *PWP* is the moisture content at permanent wilting point ($cm^3\ cm^{-3}$).

v. Water Holding Capacity: the water holding capacity for each soil depth was computed as:

$$WHC = (FC - PWP) * d_i = AW * d_i \quad (8)$$

Where: WHC is the water holding capacity (mm), d_i is the soil depth of i^{th} *layer* (mm),
For each treatment, water holding capacity is given as

$$WHC_t = \sum_{i=1}^{n} WHC_i \quad (10)$$

Where: WHC_t is the the total water holding capacity for a given treatment, WHC_i is the available water in a particular soil layer, *i* is a given soil layer.

III. RESULTS AND DISCUSSIONS

The effect of drip irrigation frequencies and water regimes on soil hydro-physical conditions, growth and yield of tomato was investigated. The results obtained are presented in subsequent sections

Soil Hydro-physical Properties

The hydro-physical properties of the soil determined include saturated hydraulic conductivity (Ksat), bulk density (BD), total porosity (Pt), macro-porosity (Ma), micro-porosity (Mi), field capacity (Fc), permanent wilting point (PWP) and available water (Aw). The correlation between these hydro-physical properties of the soil at 0-5, 5-10, 10-20, 20-30, and 0 -30 cm surface layer of tomato drip irrigated field is presented in Tables 1 - 5 respectively.

Table 4.1: Correlation between the soil physical properties of the 0-5 cm surface layer of the tomato drip irrigated field.

	Ksat	BD	Pt	Mi	Ma	FC	PWP	AW
Ksat	1							
BD	-0.04	1.00						
Pt	-0.16	-0.54**	1.00					
Mi	0.00	0.02	0.17	1.00				
Ma	-0.14	-0.49**	0.77**	-0.50**	1.00			
FC	-0.06	0.19	0.10	0.85**	-0.46*	1.00		
PWP	-0.21	0.17	-0.13	0.67**	-0.55**	0.78**	1.00	
AW	0.25	-0.02	0.35	0.06	0.27	0.07	-0.57**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.2: Correlation between the soil physical properties of the 5-10 cm surface layer of the tomato drip irrigated field.

	Ksat	BD	Pt	Mi	Ma	FC	PWP	AW
Ksat	1							
BD	-0.137	1						
Pt	-0.157	0.074	1					
Mi	0.130	-0.032	0.131	1				
Ma	-0.177	0.080	0.989**	-0.017	1			
FC	-0.039	-0.050	0.037	0.784**	-0.080	1		
PWP	-0.035	0.236	0.162	0.709**	0.057	0.495**	1	
AW	-0.002	-0.288	-0.129	0.040	-0.136	0.467*	-0.537**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.3: Correlation between the soil physical properties of 10-20 cm surface layer of the tomato drip irrigated field.

	Ksat	BD	Pt	Mi	Ma	FC	PWP	AW
Ksat	1							
BD	-0.644**	1						
Pt	0.092	0.184	1					
Mi	0.221	0.007	0.674**	1				
Ma	-0.130	0.233	0.544**	-0.253	1			
FC	-0.187	0.317	0.620**	0.860**	-0.165	1		
PWP	-0.025	0.053	-0.053	0.241	-0.342	0.346	1	
AW	0.011	-0.053	0.034	-0.270	0.350	-0.357	-0.989**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.4: Correlation between the soil physical properties of the 20-30 cm surface layer of the tomato drip irrigated field.

	Ksat	BD	Pt	Mi	Ma	FC	PWP	AW
Ksat	1							
BD	0.032	1						
Pt	-0.191	0.190	1					
Mi	-0.048	-0.155	-0.040	1				
Ma	-0.041	0.219	0.473*	-0.899**	1			
FC	0.072	0.086	0.265	0.267	-0.120	1		
PWP	0.404*	0.184	0.179	-0.223	0.275	0.178	1	
AW	-0.090	-0.262	-0.370	0.081	-0.233	-0.160	-0.577**	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.5: Correlation between the soil physical properties of the 0-30 cm surface layer of the tomato drip irrigated field.

	Ksat	BD	Pt	Mi	Ma	FC	PWP	AW
Ksat	1							
BD	-0.328**	1						
Pt	-0.029	-0.016	1					
Mi	0.019	-0.061	0.031	1				
Ma	-0.035	0.025	0.778**	-0.604**	1			
FC	-0.064	-0.032	0.189	0.297**	-0.036	1		
PWP	0.003	0.004	0.136	0.011	0.102	0.504**	1	
AW	-0.030	0.184	-0.179	0.024	-0.158	-0.351**	-0.668**	1

**. Correlation is significant at the 0.01 level (2-tailed).

IV. CONCLUSIONS AND RECOMMENDATIONS

The effect of irrigation frequency and depth on soil hydro-physical properties of a tomato field was determined, it was obtained that irrigation frequency and regimes have significant effects on the hydro-physical properties of the soil including water holding capacity, saturated hydraulic conductivity, bulk density, total porosity, macro-porosity, micro-porosity, field capacity, permanent wilting point and available water (Aw)

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