YIELD AND WATER PRODUCTIVITY OF TOMATO UNDER FULL AND DEFICIT IRRIGATION IN NORTHERN NIGERIA

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ABSTRACT

The study was conducted using two field experiments at the Institute for Agricultural Research (IAR) irrigation site, Kadawa, Kano State, Nigeria during the 2016/2017 and 2018/2019 irrigation season. The main aim of the study is to determine yield and water-use responses of tomato (UC 82B) crop to full and Deficit Irrigation Practice (DIP) and also to determine the optimum crop water requirement of tomato in Sudan Savannah agro-ecological zone of Nigeria. The experiment consisted of nine irrigation treatments and was carried out using a Randomized Complete Block Design (RCBD) with three replications. Furrow irrigation method was employed for water application. The treatments were based on water application regulated at selected crop growth stages. The growth stages were Initial (I), Development (D), Middle (M) and Late (L) and the irrigation deficit level were 0, 25 and 50%. The treatments were T1 ($I_{100}D_{100}M_{100}L_{100}$), T2 ($I_{100}D_{50}M_{100}L_{100}$), T3 ($I_{100}D_{100}M_{50}L_{100}$), T4 ($I_{100}D_{100}M_{100}L_{50}$), T5 ($I_{100}D_{75}M_{100}L_{100}$), T6 ($I_{100}D_{100}M_{75}L_{100}$), T7 ($I_{100}D_{100}M_{100}L_{75}$), T8 ($I_{100}D_{50}M_{50}L_{50}$) and T9 ($I_{100}D_{75}M_{75}L_{75}$). The result from the two experiments showed that the yield of tomato is significantly affected by water stress. The mean fresh tomato yield varied from 72.52 t/ha to 40.81 t/ha. The highest mean yield of 72.52 t/ha was obtained in the control treatment T1 ($I_{100}D_{100}M_{100}L_{100}$) which was subjected to full irrigation, whereas the least mean yield of 40.81 t/ha was obtained in the fully stressed treatment T8 ($I_{100}D_{50}M_{50}L_{50}$). The development- and middle growth- stages of tomato crop were highly sensitive to water stress particularly at 50% deficit level (DL), while late growth-stage of the crop was less sensitive to water stress particularly at both 50% and 25% DL. Imposing DL of 25% at development growth-stage resulted in yield reduction of 7%, while imposing DL of 50% at the three (development, middle and late) growth-stage of tomato resulted in yield reduction of 44%. The optimum seasonal water requirement for tomato crop in Sudan Savannah agro-ecological zone of Nigeria was 554 mm. Also, for optimum yield and irrigation water productivity of tomato crop under DIP, imposition of 25% deficit level in the late growth-stage was recommended.

KEYWORDS: Tomato yield, Water productivity, Deficit irrigation

1. INTRODUCTION

Rapid population growth, climate change, increasing water demand, rapid siltation of reservoirs, over-exploitation of natural resources and environmental degradation have significantly degraded the world's freshwater resources (IPCC, 2007). According to Ngigi, (2009) the number of countries in Sub-Saharan Africa (SSA) where water demands outstrip available resources is increasing and many African countries are experiencing either water stress (less than 1,700 m^3 per capita per annum) or water scarcity (less than 1,000 m^3 per capita per annum). Moreover, food insecurity remains endemic in most parts of Africa. Currently, the outlook for food security in many developing countries including Nigeria is a cause for serious concern. According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007), agriculture would be affected by reducing growing seasons and higher temperatures and thus, higher crop water need. The IPCC predicted that rain-fed crop yields in some countries would decrease by 50%, and that an estimated 50 – 250 million Africans could face increased water stress from the year 2020. With only about 6% of African crop lands and about 8% of Nigeria Arable land irrigated (Oriola, 2009); the impacts of climate change on smallholder farmers could be catastrophic. Climate change could lead to shortage of water availability for irrigation. Therefore, there is need for strategies for effective utilization of limited available water for irrigation to ensure food security in the country.

Scientific water management strategy to enhance water productivity is gaining importance in arid and semi-arid regions (Debaeke and Aboudrare, 2004). Over the past two decades, agricultural research has focussed on maximizing total production. But, in recent, the focus has shifted to the limiting factors in production systems, notably the availability of either land or water. Where water is the limiting factor in crop production, deficit irrigation (DI) has been widely investigated as a viable coping strategy (Pereira, 2006; Fereres and Soriano, 2007). Several researches around the world have shown that irrigation strategies based on crop response to water stress at different growth stages or under deficit irrigation could improve water-use efficiency (Pereira, 2006; Webber *et al*., 2006; Ali *et al*., 2007; Behera and Panda, 2009; Du *et al*., 2010). As water resources are dwindling in northern Nigeria region, practicing deficit irrigation could help to increase agricultural production by expanding irrigable land with limited available water.

Thus, the objectives of this study were to determine yield, and water-use responses of tomato crop to deficit irrigation practice and the optimum crop water requirement of tomato in Sudan Savannah agro-ecological zone of Nigeria.

2. MATERIALS AND METHODS

2.1 Description of study area

The two field experiments were conducted at the Irrigation Research Farm of the Institute for Agricultural Research (IAR), located at Kadawa (Latitude 11^0 38′41″ N, Longitude 8^0 25′ 51″E and 490 m above sea level), northern Nigeria. The area lies within the Kano River Irrigation project (KRIP), Sudan savannah zone of Nigeria, and has a surface irrigation facility. It is bordered to the South-East, west and north by river Kano and to the North-East by river Hadejia (Figure 1). Tiga dam is the main source of irrigation water to the area, which is located on river Kano about 70 km south of Kano City. The dominant slope in the study area is between 0.3 – 0.5% (HJRBDA, 1999).

The project area has three distinct climates: the warm rainy season from June to September, the cool dry season from October to February and the hot dry season from March to May. The warm rainy season is the period of precipitation with the highest rainfall in July and August and monthly mean of 172 mm lasting for maximum period of four months (June to September).

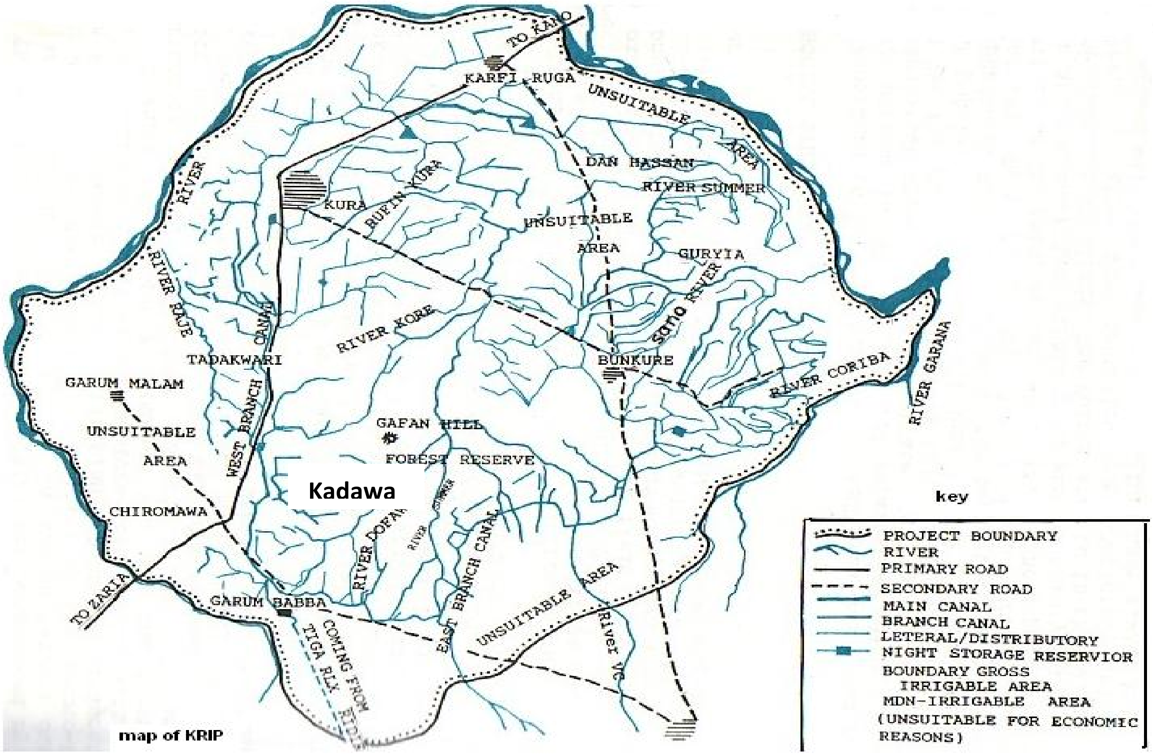

Figure 1: Water distribution network of KRIP

The meteorological data for 1st and 2nd experiments were obtained from the International Institute for Tropical Agriculture (IITA) meteorological station (Kadawa) and are presented in Tables 1 and 2, respectively.

Table 1: Mean meteorological data for 1st experiment (2016/2017 irrigation season)

Months	Relative Humidity (%)	Max. Temp (^{0}C)	Min. Temp (^{0}C)	Sunshine Hours	Wind Speed (km/day)	ET_o (mm/day)	Precipitation (mm)
Nov'16	31.80	34.2	18.7	8.81	63.32	4.1	-
Dec'16	26.94	29.4	17.5	7.61	77.82	3.7	-
Jan'17	22.84	29.6	16.2	7.40	63.84	3.6	-
Feb'17	20.29	33.3	18.5	7.51	123.36	5.3	-
Mar'17	22.81	38.5	20.7	6.88	78.37	5.0	-
Apr'17	41.71	40.1	23.8	7.13	98.14	5.6	-

Table 2: Mean meteorological data for 2nd experiment (2018/2019 irrigation season)

Months	Relative Humidity (%)	Max. Temp (^{0}C)	Min. Temp (^{0}C)	Sunshine Hours	Wind Speed (km/day)	ET_o (mm/day)	Precipitation (mm)
Nov'18	27.97	34.2	17.6	10.13	58.94	4.2	-
Dec'18	25.65	29.4	13.9	9.68	115.98	4.5	-
Jan'19	21.87	29.6	15.0	8.43	77.02	3.9	-
Feb'19	22.82	33.4	18.5	8.48	78.97	4.6	-
Mar'19	27.97	38.5	22.5	9.25	62.81	5.2	-
Apr'19	35.17	40.1	26.4	8.13	82.46	5.7	-

2.2 Experimental Design

The experiment consisted of nine irrigation treatments carried out using randomized complete block design (RCBD) with three replications and furrow irrigation method was employed for water application. The treatments were based on water application regulated at selected crop growth stages. A total area of 60 m × 94 m (5,640 m^2) was used for the experiments. The area was divided into three blocks as replicates each measuring 20 m × 94 m (1,880 m^2). On each replication, there were nine experimental treatments. Each treatment had 2.25 m × 94 m (211.5 m^2) plot size consisting of three well levelled-ridges and two furrows. The furrow spacing and length was 0.75 m and 94 m, respectively. The furrows were 'V' shaped with a depth and top width of 15 cm and 65 cm, respectively. The layout and description of experimental treatment is shown in Figure 2 and Table 3, respectively.

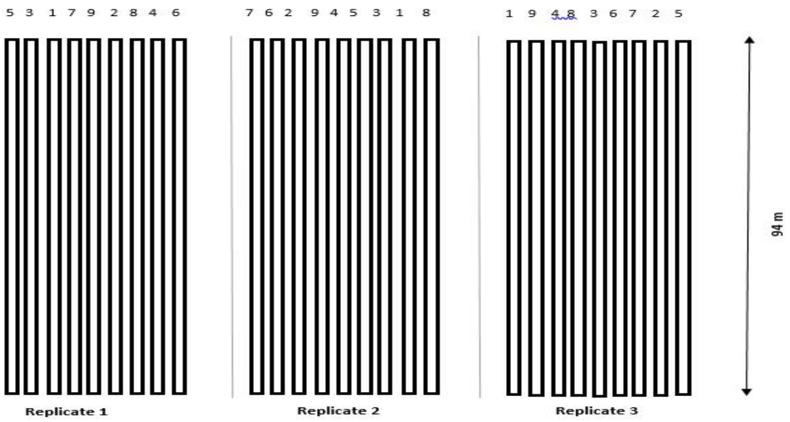

Figure 2: Layout of the experimental plots

Table 3: Description of experimental treatment

Treatment	Crop growth stages				Treatment Description
	Initial	Dev.	Middle	Late	
T1	100%	100%	100%	100%	Irrigating 100% of ETc in all the growth stages.
T2	100%	50%	100%	100%	Irrigating 50% of ETc during development stage and 100% of ETc at initial, middle and late stages.
T3	100%	100%	50%	100%	Irrigating 50% of ETc during middle stage and 100% of ETc at initial, development and late stages.
T4	100%	100%	100%	50%	Irrigating 50% of ETc during late stage and 100% of ETc at initial, development and middle stages.
T5	100%	75%	100%	100%	Irrigating 75% of ETc during development stage and 100% of ETc at initial, middle and late stages.
T6	100%	100%	75%	100%	Irrigating 75% of ETc during middle stage and 100% of ETc at initial, development and late stages.
T7	100%	100%	100%	75%	Irrigating 75% of ETc during late stage and 100% of ETc at initial, development and middle stages.
T8	100%	50%	50%	50%	Irrigating 100% during the initial stage and 50% of ETc at development, middle and late stages
T9	100%	75%	75%	75%	Irrigating 100% during the initial stage and 75% of ETc at development, middle and late stages

2.3 Field operations and measurements

2.3.1 Determination of crop water requirement

The reference evapo-transpiration was computed using ET_o – Calculator (FAO Penman Monteith equation), Version 3.2 (FAO, 2012) for the duration of the irrigation season using meteorological data for the past 15 years (2000 – 2015) and the crop evapotranspiration was calculated using Equation 1.

$$ET_c = ET_o \times K_c \quad 1$$

where:

ET_c = crop evapotranspiration, mm/day

ET_o = *reference* evapotranspiration, mm/day

K_c = crop coefficient

As indicated in Tables 1 and 2, there was no precipitation during the two experiments and hence the irrigation requirement was taken to be equal to ET_c. Irrigation water use efficiency was calculated using Equation. 2

$$WUE_f = \frac{Y}{WR} \quad 2$$

where:

WUE_f = Field irrigation water-use efficiency (kg/m^3)

Y = Crop yield (t/ha)

WR = Total amount of water applied to the fie ld (mm)

2.3.2 Irrigation

Furrow irrigation method was employed for water application. Water was applied to the furrow through the use of spiles. Irrigation interval of seven (7) days was adopted because that is the predominant practice in the study area. Water applied was based on the daily reference evapotranspiration computed from 15 years of climatic data (2000 – 2015) for the study location using ET_o – Calculator (FAO Penman Monteith equation), Version 3.2 (FAO, 2012). The depth of water applied per irrigation was calculated by summing the crop evapotranspiration computed using Equation. 1, for the duration of the irrigation interval. The irrigation schedule for 1st and 2nd experiments were as shown in Tables 4 and 5 respectively.

Table 4: Depth of water applied during the 1st experiment (2016/2017 season)

Treatments	Water applied per growth stage, mm				Seasonal Water applied (mm)
	Initial (0 – 28 DAT)	Development (29 – 60 DAT)	Middle (61 – 100 DAT)	Late (101 – 127 DAT)	
T1 ($I_{100}D_{100}M_{100}L_{100}$)	115	98	212	129	554
T2 ($I_{100}D_{50}M_{100}L_{100}$)	115	50	212	129	506
T3 ($I_{100}D_{100}M_{50}L_{100}$)	115	98	107	129	449
T4 ($I_{100}D_{100}M_{100}L_{50}$)	115	98	212	65	490
T5 ($I_{100}D_{75}M_{100}L_{100}$)	115	73	212	129	529
T6 ($I_{100}D_{100}M_{75}L_{100}$)	115	98	160	129	502
T7 ($I_{100}D_{100}M_{100}L_{75}$)	115	98	212	98	523
T8 ($I_{100}D_{50}M_{50}L_{50}$)	115	50	107	65	337
T9 ($I_{100}D_{75}M_{75}L_{75}$)	115	73	160	98	446

DAT: Days after transplanting

Table 5: Depth of water applied during the 2nd experiment (2018/2019 season)

Treatments	Water applied per growth stage, mm				Seasonal Water applied (mm)
	Initial (0 – 30 DAT)	Development (31 – 62 DAT)	Middle (63 – 102 DAT)	Late (103 – 129 DAT)	
T1 ($I_{100}D_{100}M_{100}L_{100}$)	76	122	247	133	578
T2 ($I_{100}D_{50}M_{100}L_{100}$)	76	62	247	133	518
T3 ($I_{100}D_{100}M_{50}L_{100}$)	76	122	125	133	456
T4 ($I_{100}D_{100}M_{100}L_{50}$)	76	122	247	67	512
T5 ($I_{100}D_{75}M_{100}L_{100}$)	76	92	247	133	548
T6 ($I_{100}D_{100}M_{75}L_{100}$)	76	122	186	133	517
T7 ($I_{100}D_{100}M_{100}L_{75}$)	76	122	247	101	546
T8 ($I_{100}D_{50}M_{50}L_{50}$)	76	62	125	67	330
T9 ($I_{100}D_{75}M_{75}L_{75}$)	76	92	186	101	455

2.3.3 Soil moisture measurement

Soil moisture content measurement was carried out throughout the growing seasons with the use of Theta-probe (Type: ML2x) and Moisture Meter (HH2, DELTA-T DEVICES). The actual crop evapotranspiration was determined from the measured soil moisture content data using Equation 3, as outlined by Michael (1978).

$$ET_a = \sum_{i=1}^{n} \left[\frac{M_1 - M_2}{100} \right] D_i \times B_i \qquad 3$$

where:

ET_a = actual crop evapotranspiration

M_1 = gravimetric moisture content (g/g) at first sampling in the ith layer;

M_2 = gravimetric moisture content (g/g) at second sampling in the ith layer;

D_i = depth of ith layer (mm)

n = number of layers within the soil profile

2.3.4 Determination of fruit yield

Tomato fruits yield was obtained from five (5) tagged plants in the centre ridge of each treatment. Tomato fruits harvested from the tagged plants of each treatment were weighed fresh.

3. RESULTS AND DISCUSSION

3.1 Fruit yield of tomato

The result presented in Table 6 indicated that yield of tomato was significantly affected by water stress (deficit irrigation) in both experiments. However, there was no significant difference ($p<0.05$) in yields between the two experiments. The fresh tomato yield varied from 39.99 t/ha to 71.54 t/ha and 40.62 t/ha to 73.49 t/ha in 1st and 2nd experiment, respectively. In both experiments, the highest mean yield of 72.52 t/ha was obtained in the control treatment T1 ($I_{100}D_{100}M_{100}L_{100}$), which was not subjected to water stress (full irrigation was applied), whereas minimum mean yield of 40.81 t/ha was obtained in the fully stressed treatment T8 ($I_{100}D_{50}M_{50}L_{50}$). Table 6 showed that when the water deficit level was varied at 50% ($I_{100}D_{50}M_{100}L_{100}$) and 25% ($I_{100}D_{75}M_{100}L_{100}$) with respect to ETc at the development stage, the mean fresh fruit yield was 24.8% and 7.2%, respectively, less than when there was no deficit throughout the crop growth stages, respectively. Also when a deficit level of 50% and 25% ($I_{100}D_{100}M_{50}L_{100}$ and $I_{100}D_{100}M_{75}L_{100}$) were imposed at the middle stage, the mean fresh fruit yields were 27.3% and 23.6%, respectively, less when compared to that of no deficit throughout the crop growth cycle. This implies that the middle stage seems to be very sensitive to water stress.

Table 6: Fresh fruit yield and fresh fruit yield reduction for 1st and 2nd Experiments

	1st Experiment		2nd Experiment		Mean values	
Treatments	FFY (t/ha)	ΔFFY (%)	FFY (t/ha)	ΔFFY (%)	FFY (t/ha)	ΔFFY (%)
T1($I_{100}D_{100}M_{100}L_{100}$)	71.54a	0.00	73.49a	0.0	72.52	0.00
T2($I_{100}D_{50}M_{100}L_{100}$)	54.16d	24.3	54.89g	25.3	54.53	24.8
T3($I_{100}D_{100}M_{50}L_{100}$)	50.73e	29.1	54.73h	25.5	52.73	27.3
T4($I_{100}D_{100}M_{100}L_{50}$)	65.75c	8.10	64.78d	11.9	65.27	10.0
T5($I_{100}D_{75}M_{100}L_{100}$)	66.20c	7.50	68.45c	6.9	67.33	7.20
T6($I_{100}D_{100}M_{75}L_{100}$)	54.18d	24.3	56.67f	22.9	55.43	23.6
T7($I_{100}D_{100}M_{100}L_{75}$)	68.09b	4.80	70.31b	4.3	69.20	4.60
T8($I_{100}D_{50}M_{50}L_{50}$)	39.99f	44.1	41.62i	43.4	40.81	43.8
T9($I_{100}D_{75}M_{75}L_{75}$)	54.43d	23.9	58.02e	21.1	56.23	22.5
LSD	**0.5986**		**0.0490**			

Means followed with the same letter are not significantly different
FFY - Fresh fruit yield; ΔFFY - % Difference in fresh fruit yield compared to (T1); control

When a deficit level of 50% and 25% were imposed at the late stage ($I_{100}D_{100}M_{100}L_{50}$ and $I_{100}D_{100}M_{100}L_{75}$), mean fresh fruit yield were found to be 10% and 4.6%, respectively, less when compared to the no deficit treatment T1($I_{100}D_{100}M_{100}L_{100}$). Similarly, when the same deficit level of 50% ($I_{100}D_{50}M_{50}L_{50}$) and 25% ($I_{100}D_{75}M_{75}L_{75}$) were imposed at the three growth stages (development, middle and late), the corresponding mean of fresh fruit yields reduction were 43.8% and 22.5% respectively.

In both field experiments, the mean highest yield reduction value of 43.8% for fresh fruit occurs when a 50% deficit level T8 ($I_{100}D_{50}M_{50}L_{50}$) was imposed at the three crop growth stages (development, Middle and late) followed by T3 ($I_{100}D_{100}M_{50}L_{100}$) and T2 ($I_{100}D_{50}M_{100}L_{100}$) with corresponding fresh fruit yield decrease of 27.3% and 24.8%, respectively. This supported the fact reported by many researchers (Nadal and Arola, 1995; Angela, 2012; Algharibi *et al*., 2013; Sawmadal, 2015; Mohmed *et al*., 2018, etc.) that development and middle stages of tomato crop are very sensitive to water stress particularly at 50% deficit level as observed in the two experiments.

An analysis of variance (ANOVA) was carried out to investigate the effect of water deficit on fruit yield of tomato crop in both 1st and 2nd field experiments. The treatments were found to be significant at 5% level of significance for both experiments. The least significant difference (LSD) of 0.5986 and 0.049 were obtained for 1st and 2nd experiment, respectively, as shown in Table 6. Treatment T1 recorded the highest yield in both experiments. In the 1st experiment, Treatment T1 recorded the highest yield of 71.54 t/ha, followed by T7, T5, T4, T9, T6, T2 and T3, while T8 recorded the least yield of 39.99 t/ha. The difference in fresh fruit yield between T9, T6 and T2 was not significant at 5% probability level. Similar trend was obtained in the 2nd experiment (Table 6) with T1 recording the highest fresh fruit yield of 73.49 t/ha, while T8 recorded the least fresh fruit yield of 40.62 t/ha.

The mean fresh fruit yield range obtained for the two experiments (40.81 to 72.52 t/ha) was consistent with the report of Steduto *et al*. (2012), who reported that fresh yield of tomato ranges from 60 to 120 t/ha; Nwadukwe and Abdulmumini (1989), who obtained fresh fruit yield ranging from 20.3 to 75.4 t/ha in Kadawa, Nigeria. Katerji *et al.* (2013), in the Mediterranean region reported a yield of 35 to 89 t/ha for fresh fruit. Darko *et al.* (2016) in the tropical humid coastal savannah zone of the central region, Ghana, reported a fresh fruit yield ranging from 32.27 to 90.56 t/ha in the two experiments conducted using plastic buckets filled with sandy loam soil as a growing medium. Sawmadal (2015), obtained fresh fruit varying from 27.9 to 70.4 t/ha while Algharibi *et al.*, (2013) reported a fresh fruit yield of 54.9 to 71.3 t/ha. Differences in the yield reported may be attributable to the following: crop variety, deficit level imposed (treatment), irrigation method, climate and other agronomic practices. However, the yield obtained in this study falls within the range (60 to 120 t/ha) giving by Food and Agriculture Organization of the United Nation for fresh tomato as reported by Steduto *et al.* (2012).

3.2 Water Productivity (Water-use efficiency)

Table 7 presents the productivity of seasonal irrigation water applied during the two experiments with respect to fresh fruit yield. The irrigation water productivity (IWP) with respect to fresh fruit yield ranged from 10.70 to 13.42 kg/m^3 and 10.60 to 12.88 kg/m^3 for 1st and 2nd field experiment, respectively. There was no significant difference in the irrigation water productivity values obtained for the two field experiments. However, statistical analysis showed that there was significant difference between the treatments at 5% probability level in both the field experiments conducted.

In the 1st experiment, T4 ($I_{100}D_{100}M_{100}L_{50}$) had the highest irrigation water productivity of 13.42 kg/m^3, while T2 ($I_{100}D_{50}M_{100}L_{100}$) recorded the lowest value of 10.70 kg/m^3. In the 2nd experiment, T7 ($I_{100}D_{100}M_{100}L_{75}$) had the highest irrigation water productivity of 12.88 kg/m^3, followed by T1 ($I_{100}D_{100}M_{100}L_{100}$) with value of 12.71 kg/m^3, while T2 ($I_{100}D_{50}M_{100}L_{100}$) recorded the lowest value of 10.60 kg/m^3.

Table 7: Fresh fruit yield and irrigation water productivity

Treatments	1st Experiment					2nd Experiment				
	FFY (t/ha)	SWA (mm)	IWP (Kg/m^3)	Rank on FFY	Rank on IWP	FFY (t/ha)	SWA (mm)	IWP (Kg/m^3)	Rank on FFY	Rank on IWP
T1($I_{100}D_{100}M_{100}L_{100}$)	71.54a	554	12.91c	1	3	73.49a	578	12.71b	1	3
T2($I_{100}D_{50}M_{100}L_{100}$)	54.16d	506	10.70i	7	9	54.89g	518	10.60g	7	9
T3($I_{100}D_{100}M_{50}L_{100}$)	50.73e	449	11.30g	8	7	54.73h	456	12.00e	8	7
T4($I_{100}D_{100}M_{100}L_{50}$)	65.75c	490	13.42a	4	1	64.78d	512	12.65c	4	4
T5($I_{100}D_{75}M_{100}L_{100}$)	66.20c	529	12.51d	3	4	68.45c	548	12.49d	3	6
T6($I_{100}D_{100}M_{75}L_{100}$)	54.18d	502	10.79h	6	8	56.67f	517	10.96f	6	8
T7($I_{100}D_{100}M_{100}L_{75}$)	68.09b	523	13.02b	2	2	70.31b	546	12.88a	2	1
T8($I_{100}D_{50}M_{50}L_{50}$)	39.99f	337	11.87f	9	6	41.62i	330	12.61c	9	5
T9($I_{100}D_{75}M_{75}L_{75}$)	54.43d	446	12.20e	5	5	58.02e	455	12.75b	5	2
LSD	**0.5986**		**0.0413**			**0.0490**		**0.0597**		

Means followed with the same letter are not significantly different
FFY - Fresh fruit yield; IWP – Irrigation water productivity

Water productivity gives a quantitative measurement of how much biomass or yield is produced over a growing season with respect to the amount of water used up in the process. The results from these two experiments imply that about 10.60 to 13.42 kg of fresh tomato fruit was produced from every cubic metre depth of water applied.

Table 8 shows the amount of water saved, yield reduction and irrigation water productivity for the 1st and 2nd field experiments. The table shows that accepting yield reduction of 21 to

24% can lead to saving about 20 to 21% of irrigation water through imposing 25% deficit level throughout the three crop growth stages, T9 ($I_{100}D_{75}M_{75}L_{75}$), which is a better alternative than T2 and T3 with less quantity of water saved (9% and 19%, respectively) and higher corresponding yield reduction (24% and 29%, respectively) when compared to T9.

Table 8: Irrigation water productivity for fresh fruit, amount of water saved and yield reduction

		1st Field Experiment		2nd Field Experiment		
Treatments	IWP (FFY)	Water Saved (%)	Yield Reduction (%)	IWP (FFY)	Water Saved (%)	Yield Reduction (%)
T1($I_{100}D_{100}M_{100}L_{100}$)	12.91c	0	0.0	12.71b	0	0.0
T2($I_{100}D_{50}M_{100}L_{100}$)	10.70i	9	24.3	10.60g	10	25.3
T3($I_{100}D_{100}M_{50}L_{100}$)	11.30g	19	29.1	12.00e	21	25.5
T4($I_{100}D_{100}M_{100}L_{50}$)	13.42a	12	8.1	12.65c	11	11.9
T5($I_{100}D_{75}M_{100}L_{100}$)	12.51d	5	7.5	12.49d	5	6.9
T6($I_{100}D_{100}M_{75}L_{100}$)	10.79h	9	24.3	10.96f	11	22.9
T7($I_{100}D_{100}M_{100}L_{75}$)	13.02b	6	4.8	12.88a	6	4.3
T8($I_{100}D_{50}M_{50}L_{50}$)	11.87f	39	44.1	12.61c	43	43.4
T9($I_{100}D_{75}M_{75}L_{75}$)	12.20e	20	23.9	12.75b	21	21.1

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusions

Based on the findings from the two field experiments conducted, the following conclusions were made:

I. yield of tomato is significantly affected by water stress.
II. development and middle growth stage of tomato crop are highly sensitive to water stress particularly at 50% deficit level.
III. late growth stage of tomato crop is less sensitive to water stress particularly at both 50% and 25% deficit level.
IV. imposing deficit level of 25% at development growth stage of tomato resulted in mean yield reduction of 7% as obtained in the two field experiments conducted.
V. imposing deficit level of 50% in the three (development, middle and late) growth-stage of tomato result in highest mean yield reduction of 44% as obtained in the two field experiments conducted.

4.2 Recommendations

Based on the findings from the two field experiments conducted the following recommendations were made:

1. the optimum seasonal water requirement for tomato crop in Sudan Savannah agro-ecological zone of Nigeria is 554 mm.
2. for optimum yield and irrigation water productivity of tomato crop under deficit irrigation practice, imposition of 25% deficit level in the late growth-stage is recommended.

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