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EFFECTS OF DEFICIT IRRIGATION AND MULCH PRACTICES ON YIELD AND YIELD RESPONSE FACTORS OF TOMATO (*Lycopersicon esculentum*) AT KANO RIVER IRRIGATION PROJECT (KRIP), KANO-NIGERIA

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ABSTRACT

Integrated solutions to make optimum use of water and water management *cannot be over emphasized as this management minimizes damage to life and property and to maximize efficient beneficial use. Agriculture has been facing threat due to insufficient rainfall most especially in arid and semi-arid region of the world due to climate change which make water saving techniques paramount in order to meet up with the food needed by the growing population. It is on this note that this research; the effects of deficit irrigation and mulching practices in relation to crop yield and yield response factors (Ky) of tomato (UC 82B variety) examined at Kano River Irrigation Project (KRIP), Kadawa Kano. The experiments comprised of four levels of water application depths (40, 60, 80, and 100% of weekly reference evapotranspiration) and four levels of mulching; No-Mulch (NM), rice-straw-mulch (RSM), wood-shaving-mulch (WSM) and white-polyethylene-mulch (WPM). The total mean yields ranged from 6.98 to 23.67 t/ha with an annual averages of 11.48, 18.48, 11.98 and 13.33 t/ha for NM, RSM, WSM and WPM treatments respectively. It was observed that both RSM and WPM treatments has low Ky values of 0.57 and -0.13 respectively except WSM (1.1) as compared with NM treatment of Ky value of 0.85; this implies that the proportional decrease in yield under the NM condition was much higher than under RSM and WPM conditions. The statistical analysis shows that the effect of various levels of irrigation and mulching practices on yield were found to be highly significant (**) at 5% level of significance with high mean value of 15.84t/ha and 18.48t/ha obtained at I_{80} and RSM respectively. This means that both deficit irrigation and mulching practices has significant effect on the yield of tomato in the study area. However, it was statistically concluded that the best level of irrigating tomato at the experimental site was at I_{80} (15.84 t/ha) and this corresponds to mulching practice of RSM (18.48t/ha).* Therefore, it is recommended that, *tomato producers should adopt water application at I_{80} and use of RSM as a way of suitable deficit irrigation and water conservation respectively*.

Keywords: *Deficit irrigation, mulching, Crop yield, Yield response factor (Ky), Tomato, Irrigation.*

1.0 INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the important and popular grown crop world wide. It has less popularity and use when it was first introduced to Europe from the Northern Andes in the early days of New World exploration, but today, tomato is a major World Food Plant, the production of which comes to about 18 million tonnes yearly, mostly in Europe and North America (Bodunde, 1998). Tomato is grown almost throughout the country (Nigeria) but the most important areas lie in the Northern and South-western parts of Nigeria. In the Southern parts of the country, the crop is grown in small holdings under rain-fed conditions while it is grown extensively under irrigation in the Northern parts of the country. Tomato yields of between 18 and 52 tonnes/ha have been reported for northern savannah regions (Quim, 1980) and between 12 and 24 tonnes/ha for southern rainforest areas of the country (Oyinlola and Akintoye, 2004). Much lower yields are obtained in local farms because of the use of low yielding varieties, diseases and pests problems and also inadequate cultural management as well as reliance on rain-fed production and residual soil fertility (Olorunaiye, 2009). North been the major area where tomato crop is mostly grown in Nigeria, especially under irrigation therefore requires proper management of water as reported by Thimme *et al*., (2013) that fresh water is becoming increasingly scarce worldwide. Aridity and drought are natural causes of scarcity and more recently however, man-made desertification and water shortages have aggravated natural scarcity while at the same time population is increasing and there is increased competition for water among water user sectors and regions. Thus, improved management and planning of the water resources are needed to ensure proper use and distribution of the water among competing users. A scarce water resource and growing competitions for water will reduce its availability for irrigation. Achieving greater efficiency of water use will be a primary challenge for the near future and will include the employment of techniques and practices that deliver a more accurate supply of water to crops. Hence, deficit irrigation is required; which is the practice of irrigating crops deliberately below their water requirements. Such practice is aimed at minimizing water applied to the crop so as to maximize crop yield per water applied. Deficit (or regulated deficit) irrigation is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied. Reduced yield as a result of deficit irrigation, especially under water limiting situations, may be compensated by increased production from the additional irrigated area with the water saved by deficit irrigation (Bekele and Tilahun, 2007; Ayana, 2011 and Igbadun and Oiganji, 2012). Mulching practice is one of the way in which water can be conserved. According to Igbadun and Oiganji (2012), Mulching is well known to be one means of conserving soil moisture and reducing evaporation from the top soil area. Mulching can be done with organic or inorganic materials like polyethylene sheets. Besides conserving soil moisture, polyethylene mulch also increases soil temperature and moisture in early spring, reduce weed problems and certain insect pest and also stimulate higher crop yields by more efficient utilization of soil moisture (Igbadun and Oiganji, 2012). Unknown quantity of water supply to tomato crop in the study area can lead to the development of crop water deficit or over irrigating the crop which can result in reduced yield and waste of available water for irrigation due to improper management as practiced by the farmers in the study area. In the study area, the farmers are faced with problem of irrigation (without knowing the required quantity of water to be applied to the grown crops) most especially during the dry season farming which may reduce/affect the yield of grown crops. In achieving proper management of application of required amount of water to tomato crop and harness yield, there is need to determine the effect of deficit irrigation and mulching practices on yield and yield response factor at Kano River Irrigation Project (KRIP), Kano-Nigeria. Hence, it is expected to generate information that would be useful to the farmers for the general improvement of irrigation and conservation of water management in the study area. Consequently, the results obtained from the study could also be used as a guide by researchers for further research and design of irrigation systems.

2.0 MATERIALS AND METHODS

2.1 Climate and location

The study was conducted at the Irrigation Research Station, Kadawa, situated in the Kano River Irrigation Project I (KRIP) under Hadejia Ja'amare River Basin Development Authority (HJRBDA). It is located between latitudes 11°32`N and 11°51`N and longitudes 8°20`E and 8°40`E within the Sudan savannah zone of Northern Nigeria (Jibrin *et al.,* 2008). It has a planned gross irrigable area of 22,000 ha comprising two main canals called the West Branch and East Branch canals as Phase I and Phase II respectively. The study area been tropical has wet-and-dry type climate with relatively wide and rapid changes in temperature and humidity. The mean daily maximum and minimum temperatures are 31°C and 21°C, respectively. Rainfall is concentrated between July and September with maximum and minimum of 214.0 mm and 132.7 mm, respectively as reported by Maina *et al.,* (2012) and the rains are preceded by violent sand storms and the average annual rainfall is 884.4 mm with 60% of which falls in July and August.

2.2 Field/Laboratory Work

2.2.1 Soil Moisture content: The moisture content was determined gravimetrically by the process described by Michael and Ojha (2005) using Equation 1.

$$MC = \frac{M_w - M_s}{M_s} \times 100 \quad (1)$$

Where MC = moisture content in %, (wet basis)
M_w = mass of wet soil, (g)
M_s = mass of oven dried soil, g

2.2.2 Bulk density: Bulk density was evaluated using the core sampler method (Grossman and Reinsch, 2002), using Equation 2.

$$P_b = \frac{M_s}{V_c} \quad (2)$$

Where, ρ_b is the soil bulk density in g/cm^3, M_s is the mass of oven dried soil, in g, and V_c is the volume of the core cutter in cm^3.

2.3 Description of experimental treatments

Field work was conducted using tomato (UC 82B) variety at KRIP, Kadawa. The field experiments consisted of 16 treatments. The treatments comprised four levels of irrigation (water application depths) and four levels of mulch practices, thus constituting a 2^4 factorial experiment. The four levels of irrigation included water application depths of 100, 80, 60, and 40% of weekly reference evapotranspiration (WRET), while the four levels of mulch practice consisted of no mulch (NM); use of rice straw mulch (RSM), wood shaving mulch (WSM) and white polyethylene mulch (WPM); this materials are chosen because of their availability. The 16 treatments were replicated three times, making a total of 48 treatments. Table 1 presents further description of the experimental treatments. The experiments were laid on the field with treatments assigned to plots in a randomized complete block design (RCBD), with the blocks lying across the general slope of the field (Figure 1). The blocks were separated by a distance of approximately 3.5 m, while the basins in each block were separated by a distance of approximately 1 m which minimizes lateral movement of water from one basin to another.

Table 1: Experimental treatments description.

Treatment No.	Treatment label	Description
1	$I_{100}M_{NM}$	Water application depth of 100 % WRET, no mulch.
2	$I_{80}M_{NM}$	Water application depth of 80 % WRET, no mulch.
3	$I_{60}M_{NM}$	Water application depth of 60 % WRET, no mulch.
4	$I_{40}M_{NM}$	Water application depth of 40 % WRET, no mulch.
5	$I_{100}M_{RSM}$	Water application depth of 100 % WRET, mulched with rice straw.
6	$I_{80}M_{RSM}$	Water application depth of 80 % WRET, mulched with rice straw.
7	$I_{60}M_{RSM}$	Water application depth of 60 % WRET, mulched with rice straw.
8	$I_{40}M_{RSM}$	Water application depth of 40 % WRET, mulched with rice straw.
9	$I_{100}M_{WSM}$	Water application depth of 100 % WRET, mulched with wood shaving.
10	$I_{80}M_{WSM}$	Water application depth of 80 % WRET, mulched with wood shaving.
11	$I_{60}M_{WSM}$	Water application depth of 60 % WRET, mulched with wood shaving.
12	$I_{40}M_{WSM}$	Water application depth of 40 % WRET, mulched with wood shaving.
13	$I_{100}M_{WPM}$	Water application depth of 100% WRET, mulched with white polyethylene
14	$I_{80}M_{WPM}$	Water application depth of 80% WRET, mulched with white polyethylene
15	$I_{60}M_{WPM}$	Water application depth of 60% WRET, mulched with white polyethylene
16	$I_{40}M_{WPM}$	Water application depth of 40% WRET, mulched with white polyethylene

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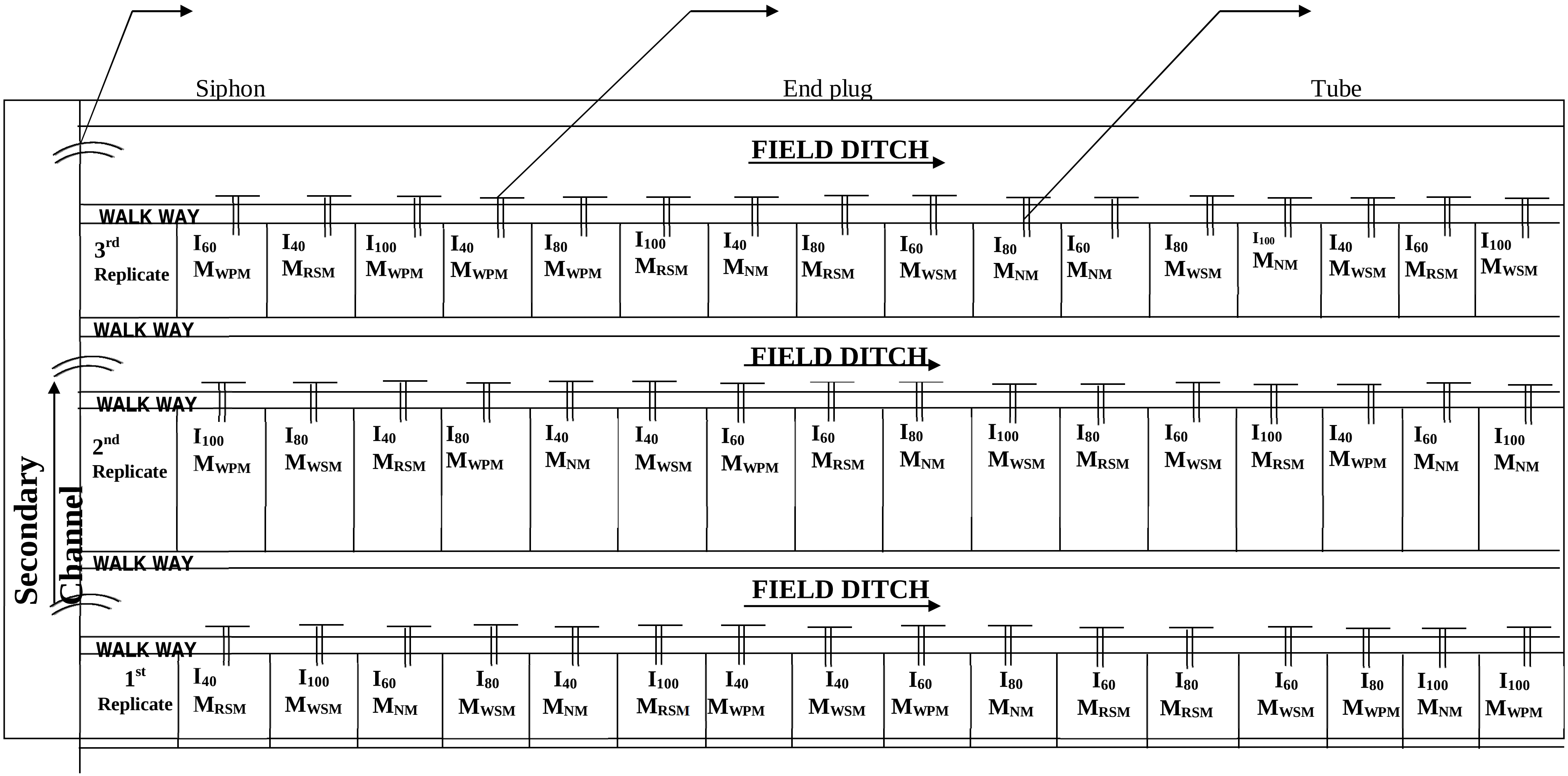

Figure 1: Experimental field layout indicating tube installations and randomization of plots

2.4 Agronomic operations

A land area of 60 m × 25 m was prepared into levelled basins of 2.5 m × 2.5 m. The field was weeded in order to destroy grown weeds on the field and then irrigated before transplanting. Tomato (UC 82B variety) seedlings was transplanted. Tomato seedlings are usually transplanted 3 - 6 weeks after planting in the nursery beds (FAO, 2013). The transplanting were done in row at plant spacing of 30 cm between plant and 30 cm between rows (this is the practice in the experimental site) and the plants population per plot was approximately 80 tomatoes and consequently, 3,840 tomato stands for the entire fourty-eight (48) experimental plots. Fertilizer (Di-ammonium phosphate fertilizer (NPK 15:15:15)) was applied two weeks after transplanting and weeding. The fertilizers and the rates of application were as recommended by FAO (2013). The mulch materials, except white polyethylene materials (this is because placing the white polyethylene materials after the tomato crop have established will distort the smooth growing of the crop), were placed two weeks after transplanted tomatoes were fully established. The white polyethylene materials were cut into size and placed over the entire basin on the day of transplanting, precisely before transplanting. Holes were created in accordance with the plant spacing and the tomato seedlings were passed through the holes. The average weight of rice straw and wood shaving mulch spread in each of the plots with such treatment were 1.2 kg and 2.25 kg respectively because the amount was sufficiently enough to cover the plot area. Weeding was done three times on plots with mulch and without mulch treatments respectively, while no weeding was carried out on plots with white polyethylene mulch material after transplanting. Plate 1 depicts the general overview of the operational field setup from plot layout up to overall setup of the experiment. Systemic insecticide (Cypermathrin) was applied on weekly basis at early flowering stage while at 3-day interval during mid to maturity stages. This was to enable less damage to the crop fruits from disease and pests.

Plate 1: Experimental field showing the general overview of the mulch treatment plots

2.5 Irrigation water application

Surface irrigation method was adopted. Water was released from the secondary canal into a tertiary ditch that conveys the water to the field ditches via a siphon and eventually served the basins. A 75 mm diameter PVC tube of length approximately 2 m was installed in each basin to admit water into the basins. The PVC tubes were installed through the embankment of each basin with one end in the field ditch and the other end in the basin. The tubes were installed to give a free orifice flow into the basins. Stage gauges were placed at the water inlet of each basin to measure the depth of water over each tube as water enters the basin. PVC corks were placed at the entrance such that when the corks were removed, water flows into the basins. When the desired depth of water was applied, the PVC corks were also used to stop the flow of water into the plot. Using the orifice flow equation stated below (Equation 3) and the depth of flow recorded from the stage gauge, the flow rates into each basin were determined and related to time of application to give to each plot the desired depth of water application. The time required to apply the depth of water were monitored using a stop watch.

The amount of water applied (see Equation 3) at every irrigation event (weekly interval) were observed throughout the crop growing season) and was based on the reference evapotranspiration amount for that week of irrigation and the experimental treatment.

$$Q = AVK = A \times \sqrt{2gh} \times K = \pi\left(\frac{d}{2}\right)^2 \times \sqrt{2gh} \times K$$

(Nally, 2013) (3)

Where, Q = flow in cubic meter per second (m^3/sec), A = area of the orifice in square meters (m^2), V = velocity of the liquid in meters per second (m/sec), K = 0.82 Constant for tube, g = 9.81 m/sec^2 = Acceleration due to gravity in meter per square second (m/sec^2), h = Head across the orifice in meters (m), d = diameter of the orifice in meters (m),

But it should be noted that;

$$\text{Volume} = A \times WRET \ (m^3) \quad (4)$$

Where A= area of plot = 2.5 x 2.5 mm = 6.25 mm^2 and WRET= weekly reference evapotranspiration (mm/week)

Also, $\text{Volume} = Q \times t \ (m^3)$ (5)

$$\therefore t = \frac{Volume}{Q} \quad (6)$$

Where t = time (i.e. duration for irrigation) (sec.)

2.6 Soil Moisture Measurement

The soil moisture status of the experimental field was monitored throughout the crop growing season using soil moisture meter at 0 - 20, 20 - 40, 40 - 60 and 60 - 80 cm depths, respectively.

Soil moisture measurements were carried out twice a week, at two days after irrigation and on the seventh day (just before the next irrigation). It was assumed that most soil will attain field capacity two days after irrigation (Igbadun and Oiganji, 2012).

2.7 Crop Water Requirement (ETc)

The crop water use between successive moisture measurements were estimated using the soil moisture depletion method (Igbadun and Oiganji, 2012), with the expression given in Equation 7.

$$CWU = \frac{\sum_{i-1}^{n}(MC_{1i} - MC_{2i}) \times A_{si} \times D_i}{t} \quad (7)$$

where, CWU is average daily crop consumptive use between successive soil moisture content sampling periods (mm/day); MC_{1i} is soil moisture content (g/g) at the time of first sampling (2 days after irrigation) in the i^{th} soil layer; MC_{2i} is soil moisture content (g/g) at the time of second sampling (7 days after irrigation) in the i^{th} layer; A_{si} is bulk density (g/cm^3) of the i^{th} layer; D_i is thickness of i^{th} layer (mm); 'n' is number of soil layers sampled in the root zone depth D, and 't' is number of days between successive soil moisture content sampling.

The weekly consumptive use were obtained as the product of the daily crop consumptive use between successive soil moisture content sampling and the number of days in the week while the seasonal crop water use is the summation of the weekly CWU. The crop consumptive use of the treatments irrigated at 100% WRET (with or without mulch), were regarded as actual consumptive use while the CWU of the deficit irrigated treatments (I_{80}, I_{60} and I_{40}) were regarded as deficit consumptive use ($CWU_{deficit}$).

2.8 Tomato Maturity and Computation of Crop Yield

The tomato crop began to show signs of maturity by changing of colour from greenish to reddish at 10 weeks after transplanting. Plate 2 and 3 shows experimental field displaying tomato fruits at maturity and maturity-harvest stage respectively. Harvesting was carried out about four weeks and was done by plugging the ripped tomato fruits and labelled according to the treatment applied to the plots and then weighed.

The crop yield was computed for each of the experimental plot in accordance with Igbadun *et al*. (2012) using Equation 8.

$$Y = \frac{W}{A}\left(kg/m^2\right) \tag{8}$$

Where Y is the crop yield (kg/m^2), W is the weight of harvested tomatoes (kg) and A is the plot area of the harvested tomatoes (m^2)

Plate 2: Experimental field showing tomato fruits at maturity stage

Plate 3: Experimental field showing tomato fruits at maturity-harvest stage

2.9 Computation of Yield Response Factor

The yield response factor was computed for each of the mulch practice using the Equation 9 given by Igbadun and Oiganji (2012) as:

$$Ky = \frac{\left(1 - \frac{Ya}{Ym}\right)}{\left(1 - \frac{SCWU_{deficit}}{SCWU}\right)} \quad (9)$$

where, Ya is tomato yield of deficit irrigated treatments, Ym is tomato yield of the fully irrigated (I_{100}) treatments, $SCWU_{deficit}$ is seasonal consumptive water use of the deficit irrigated treatments and SWCU is crop water use of the fully irrigated treatment.

3.0 RESULTS AND DISCUSSION

3.1 Soil of the experimental site

The soil of the site where the experiments were carried out was found to have an average bulk density of 1.3 g/cm^3 and average moisture content of 25.12% (Table 2).

Table 2: Bulk density and initial soil moisture content of the experimental site

Soil depth (cm)	Mass of wet soil+tin M_w (g)	Mass of oven dried soil+tin M_s (g)	Mass of tin M_t (g)	Bulk density (g/cm^3) P_b	Moisture Content (%wb*)
0 - 20	277.6	261.0	177.92	1.1	19.9
20 - 40	310.5	287.3	189.11	1.3	23.63
40 - 60	315.4	287.7	189.51	1.3	28.21
60 - 80	323.3	292.9	187.16	1.4	28.75
		Average		**1.3**	**25.12**

* wb = wet basis

3.2 Daily crop water use

The result of daily crop water use ranged from 1.67 to 11.41 mm/day across the treatments as indicated on Table 3. A comparison of the daily crop water use on the bases of irrigation treatment indicated that daily crop water use decreased with increase in deficit irrigation. The average peak crop water use of the treatments given full irrigation (I_{100}) was 7.99 mm/day. The average peak crop water use of the deficit irrigated treatments (that is, I_{80} (20% deficit), I_{60} (40% deficit), and I_{40} (60% deficit)) were 7.66, 5.21 and 3.51 mm/day and all the peak values were obtained in the no-mulch treatments of the experiment. The decrease in daily crop water use due to deficit irrigation ranged from about 20 to 30% with the highest values in the range occurring at I_{40} (60% deficit) treatments. The mode of decrease in crop water use as a result of deficit irrigation was expected since the amount of water available in the soil for plant uptake reduces with deficit irrigation. However, the study reveals that applying water at 80% (20% deficit) of reference evapotranspiration (ETo) reduces peak crop water use of the tomato crop by about 10%. More so, if water is applied at 40% (60% deficit) of ETo, the peak consumptive use of the tomato crop will be reduced by about 56%. A comparison of the daily crop water use as influenced by mulching shows that the daily CWU of the no mulch (NM) treatments ranged from 2.45 to 11.41 mm/day across irrigation regimes, while the average daily CWU of the mulched treatments ranged from 1.67 to 10.8 mm/day across irrigation regimes. However, the trend of the daily CWU was carefully studied and this reveals that, the daily crop water use was more pronounced in the developmental and fruit formation stage of the growth, most especially the NM treatments among other mulch treatments.

Observed among the mulched treatments were the rice straw mulch (RSM) treatments, which were found to be higher than other mulched treatments, consequently, wood shaving mulch (WSM) followed and lastly by white polyethylene mulch (WPM). The average peak crop water use of the NM treatments was noticed to be higher than the RSM treatment by 7.3 - 60% across the treatment, with higher value in the range occurring at higher irrigation deficit. The average peak crop water use of the RSM was also found to be higher than the other mulched treatment by 13.4 to 65.5% across the other mulch treatments. Higher CWU in the NM treatments compared to the mulched treatments at establishment to maturity-harvest growth stages can be attributed to the influence of direct surface evaporation since the soil cover was exposed to the atmosphere.

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Table 3: Average daily crop water use of the Tomato crop

Treatment		Growth stage													
		Establishment		Development				Fruit formation				Maturity-Harvest			
		Days after transplanting													
		2 – 9	10 – 16	17 – 23	24 – 30	31 – 37	38 – 44	45 – 51	52 – 58	59 – 65	66 – 72	73 – 79	80 – 86	87 – 93	94 - 100
NM	I_{100}	5.45	**5.73**	6.96	**7.39**	7.48	**7.61**	11.01	**10.80**	11.41	**10.49**	7.09	**7.25**	6.60	**6.54**
	I_{80}	5.10	**5.31**	6.46	**6.90**	7.05	**7.39**	10.50	**10.38**	11.01	**10.29**	6.95	**7.03**	6.40	**6.47**
	I_{60}	3.86	**4.02**	5.01	**5.41**	5.47	**5.87**	5.59	**5.64**	5.97	**5.41**	5.46	**5.47**	4.90	**4.90**
	I_{40}	2.45	**2.61**	3.41	**3.64**	3.61	**3.72**	4.92	**3.72**	3.92	**3.53**	3.64	**3.53**	3.17	**3.29**
RSM	I_{100}	4.98	**5.26**	6.55	**6.99**	7.08	**7.18**	9.76	**10.16**	10.80	**9.67**	6.46	**6.76**	6.05	**5.99**
	I_{80}	4.77	**5.05**	6.41	**6.93**	6.79	**6.98**	9.24	**9.85**	10.49	**9.36**	6.34	**6.62**	5.99	**5.84**
	I_{60}	3.71	**3.87**	5.02	**5.44**	5.33	**5.49**	4.89	**5.30**	5.52	**4.90**	4.85	**5.14**	4.57	**4.57**
	I_{40}	2.43	**2.62**	3.30	**3.59**	3.55	**3.58**	3.13	**3.49**	3.60	**3.29**	3.26	**3.29**	2.94	**3.07**
WSM	I_{100}	4.69	**4.90**	6.20	**6.66**	6.79	**6.91**	9.24	**9.65**	10.40	**9.27**	6.19	**6.49**	5.84	**5.77**
	I_{80}	4.55	**4.61**	6.00	**6.37**	6.38	**6.77**	8.93	**8.82**	10.19	**8.85**	6.13	**6.30**	5.70	**5.63**
	I_{60}	3.52	**3.64**	4.69	**4.99**	5.06	**5.30**	4.79	**4.72**	5.42	**4.80**	4.85	**4.69**	4.39	**4.45**
	I_{40}	2.34	**2.46**	3.19	**3.31**	3.44	**3.54**	3.22	**3.01**	3.61	**3.27**	3.22	**3.15**	2.79	**2.83**
WPM	I_{100}	4.10	**4.39**	5.64	**6.09**	6.15	**6.35**	8.53	**8.84**	9.58	**8.34**	5.63	**5.93**	5.22	**5.14**
	I_{80}	3.89	**4.33**	5.35	**5.80**	5.86	**6.07**	8.43	**8.65**	9.38	**8.03**	5.57	**5.65**	5.14	**5.07**
	I_{60}	3.05	**3.40**	4.23	**4.53**	4.52	**4.63**	4.45	**4.63**	5.03	**4.35**	4.34	**4.41**	4.00	**4.00**
	I_{40}	2.06	**2.30**	2.83	**1.69**	1.67	**1.73**	2.94	**3.15**	3.27	**2.95**	2.87	**2.95**	2.71	**2.71**

3.3 Crop Yield

Table 4 show the total yields of tomato and mean yield harvested in the experimental field. The total mean yields ranged from 6.98 to 23.67 t/ha with an annual averages of 11.48, 18.48, 11.98 and 13.33 t/ ha for NM, RSM, WSM and WPM treatments respectively, but however, the result of annual RSM yield agrees with that reported by Quim, (1980) who gave the range of tomato yield in northern Nigeria as 18 to 52 ton/ha while other mulch treatments disagree with it. The least yield was obtained from the $I_{40}M_{wsm}$ treatment, while the highest yield was obtained from the $I_{60}M_{rsm}$ treatment. It was expected that the least irrigated treatments (I_{40}) will produce the lowest yield while the fully irrigated treatments (I_{100}) will produce the highest yield since tomato crop is known to be responsive to water, also high yield was expected from WPM which is known to increase soil temperature thereby improving the yield compare to other treatment but this is not the real case, hence this may be as a result of lack of weeding effect as compared to other treatments which weeding was carried out three times before harvest. The least irrigated treatment (I_{40}) had the least yield of 6.97 t/ha while the 40% deficit irrigated treatment (I_{60}) had the highest yield of 23.67 t/ha. However, statistical analysis show highly significant difference among the yield obtained where I_{80} is been ranked as the highest while I_{40} as the least. Moreover, statistical significant difference was noticed between seasonal crop water use values of the treatments. There were highly significant differences ($p < 0.01$) among the irrigation treatments and the mulch treatments with least significant difference (LSD) of 0.2111. The interaction between irrigation and mulching was also highly significant. This pattern of result was noticed both in the mulched and no-mulch treatments, which implies that irrespective of mulching, water application depth significantly influences tomato yield, and this agrees with FAO (2013) who reported that tomato yield decreased with increase in water deficit. The result of statistical analysis suggests that water application depth per irrigation may be reduced to 80% of ETo water demand without causing a significant lost in yield of tomato crop. However, the yield of the rice straw mulch was statistically ranked highest corresponding to the irrigation water level of I_{80} and the yield was also significantly different from the yields of the other mulch treatments and No-mulch treatments. These results imply that mulching significantly influence soil water conservation of irrigated tomato crops as well as seasonal crop water use.

Table 4: Total yields of tomato and mean yield

Treatment	Replicate 1 (ton/ha)	Replicate 2 (ton/ha)	Replicate 3 (ton/ha)	Mean (ton/ha)
$I_{100}M_{nm}$	14.91	15.47	15.52	15.30
$I_{80}M_{nm}$	11.66	11.70	11.60	11.65
$I_{60}M_{nm}$	10.19	10.37	10.64	10.40
$I_{40}M_{nm}$	8.29	8.45	8.99	8.58
Annual average				**11.48**
$I_{100}M_{rsm}$	18.59	18.85	18.85	18.76
$I_{80}M_{rsm}$	22.08	21.90	21.95	21.98
$I_{60}M_{rsm}$	23.98	23.49	23.55	23.67

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$I_{40}M_{rsm}$	9.92	9.44	9.12	9.49
		Annual average		**18.48**
$I_{100}M_{wsm}$	16.66	16.90	16.85	16.80
$I_{80}M_{wsm}$	14.06	14.18	14.11	14.12
$I_{60}M_{wsm}$	9.78	9.57	10.72	10.02
$I_{40}M_{wsm}$	7.15	6.91	6.86	6.98
		Annual average		**11.98**
$I_{100}M_{wpm}$	11.55	11.71	11.63	11.63
$I_{80}M_{wpm}$	15.62	15.70	15.55	15.62
$I_{60}M_{wpm}$	15.65	15.81	15.92	15.79
$I_{40}M_{wpm}$	10.26	10.19	10.38	10.28
		Annual average		**13.33**

3.4 Yield Response Factors

Figures 2 to 5 present the yield response factors (Ky) for the NM, RSM, WSM and WPM treatments, respectively, which was obtained by plotting the pooled data of the relative yields and relative seasonal crop water use (Table 5). The seasonal Ky values were obtained as 0.85, 0.43, 1.1 and -0.13 for the NM, RSM, WSM and WPM, respectively. According to Smith and Steduto (2014), Ky >1.0 indicate crop response is very sensitive to water deficit with proportional larger yield reductions when water use is reduced because of stress, Ky <1.0 also implies crop is more tolerant to water deficit, and recovers partially from stress, exhibiting less than proportional reductions in yield with reduced water use while Ky =1.0 means yield reduction is directly proportional to reduced water use. The results of yield response factors (Ky) in this study reveals that all the treatments except WSM were less than unity (Figures 2, 3 and 5) which implies that deficit irrigation practices seem to be acceptable with this treatments (NM, RSM and WPM). The result of Ky of NM closely agree with one of those reported by Nardella *et'al.*, (2012) who gave seasonal Ky values of 0.86, 0.88 and 0.91. It was however noticed that the Ky value (1.1) of the WSM treatment was higher than the one recommended by Smith and Steduto (2014) and FAO (2013) whose gave seasonal Ky value of 1.05 and this means that the crop response under this treatment (WSM) was very sensitive to water deficit with proportional larger yield reductions when water use was reduced because of stress and this might result from the nature of the mulch which has the potential of sucking part of the water applied on the plot. Apart from WSM, it can be observed that both RSM and WPM treatments has low Ky values of 0.57 and -0.13 respectively as compared with NM treatment of Ky value of 0.85; this implies that the proportional decrease in yield under the no mulch condition was much higher than the mulched (RSM and WPM) condition. This suggests that mulching (RSM and WPM) helped to reduce the impact of the deficit irrigation on yield. It was further observed that the white polyethylene mulch helped to reduce the relative decrease in yield as a result of water deficit more than the rice straw mulch but the initial cost of WPM does not compensate the overall output compare to RSM.

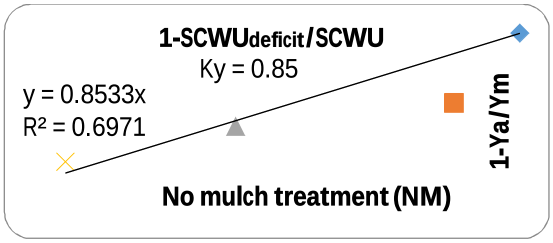

Figure 2: Yield response factor (Ky) of the no-mulch treatment.

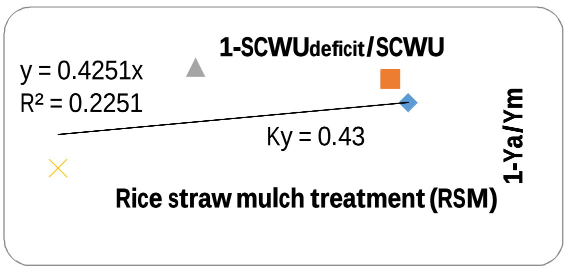

Figure 3: Yield response factor (Ky) of the rice straw mulch treatment.

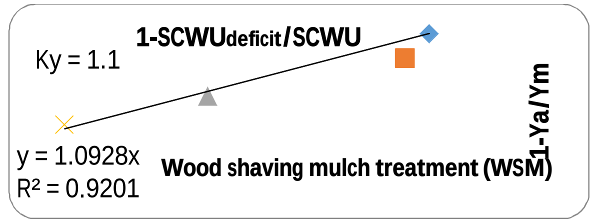

Figure 4: Yield response factor (Ky) of the wood shaving mulch treatment.

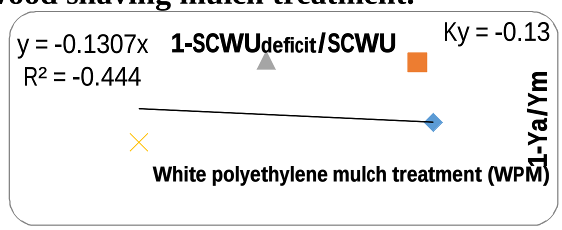

Figure 5: Yield response factor (Ky) of the white polyethylene mulch treatment.

Table 5: Relative yield and relative seasonal crop water use of the tomato crop

Treatment		Relative $SCWU_{deficit}$	Relative decreasing yield
NM	I_{100}	0.00	0.00
	I_{80}	0.08	0.24
	I_{60}	0.35	0.32
	I_{40}	0.56	0.44
RSM	I_{100}	0.00	0.00
	I_{80}	0.03	-0.17
	I_{60}	0.34	-0.26
	I_{40}	0.56	0.49
WSM	I_{100}	0.00	0.00
	I_{80}	0.04	0.16
	I_{60}	0.34	0.40
	I_{40}	0.56	0.58
WPM	I_{100}	0.00	0.00
	I_{80}	0.03	-0.34
	I_{60}	0.34	-0.36
	I_{40}	0.60	0.12

3.5 Effect of Deficit Irrigation and Mulch on Yield and Crop Water Use

Table 6 shows the statistical analysis (Statistical Analysis for Science (SAS)) of the mean effects of deficit irrigation and mulching practices on yield and crop water use of tomato grown on the experimental site. The analysis shows that the effect of various levels of irrigation and mulching practices were found to be highly significant (**) at 5% level of significance. This means that both deficit irrigation and mulching practices of tomato crop have significant effect on the yield of the crop. The table also presented the result of the analysis that compared the various irrigation levels as well as the different mulching practices and found to be highly significant (**) at 5% level of significance. This also means that both deficit irrigation irrespective of the level and mulching practices have significant effect on yield and crop water use of tomato grown in the study area. The interaction between the irrigation (I) and mulching practices (M); (I*M) was also found to be highly significant (**) at 5% level of significance. This result further reveals that the best level of irrigating tomato crop at the experimental site is at I_{80} giving mean yield of 15.84 t/ha at mean crop water use of 675.40 mm/season and this correspond to mulching practice of rice straw mulch (RSM).

Table 6: Statistical Analysis of Effect of Deficit Irrigation and Mulch on yield and crop water used and the interaction of Deficit Irrigation and Mulch

Treatment	Y	c
I		
I_{100}	15.62b	707.70a
I_{80}	15.84a	675.40b
I_{60}	14.97c	466.30c
I_{40}	8.83d	303.60d
significance	**	**
LSD (@ 5%)	0.2111	0.00
M		
NM	11.48d	589.30a
RSM	18.48a	556.60b
WSM	11.98c	530.10c
WPM	13.33b	476.90d
Significance	**	**
LSD (@ 5%)	0.2111	0.00
Interaction		
I x M	**	**

*** = Highly significance at 5%*   *I =Irrigation*   *NM = No mulch*
y = yield   *M = Mulch*   *RSM = Rice straw mulch*
c = crop water used   *WSM = Wood shaving mulch*   *WPM = White polyethylene mulch*

4.0 CONCLUSION

Crop yield and yield response factors (Ky) of tomato crop under deficit irrigation and mulch practice were determined in this study. The total mean yields ranged from 6.98 to 23.67 t/ha with an annual averages of 11.48, 18.48, 11.98 and13.33 t/ ha for NM, RSM, WSM and WPM treatments respectively. It was observed that both RSM and WPM treatments have low Ky values of 0.57 and -0.13 respectively except WSM (1.1) as compared with NM treatment of Ky value of 0.85; this implies that the proportional decrease in yield under the no mulch condition was much higher than the mulched (RSM and WPM) condition. The statistical analysis shows that the effect of various levels of irrigation and mulching practices were found to be highly significant (**) at 5% level of significance. This means that both deficit irrigation and mulching practices of tomato crop have significant effect on the yield of the crop. The result further reveals that both deficit irrigation irrespective of the level and mulching practices have significant effect on yield and crop water use of tomato grown in the study area. However, it was statistically concluded that the best level of irrigating tomato crop at the experimental site was at I_{80} giving mean yield of 15.84 t/ha at mean crop water use of 675.40 mm/season and this corresponds to mulching practice of rice straw mulch (RSM).

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