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ORIGINAL RESEARCH ARTICLE

CROP COEFFICIENT OF TOMATO UNDER DEFICIT IRRIGATION AND MULCH PRACTICES AT KANO RIVER IRRIGATION PROJECT, NIGERIA

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ABSTRACT

This work determined the effects of deficit irrigation and mulching practices on crop coefficient (Kc) of tomato in the Kano River Irrigation Project (KRIP) Kadawa, Kano, Nigeria. 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)) was conducted to examine changes in Kc value. The mean Kc values (early, developmental, mid and late stages) of fully irrigated treatments were 0.70, 0.81, 1.07 and 0.78; 0.64, 0.76, 0.99 and 0.71; 0.60, 0.73, 0.94 and 0.69; and 0.53, 0.66, 0.86 and 0.62 for NM, RSM, WSM and WPM respectively while that of deficit irrigation ranged from 0.17 to 1.13 across the treatments, noting that the highest Kc was observed under NM treatments. Statistical analysis reveals that the effect of various levels of irrigation and mulching practices on Kc of tomato was highly significant at P < 0.05 level of significance with a high mean value of 1.13 obtained at I100 and NM respectively. It was concluded to encourage tomato farmers in KRIP to adopt the use of their rice straw for mulching cum deficit irrigation (20%) towards conserving irrigation water for sustainability. Also, results obtained from this study can be used as a guide to farmers in irrigating tomato crop and to engineers in the design of irrigation systems.

1.0 Introduction

Tomato *(Lycopersicon esculentum)* is an essential and popular vegetable crop grown in Nigeria. Tomato is grown almost throughout the country, though the most important areas lie in the Northern and South-western regions. 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 (Olorunaiye, 2009). 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 yields varieties, diseases and pests problems and inadequate cultural management as well as reliance on rain-fed production and residual soil (Olorunaiye, 2009). Thus, improved management and planning of the water resources are needed to ensure proper use and distribution of the water among competing water users. 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 (Geerts and Raes, 2009). Hence, deficit irrigation practice is aimed at minimizing water applied to the crop to maximize crop yield per water applied (Faloye and Alatise, 2015).

A preliminary study (oral interview physical and observation) indicates the problems of waterlogging, off-farm water overflow, and the increasing rise of the water table in the study area while areas downstream of the schemes rarely received water. Moreover, majority of the farmers in the study area applies irrigation water base on their personal experiences. Towards establishing best irrigation water management practice in KRIP, knowledge of the amount of water required for growing the crops is essential. The crop coefficient (Kc) remains a useful parameter in determining the amount of water the crop requires. However, the Kc values of the majority of the crops grown in Nigeria and particularly in KRIP have not been determined for the area. Farmers and researchers mostly rely on published literature which are mainly determined elsewhere. Therefore, this work attempted to determine the Kc values of UC 82B tomato variety in the study area, also investigates the effect of mulching and deficit irrigation practices on the Kc values.

2. 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 Jamare River Basin Development Authority (HJRBDA), Kano State, Nigeria. The study area 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 (Jibril et al., 2008). It has a planned gross irrigable area of 22,000 ha comprising of two main canals called the West Branch and East canals as Phase I and Phase II respectively. The area being tropical has a wet-and-dry type climate with relatively broad and rapid changes in temperature and humidity. The mean daily maximum and minimum temperatures were 31°C and 21°C, respectively. Rainfall was concentrated between July and September with maximum and minimum of 214.0 and 132.7 mm, respectively as reported by Maina et al. (2012) and the rainfall preceded by violent sand storms and the average annual rainfall was 884.4 mm, 60% of which falls in July and August.

2.2 Field/Laboratory Work

2.2.1 Soil moisture content determination

Soil samples were collected randomly at upstream, midstream, and downstream of the experimental site using core sampler. The soil moisture content was determined gravimetrically following the methods described by Michael and Ojha (2005) using equation 1.

$$M_W = \frac{W_W}{W_t} \times 100 \quad (1)$$

Where: M_w = wet basis moisture content in %
W_w = weight of water in g
W_t = total weight of the soil in g

2.2.2 Bulk density determination

Soil bulk density obtained following the core sampler method as reported by (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.

2.2.3 Depth of root zone determination

The depth of the root zone for the tomato crop was obtained from (ERZD, 2014), as reported vegetables are generally shallow-rooted, which ranges between 50 – 60 cm (FAO, 2013).

2.3 Experimental treatments

A total area of 1,500 m^2 land was used in this study. The fieldwork was conducted using tomato crop of UC 82B variety at KRIP, Kadawa, Kano State, Nigeria, and the seeds were purchased from the State Ministry of Agriculture. 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 24 factorial experiment. The four levels of irrigation were 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); straw milled (RSM), wood shaving (WSM) and white polyethylene mulch (WPM) as mulch materials. The 16 treatments were replicated three times, making 48 treatments in total (Igbadun and Oiganji, 2012). The experimental treatments were assigned to plots in a randomized complete block design (RCBD), with the blocks lying across the general field slope (See Figure 1a, b, and c). A distance of approximately 3.5 m separated the blocks 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.

2.4 Agronomic operations

A land area of 60 m × 25 m was harrowed and prepared into leveled basins of 2.5 m × 2.5 m. The field was cleared by weeding grown weeds and then irrigated before transplanting. Tomato (UC 82B variety) seedlings were transplanted. The tomato seedlings were raised in the nursery and transplanted three (3) weeks after planting (FAO, 2013). The transplanting was done in a row at plant spacing of 30 cm between plant and 30cm between rows and the plant's population per plot was approximately 80 tomatoes, and consequently, 3,840 tomato stands for the entire forty-eight (48) experimental plots.

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Fertilizer (Di-ammonium phosphate fertilizer (NPK 15:15:15) was applied two weeks after transplanting and weeded, as recommended by FAO (2013). The mulch materials, except white polyethylene materials, were placed two weeks after transplanted tomatoes were well established. The white polyethylene materials placed on the same day of transplanting. Because it will be difficult and may distort the smooth growth of the tomato after the establishment of the tomato plants, the white polyethylene materials were cut into 6.25 m^2 size and placed over the entire basin on the day of transplanting, precisely before transplanting in order not to distort the smooth growth of the tomato plants. In additions, planting of tomato was carried out by the plant spacing, and the tomato seedlings passed through the holes.

The average weights of rice straw and wood-shaving mulch spread in each of the plots with assigned treatments of rice straw and wood-shaving were 1.2 kg and 2.25kg, respectively. Weeding was carried out three times before harvesting on plots with mulch and without mulch treatments, while no weeding was carried out on plots with white polyethylene mulch material after transplanting. Figures 1a, b, and c show the operational field setup from plot layout up to the overall setup of the experiment. Systemic insecticide (Cypermathrin) was applied at the rate of 65 kg/ha every week at the early flowering stage. The duration or interval was reduced to the 3-day interval during mid to maturity stages; this was to minimize damage to occur to the crop fruits from disease and pests.

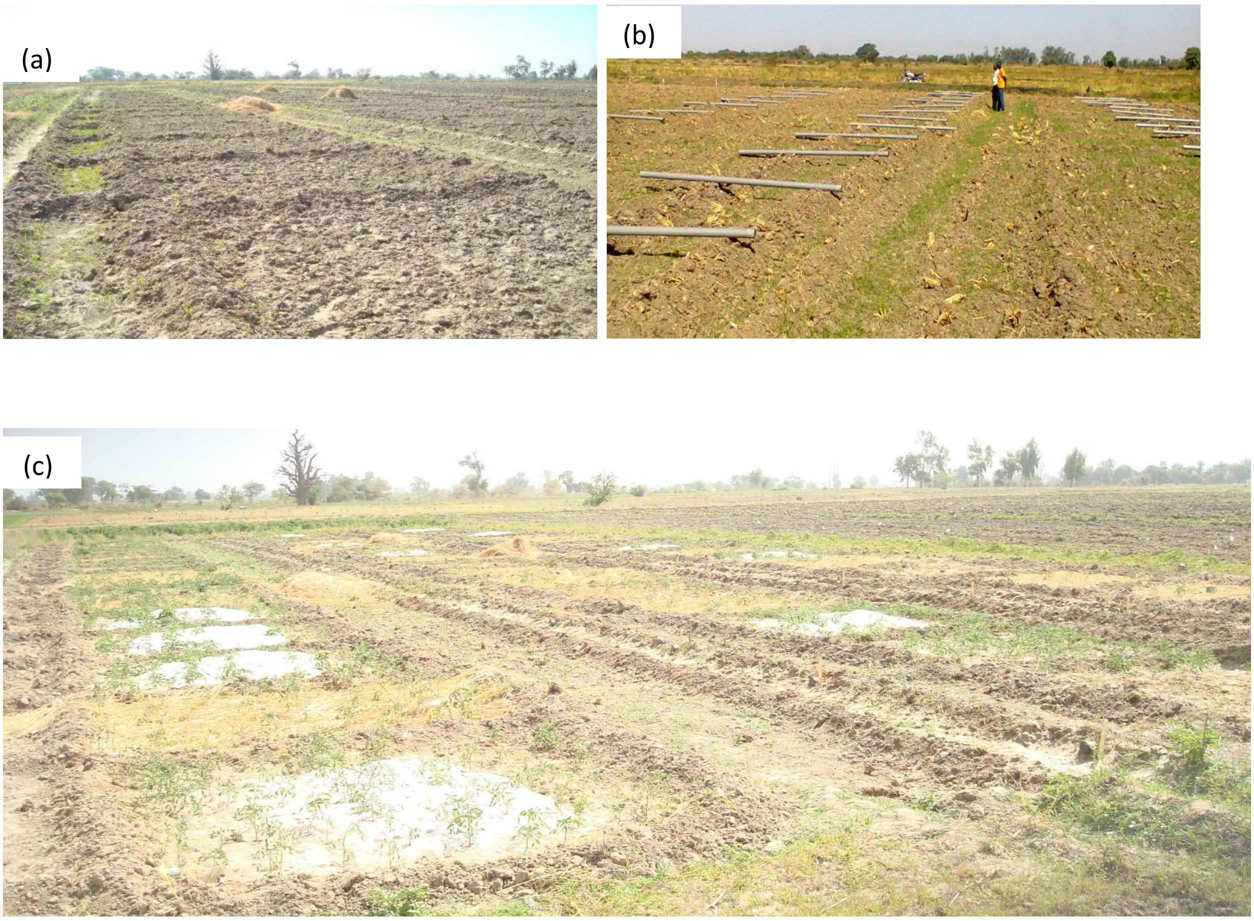

Figure 1. (a) Field setup before water measurement installation (b) Water conveyance PVC pipes before installation (c) Ariel view of the mulch treatment plots.

2.5 Irrigation water application

Basin irrigation method was adopted because it is the most dominant practice by the farmers around the study area. Water is released from a secondary canal into a tertiary ditch that conveyed 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 flowed into the basins. When the desired depth of water was applied, the PVC corks use to stop the water flow into the plot. The flow rates into each basin were determined and related to the time of application. The time required to apply the depth of water was monitored using a stopwatch. The flowrate for each basin was calculated using equation 3.

$$Q = AVK = A \times \sqrt{2gh} \times K = \pi \left(\frac{d}{2} \right)^2 \times \sqrt{2gh} \times K \quad \text{(Nally, 2013)} \qquad (3)$$

where: Q = water flow rate in the basin, m3/s, A = area of the orifice in m^2, V = velocity of the liquid in m/s, K = 0.82 Constant for the shape of tube used (Nally, 2013), g = Acceleration due to gravity in m/s^2 = 9.81 m/s^2, h = Head across the orifice in m, d = diameter of the orifice in m.

Moreover, The amount of water applied (Equation 4,5, and 6) at every irrigation event (weekly interval) was observed throughout the crop growing season and was based on the reference evapotranspiration amount for that week of irrigation and the experimental treatment, and this is in accordance with (Igbadun and Oiganji, 2012).

But it should be noted that; $\text{Volume} = A \times WRET$ (m^3) (4)

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

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

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

where: t = time duration for irrigation (s) (Allen et al., 2011).

2.6 Soil moisture measurement

The soil moisture status of the experimental field was monitored throughout the crop growing season using an in-situ soil moisture meter. The soil moisture meter was used to monitor the soil moisture at 0 - 20, 20 - 40, 40 - 60 and 60 - 80 cm depths respectively, this is by Igbadun and Oiganji (2012).

Soil moisture measurements were carried out twice a week, at two days after irrigation and on the seventh day (just before the next irrigation), because the soil most have attained its field capacity at two days after irrigation while on the seventh day, the soil has reached its wilting

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point. With an assumption that most soil would attain field capacity two days after irrigation (Igbadun and Oiganji, 2012).

2.7 Determination of reference evapotranspiration (ET_O)

Reference evapotranspiration (ET_O) of the site was computed using the FAO-Penman-Monteith method incorporated in the CROPWAT model (FAO, 1977).

The weather data for the calculation of ET_O were obtained from National Horticultural Research Institute, Bagauda; Irrigation Research Station-Institute for Agricultural Research, Ahmadu Bello University, Kadawa and Nigeria Meteorological Station (NIMET) situated in Aminu Kano International Airport, Kano. Daily maximum and minimum temperatures, relative humidity, wind speed at 2 m height, sunshine hours, and rainfall data were used.

FAO-Penman Monteith explicit equation incorporated in the CROPWAT model used in the estimation of ETo as given in Equation 7 (FAO, 1977).

$$ET_O = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_q)}{\Delta + \gamma(1 + 0.34U_2)} \quad (7)$$

where: ET_O = reference evapotranspiration (mm/day); Rn = net radiation at the crop surface (MJ/m^2/day); G=soil heat flux density (MJ/m^2/day); T=average temperature at 2m height (°C); U2=wind speed measured at 2m height (kPa); Δ=slope of vapour pressure curve (kPa/°C), γ =psychometric constant (kPa/°C), 900 = coefficient for the reference crop (KJ-1 Kg K/day); $(e_s - e_q)$ = vapour pressure deficit for measurements at 2m height (kPa); 0.34=wind coefficient for the reference crop and 0.408 = value for λ^{-1} (reciprocal of the latent heat flux required to vaporize one unit of water).

2.8 Crop water requirement (ET_C)

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 8.

$$CWU = \frac{\sum_{i-1}^{n} (MC_{1i} - MC_{2i}) \times A_{si} \times D_i}{t} \quad (8)$$

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

The weekly consumptive use was 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 consumptive crop use of the treatments irrigated at 100% WRET (with or without mulch), was regarded as actual consumptive use while the CWU of the deficit irrigated treatments (I80, I60, and I40) was regarded as deficit consumptive use (CWUdeficit), (Igbadun and Oiganji, 2012)

2.9 Determination of crop coefficient (K_c)

The Kc (Crop coefficient is also known as crop evaporation rate) of tomato crop for both full and deficit irrigation were measured on the field by Igbadun and Oiganji (2012) using equation 9a, and b;

$$Kc = \frac{CWU}{ET_o} \tag{9a}$$

$$Kc_{deficit} = \frac{CWU_{deficit}}{ET_o} \tag{9b}$$

where: Kc = Crop coefficient, ET_o =Reference Evapotranspiration

2.10. Statistical analysis

Results shown are expressed as mean ± standard deviation. Analysis of variance (ANOVA) was used to test the significance of the results, and the differences were considered statistically significant when $P < 0.05$.

3.0 Results and discussion

3.1 Meteorological data of the Site

Meteorological data averaged between 2002 and 2012 is presented in Table 1. The average relative humidity in March was found to be 31%, which was the lowest. This might be attributed to the peak dry season while the highest (84%) was recorded in August. The reason may be due to the peak wet season. The average minimum and maximum temperatures are 16.9°C and 39.8°C, respectively while the minimum wind speed (113 km/day) was observed in September and the maximum wind speed (477 km/day) in March. The ET_O obtained are 7.12, 8.83, 10.48, and 8.86 mm/day for January, February, March, and April respectively.

Table 1: Meteorological data averaged between 2002 and 2012 (NHRI, 2013).

Month	Minimum temperature (°C)	Maximum temperature (°C)	Relative humidity (%)	Wind speed (km/day)	Sunshine hours	ET_O (mm/day)
January	16.9	28.7	42	474	9.1	7.12
February	17.1	34.5	38	460	9.6	8.83
March	21.1	37.4	31	477	9.1	10.48
April	24.1	39.8	52	424	8.3	8.86

3.2 Daily Crop Water Use

The soil of the site was found to have an average bulk density of 1.3 g/cm^3 and the average moisture content of 25.12%. Further, the daily crop water use ranged from1.67 to 11.41 mm/day

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across the treatments, as shown in Table 2. 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 plants given full irrigation (I100) was 7.99 mm/day. The average peak crop water use of the deficit-irrigated plant (that is, I80 (20% deficit), I60 (40% deficit), and I40 (60% deficit)) were 7.66, 5.21 and 3.51 mm/day respectively. All the peak values were obtained in the no-mulch treated plants of the experiment, and this may be because the plots are directly exposed to the atmosphere, unlike the other plots treated with mulch materials. The decrease in daily crop water use due to deficit irrigation ranged from about 20 to 40% of moisture content with the highest values in the range occurring at I40 (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 (Igbadun and Oiganji, 2012).

However, it was observed that applying water at 80% (20% deficit) of ET_o reduces peak crop water use of the tomato crop by about 10%. Additionally, if water was applied at 40% (60% deficit) of ET_o, the peak consumptive use of the tomato crop will be reduced by about 56% (Igbadun, 2012). A comparison of the daily crop water use as influenced by mulching showed that the daily CWU of the no mulch (NM) treated plants ranged from 2.45 to 11.41 mm/day across irrigation regimes, while the average daily CWU of the mulched plants ranged from 1.67 to 10.8 mm/day across irrigation regimes.

The trend of daily CWU was carefully studied, and this revealed that the daily crop water use was more pronounced in the developmental and fruit formation stages of the growth, most especially in the NM treated plants. It was observed that among the mulched treatments; the rice straw mulch (RSM) treatments were found to be higher than other mulched treatments and consequently, wood shaving mulch (WSM) followed and lastly by white polyethylene mulch (WPM). The average peak crop water use in NM treated plants was noticed to be higher than in RSM-treated plants 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 RSM-treated plants was also found to be higher than the other mulch treatment by 13.4 to 65.5%. The higher CWU in the NM treated plants compared to the mulched treatments at the 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 (Igbadun and Oiganji, 2012).

3.3 Crop coefficients under full irrigation conditions

Table 3 shows the crop coefficient values for tomato crop. The Kc of the fully irrigated plants ranged from 0.70 to 1.15, 0.64 to 1.08, 0.59 to 1.04, and 0.53 to 0.96 for the NM, RSM, WSM, and WPM treatments, respectively. The least values of Kc in the ranges above were found at the establishment stage of the season (which is taken as the $Kc_{initial}$) while the highest values (peak Kc) were recorded at fruit formation stage (which is taken as the Kc_{mid}). Moreover, the mean Kc values for the four growth stages of the no-mulch treated plants: establishment, developmental, fruit formation, and maturity to harvest stages (which can also be classified as initial, develop, midseason and late-season) were obtained to be 0.70, 0.81, 1.07 and 0.78, respectively.

The mean Kc values for the four growth stages of the RSM treated plants were 0.64, 0.76, 0.99, and 0.71 for the initial, develop, midseason, and late season, respectively. The mean Kc values for the four growth stages of the WSM and WPM treatments were 0.60, 0.73, 0.94 and 0.69, and 0.53, 0.66, 0.86 and 0.62, respectively. The mean Kc values of midseason were a bit lower; this may be because there was very harsh weather condition in March to April (peak of the dry season) of the experimental season. Although, some researchers have recorded variability in Kc values over the years for basal and tomato crops (Shrestha and Shukla, 2014; Amayreh and Al-Abed, 2005). The Kc values obtained in this study were in agreement with those reported by (FAO, 2013). The Kc values of 0.6, 1.15 and 0.7 – 0.9 for initial, midseason and late season respectively for the tomato crop, only the Kc values of midseason that is lower than that reported by FAO, (2013), this might be due to the reason as mentioned earlier.

Despite the variation in the midseason Kc values obtained from the field compared to that reported by FAO, (2013), the results showed a reasonable degree of acceptance which is an indication of an established trend in the study area. It is important to note that Kc is affected by all the factors that influence soil water condition, among others are meteorological factors, soil characteristics and agronomic techniques that affect crop growth (Doorenbos and Pruitt, 1977; Lazzara and Rana, 2010; Stanghellini et al., 1990). Hence, Kc values reported in the literature for the same crop may vary slightly or significantly if their growing conditions differ.

3.4 Crop coefficient values under deficit irrigation conditions

Table 3 presents the crop coefficient values under deficit irrigation ($Kc_{deficit}$) conditions for different management practices. As can be seen, crop coefficients were affected significantly by irrigation deficits. The values decrease with increase in deficit irrigation. A comparison of K_c fully irrigated treatments (Kc_{fit}) and $Kc_{deficit}$ showed that the mean values of Kc were higher than $Kc_{deficit}$ by about 4, 25 and 51% for I80, I60, and I40 treatments, respectively. The peak Kc (fully irrigated treatments) values of the respective mulch management conditions were found to be higher than the peak $Kc_{deficit}$ values. As previously reported that under deficit irrigation, peak crop coefficient values may be decrease drastically (Ayana, 2011).

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Table 2: 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
	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**
NM	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**
	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**
RSM	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**
	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**
WSM	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**
	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**
WPM	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**

Table 3: Crop coefficients for the Tomato crop

Treatments		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
		Kc of NM treatment													
NM	I_{100}	0.71	0.70	0.86	0.76	0.87	0.74	1.02	0.95	1.15	1.15	0.75	0.78	0.67	0.89
		Kc deficit of NM treatments													
	I_{80}	0.67	0.64	0.80	0.71	0.82	0.72	0.97	0.91	1.11	1.13	0.74	0.76	0.65	0.88
	I_{60}	0.50	0.49	0.62	0.55	0.64	0.57	0.52	0.50	0.60	0.59	0.58	0.59	0.50	0.67
	I_{40}	0.32	0.32	0.42	0.37	0.42	0.36	0.46	0.33	0.39	0.39	0.39	0.38	0.32	0.45
		Kc of RSM treatment													
RSM	I_{100}	0.65	0.64	0.81	0.72	0.82	0.70	0.90	0.89	1.08	1.06	0.69	0.73	0.62	0.82
		Kc deficit of RSM treatments													
	I_{80}	0.62	0.61	0.79	0.71	0.79	0.68	0.86	0.87	1.05	1.03	0.67	0.72	0.61	0.80
	I_{60}	0.48	0.47	0.62	0.56	0.62	0.54	0.45	0.47	0.55	0.54	0.52	0.56	0.47	0.62
	I_{40}	0.32	0.32	0.41	0.37	0.41	0.35	0.29	0.31	0.36	0.36	0.35	0.36	0.30	0.42
		Kc of WSM treatment													
WSM	I_{100}	0.61	0.59	0.77	0.68	0.79	0.67	0.86	0.85	1.04	1.02	0.66	0.70	0.60	0.79
		Kc deficit of WSM treatments													
	I_{80}	0.59	0.56	0.74	0.65	0.74	0.66	0.83	0.77	1.02	0.97	0.65	0.68	0.58	0.77
	I_{60}	0.46	0.44	0.58	0.51	0.59	0.52	0.44	0.41	0.54	0.53	0.52	0.51	0.45	0.61
	I_{40}	0.31	0.30	0.40	0.34	0.40	0.35	0.30	0.26	0.36	0.36	0.34	0.34	0.29	0.39
		Kc of WPM treatment													
WPM	I_{100}	0.54	0.53	0.70	0.62	0.71	0.62	0.79	0.78	0.96	0.92	0.60	0.64	0.53	0.70
		Kc deficit of WPM treatments													
	I_{80}	0.51	0.52	0.66	0.59	0.68	0.59	0.78	0.76	0.94	0.88	0.59	0.61	0.53	0.69
	I_{60}	0.40	0.41	0.52	0.46	0.53	0.45	0.41	0.41	0.50	0.48	0.46	0.48	0.41	0.54
	I_{40}	0.27	0.28	0.35	0.17	0.19	0.17	0.27	0.28	0.33	0.32	0.31	0.32	0.28	0.37

The mean $Kc_{deficit}$ values of the no-mulch treated plants for four growth stages of the crop: establishment, developmental, fruit formation, and maturity to harvest stages were also found to be 0.65, 0.76, 1.03 and 0.76; 0.50, 0.60, 0.55 and 0.59; and 0.32, 0.39, 0.39 and 0.39, for I_{80}, I_{60} and I_{40} respectively. Similarly, the mean $Kc_{deficit}$ values of the rice straw mulched plants were also found to be 0.62, 0.74, 0.95 and 0.70; 0.48, 0.58, 0.50 and 0.54; and 0.32, 0.38, 0.33 and 0.36, for I_{80}, I_{60} and I_{40} respectively.

Furthermore, the mean $Kc_{deficit}$ values at the four stages for the wood shaving and white polythene mulch treated were 0.58, 0.70, 0.90 and 0.67; 0.45, 0.55, 0.48 and 0.52; and 0.30, 0.37, 0.32 and 0.34, and 0.52, 0.63, 0.84 and 0.61; 0.41, 0.49, 0.45 and 0.47; and 0.27, 0.18, 0.30 and 0.32, for I_{80}, I_{60} and I_{40}, respectively. It was observed that there were variations among the mean $Kc_{deficit}$ values of mulched and no-mulch plants. The present study supported the fact that mulching has a great influence on crop coefficient under deficit irrigation (Chakraborty et al., 2008; Mirani et al., 2011).

4. Conclusion

Crop coefficient, Kc of tomato crop under deficit irrigation, and mulch practice were obtained in this study. The Kc values of fully irrigated treatments ranged from 0.53 to 1.15, while that of deficit irrigation ranged from 0.17 to 1.13 across the treatments. This means that deficit irrigation and mulching practices of tomato crop affects Kc. The result also shows that both deficit irrigation and mulching practices irrespective of the depth of irrigation level have an effect on Kc of tomato grown in the study area. Based on our findings, we concluded that; tomato producers in KRIP, Kadawa Kano, should adopt the use of rice straw mulch as a way of water conservation which is readily available in the study area with irrigation level of 80% WRET. The results obtained from the study can also be used as a guide by farmers in irrigating tomato crop and as well as researchers for further research and design of irrigation systems.

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