

DETERMINATION OF CROP WATER STRESS INDEX OF AN EXTRA EARLY MAIZE VARIETY UNDER DIFFERENT IRRIGATION REGIMES IN KANO RIVER IRRIGATION PROJECT

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ABSTRACT

*The recognition of water stress on land and plants that arose from qualitative and quantitative restrictions on water resources are leading to an emphasis on developing methods that can help in crop management. A field research was conducted to determine the crop water stress index of maize crop (*Zea Mays L.*; SAMMAZ 29) under different irrigation scheduling using furrow irrigation. Randomized Complete Block Design was used and the experiment consisted of three levels of irrigation water application depth of 100%, 75% and 50% replacement of Total Available Water Capacity and three irrigation intervals of 7, 10 and 13 days replicated three times. Irrigation water was applied into each of 0.75m X 90m furrow using siphon tube of 7.5cm diameter and 200cm length while the soil moisture was monitored using soil moisture meter PMS-714 through an effective root zone depth of 75cm at intervals of 0-20cm, 20- 40cm and 40-75cm. The results showed that the most stressed crop was at I13D-50% with stress index of 1.00 and 1200 kg/ha yield while the fully watered crop was at I7D-100% with stress index of 0.00 and 3580 kg/ha yield. From the graph, a crop water stress index of 0.175 was obtained, which shows that treatments with stress index of less than or equal to 0.175 (≤ 0.175) were not stressed while those above 0.175 were stressed. The crop water stress index would be used for monitoring and quantifying water stress as well as for irrigation scheduling.*

Keywords: Yield, water stress index, water use, maize variety, furrow irrigation.

1 INTRODUCTION

Decisions on irrigation water management are made so often without considering the effect of water stress on the crop yield. The knowledge of crop water requirement is very important to consider in the planning of water management practices at farm level, which vary substantially during the growing period as a result of variations in their canopy and climate conditions [1]. The Crop Water Stress Index (CWSI) is an approach that is based on surface canopy temperature to detect crop water stress [2]. It is a measure of the relative transpiration rate occurring from a plant at the time of measurement, using data from plant temperature (T_c) and vapor pressure deficit (VPD) which is a measurement from the air dryness [3]. The value of CSWI is assumed to vary from 0 to 1. This method is based on the fact that the difference between canopy and air temperatures ($T_c - T_a$) increases when crops are under water stress, in response to decreased evapotranspiration, which serves as a cooling mechanism for the crop [4, 5, 6, 7, 8, 9]. [10] Presents the theory behind the energy balance which partitions net radiation from the sun into two components: sensible heat that heats the air and latent heat that is used for transpiration. When a plant go through water stress, its stomata closes and transpiration decreases, such decrease therefore increases the leaf temperature, which can reach 4 to 6 °C more than the air temperature. But when there is no water stress a plant

transpires completely, and the leaf temperature fluctuates from 1 to 4° C less than the air temperature. So in this case, the CWSI is zero. In case of high water deficit, transpiration from the leaves is drastically reduced with simultaneous increase in leaf temperature; when the plant is dead or is not transpiring for a long time, the CSWI is one [11]. [12] Developed the Crop Water Stress Index (CWSI), as an empirical method used to quantify the humidity tension in crops under arid conditions, which first depends on the determination of two baselines (with or without water stress). The baselines are specific for the crop and are influenced by the climate [13]. [10] Modified the CWSI method by including more variables such as vapor pressure deficit (VPD), net radiation (R_n) and aerodynamic resistance (r_a), in order to obtain a better theoretical prediction of the effect of climate on the crop temperature. Maize is fairly sensitive to water stress [14, 15]. Varieties with higher yielding are more sensitive to water stress than varieties with low yielding [16]. The most suitable crops varieties for deficit irrigation are those with short growing season and also tolerant to drought [17]. When mean daily temperatures during the growing season are greater than 20°C, early grain varieties take 80 to 110 days and medium varieties 110 to 140 days to mature [18]. Over application of irrigation water relative to crop needs can result in problems like wastages of water and energy, increased labor, water logging, increased soil salinity, erosion, decreased in soil aeration and surface and ground water quality problems associated with nutrients, pesticides, and pathogens while under application of irrigation water stress the plant all of which result to retardation of crop growth and development and consequently yield reduction. Detailed information is therefore needed in order to provide farmers with efficient method of water management that will reduce plant stress and wastage of water by farmers. The study was aimed at determining the crop water stress index of an extra early maize variety under different irrigation intervals and irrigation depths using furrow irrigation in Kano river irrigation project. Such an index would definitely aid proper irrigation scheduling and also serve as a tool to quantify stress and the effect of other environmental parameters affecting stress and plant temperature.

2 STUDY AREA

The study was conducted during the dry season of 2013/2014 at the Irrigation Research Station of the Institute for Agricultural Research Kadawa in Kano River Irrigation Project, Garun-Mallam Local Government area of Kano State. The Kano River Irrigation Project is one of the largest irrigation projects in Nigeria which lies between latitude 11° 30' to 12° 03' N, longitude 08° 30' to 09° 40' E and 486 m above sea level within the Hadejia Jama'are River Basin, covering an area of about 75, 000 hectares. The average weather data of the study site are presented in Table 1.

Table 1. Average weather data for the study period in 2013/2014 season

Parameter	15 th	Month	15 th	
	February	March	April	May
Maximum Temperature (°C)	34.4	36.2	38.2	36.5
Minimum Temperature (°C)	20.6	22.4	26.1	23.9
Relative humidity (%)	24	21	32	31
Wind speed (km/day)	162	189	197	181
Sunshine hour (hr)	11.1	12.0	10.9	11.3

Source: meteorological station of Kadawa irrigation research station.

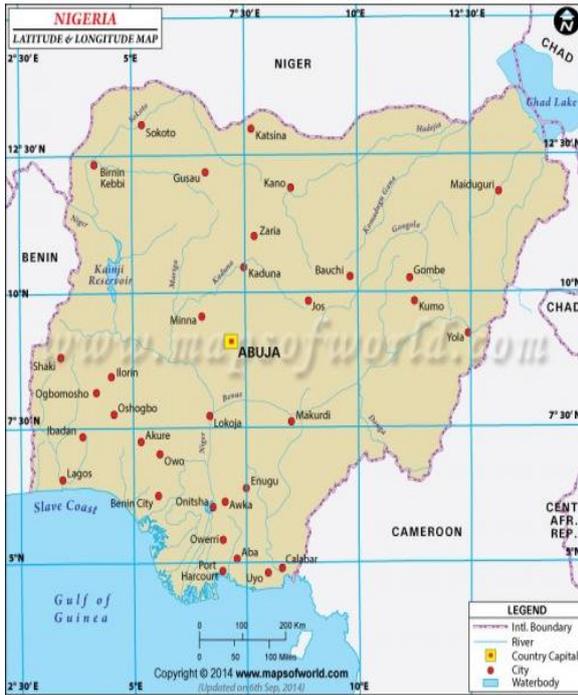


Figure 1. Map of Nigeria showing Kano State

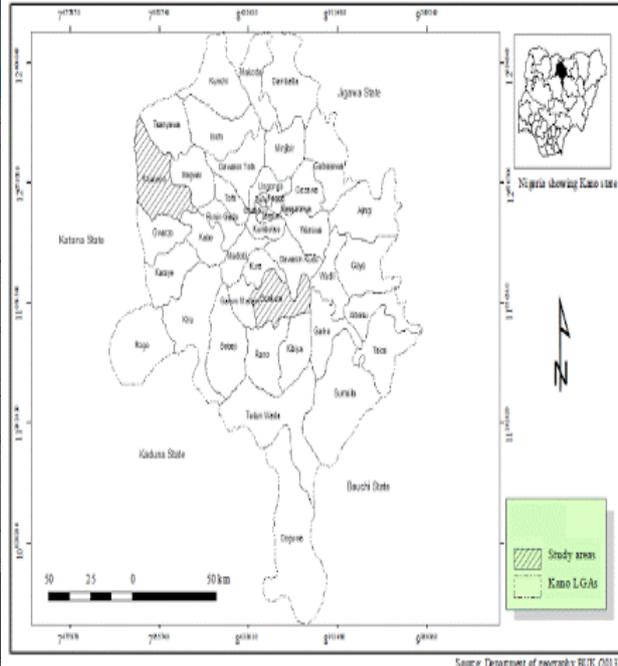


Figure 2. Map of Kano showing Garun-mallam



Figure 3. Maps of Africa and Nigeria, showing the location of Kadawa Irrigation Research Station

3 MATERIALS AND METHOD

3.1 Soil Physical Properties

The physical properties of the soil at the experimental field were determined through soil sampling and were taken to the Soil Laboratory for analysis. An effective root depth of 0.75m (75cm) was considered for maize crop in this study as recommended by [19, 20] at an incremental depths of 0 -20 cm, 20 -40 cm and 40 -75 cm. For physical properties, soil samples were taken from 0-20, 20-40

and 40-75 cm depths along the soil profile from the 3 selected points, where the moisture content at both field capacity and wilting point condition were determined using pressure plate apparatus while the soil bulk densities were determined through oven-dry method. For the purpose of textural classification, the percentages of silt, clay and sand, were determined by hydrometer method using USDA soil texture classification where individual soil samples were taking at 0-20, 20-40, and 40-75 cm depth along the soil profile from the 3 selected points. The dominant texture class of soil was sandy loam for the entire experimental plots. Table 2 presents the soil physical properties of the soil the experimental site.

Table 2. Soil Physical Properties at the experimental site

Depth (cm)	FC(%) @ 0.33bar	PWP (%) @ 15bar	Bulk Density (g/cm ³)	Clay (%)	Silt (%)	Sand (%)	Textural Class
0 - 20	35.8	6.53	1.54	14	16	70	Sandy Loam
20 - 40	37.27	8.87	1.56	18	16	66	Sandy Loam
40 - 75	39.6	10.1	1.5	18	18	64	Sandy Loam

3.2 Experimental Design and Treatments Description

The experiment consisted of three (3) levels of irrigation interval (7, 10 and 13 days) and three (3) levels of irrigation depths (Replacements of 100%, 75% and 50% of Total Available Water Capacity, TAWC), which make a total of nine (9) treatments. The experimental treatments were replicated 3 times, making a total of 27 experimental plots considered, laid in Randomized Complete Block Design (RCBD).

Table 3. Description of the experimental treatments

Treatment labels	Treatment Description
I ₇ D _{100%}	7 day Irrigation Interval with 100% Replacement of Total Available Water Capacity
I ₇ D _{75%}	7 day Irrigation Interval with 75% Replacement of Total Available Water Capacity
I ₇ D _{50%}	7 day Irrigation Interval with 50% Replacement of Total Available Water Capacity
I ₁₀ D _{100%}	10 day Irrigation Interval with 100% Replacement of Total Available Water Capacity
I ₁₀ D _{75%}	10 day Irrigation Interval with 75% Replacement of Total Available Water Capacity
I ₁₀ D _{50%}	10 day Irrigation Interval with 50% Replacement of Total Available Water Capacity
I ₁₃ D _{100%}	13 day Irrigation Interval with 100% Replacement of Total Available Water Capacity
I ₁₃ D _{75%}	13 day Irrigation Interval with 75% Replacement of Total Available Water Capacity
I ₁₃ D _{50%}	13 day Irrigation Interval with 50% Replacement of Total Available Water Capacity

3.3 Field Layout

A total area of 37m x100m (0.37ha) was used as the experimental field. The field was divided into three blocks as (REP. 1, REP. 2 and REP. 3), each measuring 10.75m x100m. On each replication, there were nine experimental treatments. The length of furrow (L) was 90m, while the spacing of the furrow (W) was 0.75m. The furrow had a ‘V’ shape with an average depth of 15cm and width of 65cm at the top. A buffer space of 2m was considered between the replications while 0.5m space was considered between the treatments in order to minimize the risk of moisture entry between the treatments.

3.4 Irrigation Water Application

Siphon tube of 7.5 cm diameter and 200 cm long was used to convey water into the furrows. Discharges from the siphon tube were cut-off as soon as the required amount of water was applied. The discharge through the siphon tube into the furrow was computed using equation.

$$Q = AV \tag{1}$$

Where: A= cross-sectional area of the siphon (m²), V= velocity of flow (m/s). The cross-sectional area was determined using equation

$$A = \pi \left(\frac{d}{2}\right)^2 \quad (2)$$

Where; d = Diameter of the tube (m), The velocity of flow was determined using equation.

$$V = c_d * \sqrt{2gh} \quad (3)$$

Where; g= Acceleration due to gravity (m²/s), c_d = Coefficient of discharge, h= Hydraulic head. The coefficient of discharge from the siphon was determined experimentally using volumetric method of determining discharge with a known volume of container.

$$C_d = \frac{4Q}{\pi d^2 \sqrt{2gh}} \quad (4)$$

3.5 Irrigation Time

The irrigation duration for each of the treatment was determined using the relation as recommended by [21] as expressed in equation (5).

$$t = \frac{W L d}{360 Q} \quad (5)$$

Where: t = Irrigation duration (elapsed time) in hours, Q= Stream size (m³/s), W= Furrow spacing (m), L = Furrow lengths (m), d = depths of water (m).

3.6 Soil moisture measurement

The soil moisture contents of the experimental plots were monitored throughout the growing season using Soil moisture meter (PMS-714) at three different points along the furrow length, representing the upper end, middle and the lower end of the furrow. At each point, soil moistures were taken through an effective root zone depth of 75cm, at incremental depths of 0-20cm, 20-40cm, 40-75 cm, before and after irrigation, as suggested by [22].

3.7 Determination of Crop Water Use

The amount of moisture used by the crop on each irrigation event was estimated from the soil moisture content measurements made two days after irrigation and just before the next irrigation using Equation 6, given as [23].

$$CWU = \frac{\sum_{i=1}^n ((MC_{2i} - MC_{1i}) BD * D_i)}{t} \quad (6)$$

Where: CWU= Crop Water Use (mm), MC_{1i} = Soil moisture content (%) at the time of first sampling in the i_{th} soil layer, MC_{2i} = Soil moisture content (%) at the time of second in the i_{th} Soil layer sampling, D_i = Depth of i_{th} soil layer (cm), BD = Bulk density of soil (g/cm³), n = Number of soil layers sampled in the root zone depth D, t = Number of days between successive soil moisture content sampling.

3.8 Total Available Water Capacity

The Total Available Water Capacity (TAWC) in the root zone was estimated as the difference between the water content at the field capacity and permanent wilting point. The TAWC was determined on each treatment before irrigation (moisture content at permanent wilting point) and two days after irrigation (moisture content at field capacity) using Soil moisture meter; (PMS-714) as showed in the equation.

$$TAWC = \sum_{i=1}^n ([1000(\theta_{FCi} - \theta_{WPI}) * Z_{ri}]) \quad (7)$$

Where: TAWC = Total Available Water Capacity (mm), θ_{FCi} = Soil Moisture Content at Field Capacity ($\frac{m^3}{m^3}$), in the i_{th} soil layer, θ_{WPI} = Soil Moisture Content at Permanent Wilting Point ($\frac{m^3}{m^3}$), in the i_{th} soil layer, Z_{ri} = Effective Root Zone Depth (m) of i_{th} soil layer.

3.9 Estimation of Crop Yield

The plant was hand harvested when a visual inspection indicated that 95% of the plant reached maturity, then it cobs dried and the leaf sheaths have turned brown. The yield of maize per experimental plot was determined first by threshing the maize separately as well as weighing it. It was then converted into kilogram per hectare using equation (7). The weight of the harvested maize was obtained by weighing the threshed maize (dry matter yield at 15% moisture content) on a weighing balance, while the area of the plot was determined by multiplying the length and width of the plot.

$$\text{Crop yield} \left(\frac{\text{Kg}}{\text{ha}} \right) = \frac{10,000 * (\text{weight of harvested maize})}{(\text{crop area})} \quad (8)$$

3.10 Determination of Crop Water Stress Index

The crop canopy temperature (T_c) of each of the experimental treatments were measured with a portable hand-held infrared thermometer (IRT) that is capable of detecting radiation in the 8–14 μm wave bands (Minolta/Land Cyclops Compaq 3). The crop is viewed using the instrument which is at a distance of 0.50m at an angle of 35° - 45° to the horizontal so as to minimize soil background in the course of view. On each treatment, three plants were considered and tagged with a level at intervals between 0-30m, 30-60m and 60-90m. On each plant, four readings of canopy temperatures were measured from four different directions, their average was determined which was used to obtain the canopy temperature of that plant. Midday canopy temperature was used which is the best indicator to detect the crop water stress as concluded by some researchers [24]. The dry and wet bulb temperatures were measured with an aspirated psychrometer at a height of 2.0 m in the open area adjacent to the experimental plots. The mean T_a was determined from the average of the dry bulb temperature readings during the measurement period. The mean vapor pressure deficit (VPD) was computed as the average of the calculated instantaneous VPDs, using the corresponding instantaneous wet and dry bulb temperatures. The CWSI values were calculated using the procedures of [12]. In this approach, the measured crop canopy temperature was scaled relative to the minimum canopy temperature expected under non water- stress conditions and the maximum temperature under severe water stress. The non-water-stressed baseline for the canopy-air temperature difference ($T_c - T_a$) versus the vapor pressure deficit (VPD) relationship was determined using the data collected only from the control treatment (I7D_{100%}). The upper (fully stressed) baseline was computed by the canopy temperatures of the fully stressed plants (I13D-50%). Using the upper and lower limit estimates, CWSI was calculated for all the treatments. Moreover, graphical method was used to determine the CWSI. Thus,

$$\text{CWSI} = \frac{A}{B} = \frac{3.8 - 2}{6.5 + 3.8} = 0.175. \quad (9)$$

The measurement was done at a point when $T_c - T_a = -3.8^\circ\text{C}$ on the graph when $\text{VPD} = 4.9^\circ\text{C}$.

3.11 Determination of Water Vapor Pressure

Water vapor pressure (e_s) which is the maximum amount of water vapor that air can hold at a given temperature (T in $^\circ\text{C}$) was calculated using equation (10).

$$e_s = 0.611 \exp \left(\frac{17.27T}{T + 237.3} \right) \quad (10)$$

Where; T = temperature ($^\circ\text{C}$)

3.12 Determination of Actual Water Vapor Pressure

Actual vapor pressure was obtained from an equation involving the relative humidity (RH) as shown in equation (11).

$$e_a = \frac{RH * e_s}{100} \quad (11)$$

RH = relative humidity of air (%)

3.13 Determination of vapor pressure deficit (VPD)

Vapor pressure deficit was determined by taking the difference between the amounts of moisture in the air and how much moisture the air can hold when it is saturated as shown in equation (12).

$$VPD = e_s - e_a \quad (12)$$

Where; e_s = water vapor pressure at saturation at a given air temperature, e_a = actual water vapor pressure (water vapor partial pressure in the atmosphere).

3.14 Graphical Determination of Crop Water Stress Index

Graphically CWSI was determined as the ratio of the vertical distance between the measured canopy-air temperature difference ($T_c - T_a$) and the lower baseline to the distance between the lower and upper baselines at the same vapor pressure deficit (VPD).

4 RESULTS AND DISCUSSION

Effects of Irrigation Depth and Irrigation Interval on Crop Water Stress Index

Table 4 shows the statistical means of crop water stress index (CWSI) as affected by irrigation depths and intervals at Kadawa which was highly significant at $P < 0.05$ and $p < 0.01$ level. When irrigation depth was adopted, highest CWSI was recorded at $D_{50\%}$ with 0.604 followed by $D_{75\%}$ with 0.469 and then the least at $D_{100\%}$ with 0.338. This was due to reduction in irrigation depth from 0% to 50%. But when irrigation interval was adopted, the highest CWSI was recorded at 13 days irrigation interval with 0.808, followed by 10 days with stress index of 0.464 while the least index was observed at 7 days irrigation interval with 0.140.

Table 4. Statistical Means of Crop Water Stress Index as affected by Irrigation Depths and Irrigation Intervals at Kadawa in 2013/2014 Dry Season on Maize

Treatment	CWSI
Depths	
$D_{100\%}$	0.338c
$D_{75\%}$	0.472b
$D_{50\%}$	0.604a
Interval	
7- Days	0.140c
10-Days	0.467b
13- Days	0.808a
CV	11.208
R^2	0.982
LSD (5%)	0.053
LSD (1%)	0.073
Significance	**

Mean followed by the same letter(s) in a row or column are statistically non significantly $P \leq 0.05$

** = Highly significant difference at 1% level

$D_{100\%}$, $D_{75\%}$ and $D_{50\%}$ are replacements of 100%, 75% and 50% total available water capacities
a, b and c = are letters indicating the ranking based on least significance difference

From Table 5, when irrigation depth was fixed at $D_{100\%}$, $D_{75\%}$ and $D_{50\%}$, 13 days recorded significant higher CWSI followed by 10 days and then 7 days. However, for 13 days, irrigation depth fixed at $D_{50\%}$ recorded the highest CWSI of 1.00 followed by $D_{75\%}$ with 0.795, then the less stressed at $D_{100\%}$ with 0.627. But for 10 days, irrigation depth fixed at $D_{50\%}$ recorded highest stress with 0.537 and was statistically not significant with 0.476 fixed at $D_{75\%}$ while least stress was recorded at $D_{100\%}$ with 0.388 which was also statistically not significant with $D_{75\%}$. However for 7 days interval, irrigation depth fixed at $D_{50\%}$ recorded the most stressed crop with 0.275 followed by $D_{75\%}$ with 0.144 while the less stress was recorded at $D_{100\%}$ with 0.00. Generally, the most stressed maize was at 13 days interval and when irrigation was made at 50% replacement of total available

water capacity with stress index of 1.00, this was because of the adoption longer irrigation and deficit irrigation while the fully watered maize was at 7 days interval and when irrigation was made at 100% replacement of total available water capacity with stress of 0.00, because the maize was replenished with 100% of the total available water capacity after every 7 days.

Table 5. Interaction of Irrigation Depths and Intervals on Crop Water Stress Index at Kadawa in 2013/2014 Dry Season on Maize

Depths	CWSI		
	7-Days	10- Days	13- Days
D _{100%}	0.000h	0.388e	0.627c
D _{75%}	0.144g	0.476de	0.795b
D _{50%}	0.275f	0.537cd	1.000a
CV	11.208		
R ²	0.982		
LSD (5%)	0.092		
LSD (1%)	0.126		
Significance	*		

Mean followed by the same letter(s) in a row or column are statistically non significantly $P \leq 0.05$

* =significant difference at 1% level

D_{100%}, D_{75%} and D_{50%} are replacements of 100%, 75% and 50% total available water capacities
a,b,c,d, e and f = are letters indicating the ranking based on least significance difference

Table 6 presents the canopy minus air ($T_c - T_a$) temperature differences for both the non-stressed (I₇D_{100%}) and the most stressed crop (I₁₃D_{50%}). The canopy minus air ($T_c - T_a$) temperature differences for the non- stressed crop (which represented lower baseline) had a range of values, fluctuated from -4.4⁰C to 4.8⁰C while the canopy minus air ($T_c - T_a$) temperature differences for most-stressed crop (which represented upper baseline) had it temperature ranges of values fluctuated from 6.5⁰C to 6.8⁰C, with an average value of 6.6⁰C.

Table 6. Canopy minus air ($T_c - T_a$) temperature differences for both the non- stressed and most-stressed crop

Date	canopy minus air ($T_c - T_a$) temperature differences for the non- stressed maize (⁰ C)	canopy minus air ($T_c - T_a$) temperature differences for the most- stressed maize (⁰ C)
15.03.14	2.9	6.8
22.03.14	1.5	6.6
29.03.14	-4.4	6.7
05.04.14	0.1	6.7
12.04.14	-2.1	6.6
19.04.14	1.8	6.5
26.04.14	3	6.6
03.05.14	4.8	6.6
10.05.14	3.8	6.7

Figure 4 shows the upper (stressed) and lower (non-stressed) baselines. The lower baseline gave a linear relationship when canopy minus air ($T_c - T_a$) temperature differences was plotted against vapor pressure deficit (VPD) with an equation (14).

$$T_c - T_a = 10.28 - 2.899VPD \quad (14)$$

The upper baseline was represented with a horizontal line, having an average value of 6.6⁰C with an equation (15).

$$T_c - T_a = 6.6^0 C$$

This suggests that the temperature difference between canopy and air ($T_c - T_a$) for the stressed crop was not responding with Vapor Pressure Deficit (VPD). This was due to moisture stress imposed on the plant, which affect the leave transpiration as the stomata closed completely. A crop water stress index of 0.175 was obtained from the graph (Fig. 4), which indicated that all treatments with less than or equal to 0.175 were not stressed while those above 0.175 were stressed. [25, 26] reported similar observations in CWSI trend in the cases of water deficit stress. [27] Reported 0.28 for maize and 0.15 for black gram. However, irrigating maize crop at 7 days interval with 100% replacement of total available water capacity ($I_7D_{100\%}$) was considered to be fully watered because it CWSI value (0.0) was less than that obtained from the graph (0.175) while irrigating maize crop at 13 days interval with 50% replacement of total available water capacity was considered to be fully stressed, because its CWSI value (1.0) was greater than that obtained from the graph (0.175).

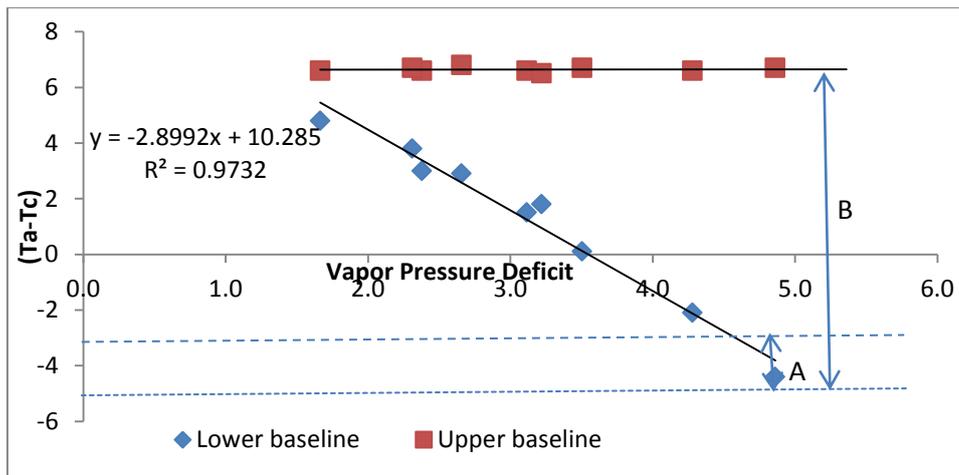


Figure 4. Baselines of Maize as influenced by irrigation interval and irrigation depth at Kadawa during 2013/2014 dry Season.

Table 7 presents the crop water stress index for all the treatments as it affect maize yield. The highest crop water stress index (1.00) was recorded on the most stressed crop, which was irrigated at 13 days interval with replacement of 50% total available water capacity ($I_{13}D_{50\%}$), this was due to the imposed of longer irrigation frequency and reduction of irrigation depth from 100% to 50%. The least stress index (0.00) was recorded on the fully watered crop which was irrigated at 7 days interval with the replacement of 100% total available water capacity ($I_7D_{100\%}$), because the crop was replenished with 100% of the total available water capacity weekly. Table 7 also shows that crop water stress index was increasing with an increase in irrigation interval from 7, 10 to 13 days and also with decreased in irrigation depth from 100% to 50% replacement of the total available water capacity. This was due to longer irrigation period and irrigation deficit.

Table 7. Crop Water Stress Index of maize as affected by Seasonal Water Applied at Kadawa during 2013/2014 dry season

Treatment	CWSI
$I_7D_{100\%}$	0
$I_7D_{75\%}$	0.144
$I_7D_{50\%}$	0.275
$I_{10}D_{100\%}$	0.388
$I_{10}D_{75\%}$	0.476
$I_{10}D_{50\%}$	0.537
$I_{13}D_{100\%}$	0.627
$I_{13}D_{75\%}$	0.795
$I_{13}D_{50\%}$	1

Figure 5 shows the effect of crop water stress index on yield. A negative linear relationship was obtained when yield was plotted against CWSI, with coefficient of determination ($R^2=0.906$). [28] reported similar trend when CWSI was plotted against yield for maize.

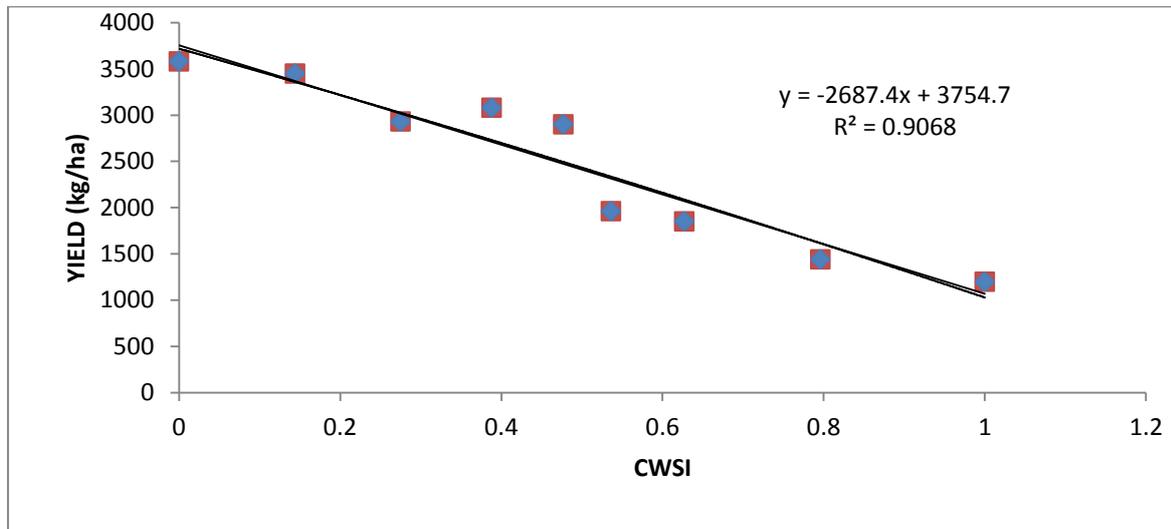


Figure 5. Crop water stress index of Maize as affected by maize yield during the 2013/2014 dry season

The most stressed crop was at I13D-50% with stress index of 1.00 and 1200 kg/ha yields while the fully watered crop was at I7D-100% with stress index of 0.00 and 3580 kg/ha yields. The results showed that the yield decreases with increase in crop water stress index. From the graph, a crop water stress index of 0.175 was obtained which was close to 0.2 threshold recommended by [29].

5 CONCLUSIONS

A threshold value of 0.175 crop water stress index for the trial crop was obtained from the study, which means treatments with stress index of less than or equal to 0.175 (≤ 0.175) were not stressed while those above 0.175 (>0.175) were stressed. This indicated the option of reducing the total inflow time, net irrigation depth or increasing irrigation intervals by the irrigators.

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