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Influence of Organic Materials on Crop Evapotranspiration and the Yield of Sorghum Crop in Semi-Arid Region of Borno State

Alkali M.
Department of Agricultural Engineering Technology,
Ramat Polytechnic Maiduguri P.M.B 1070, Borno State, Nigeria

Ali M.
Department Agricultural Technology. College of Agriculture Gujba. Yobe State, Nigeria.

Zannah A.K.M.
Department Agricultural Technology. College of Agriculture Gujba. Yobe State, Nigeria.

Liman Y.M
Department Agricultural Technology. College of Agriculture Gujba. Yobe State, Nigeria.

Mustapha B.
Department of Date Palm Research Dutse Substation. Institute for Palm Oil Research (NIFOR). Jigawa State, Nigeria.

Abstract: *The research was carried out to determine the influence of organic materials on crop evapotranspiration of sorghum in semi-arid region of Nigeria. In order to ascertain the influence; a drainage type lysimeter of 0.6m height, and 0.3 diameter with cross-sectional area of 0.85m² were used. The organic materials used were; Moringa Olifera leaves, Groundnut Haulm and Maize leaves, were grown and incorporated into the soil at tonnage of 0.45kg/m². The organic materials (treatments) were laid in Randomized Complete Block Design (RCBD. For consistency water application, an irrigation interval of 4days was maintained. Furthermore, the highest maize crop evapotranspiration were 19.2, 88.1, 127.32 and 86.10mm/day at all stages of growth and was found with Moringa Olifera leave respectively. Therefore, the study indicates that Moringa recorded the highest influence on the crop evapotranspiration on growth parameters and yield attributes (3663.8kg/ha) of Sorghum crop. Nevertheless, the statistical analysis (T-test) showed that there is no significant difference between the mean of the ETc predicted using the model and that observed from the field using lysimeter, however comparison between the predicted ETc and observed from the lysimeter using Nash-Sutcliffe efficiency (NSE) exhibited a high degree of agreement between the model output and the field observed data withR^2 = 0.9779, NSE values of 0.98, 0.68, 0.78and 0.66, RSR values of 0.11, 0.64, 0.59 and 0.58 for initial, development , middle and late stages respectively; in addition the RMSE for the same growth stages were found to be 0.86, 1.9, 1.6 and 0.92, this implies that the applicability of Hargreaves model is a good representation of calculating maize evapotranspiration for semi-arid region with sandy soil.*

Keywords: *Drainage; Evapotranspiration; Lysimeter; Organic Matter; Nash- Sutcliffe efficiency (NSE)*

1.0 INTRODUCTION

Agricultural water users need plan an of annual water budget in semi-arid and arid region lands and in areas where water usage is regulated due to ecological protection programmes, limited resources and competitive demand (Meysam, 2015). Irrigation plays an important role in food production globally. Irrigation is the supply of water to agricultural crops by artificial means, designed to permit farming in arid region and to offset the effect of drought in semi-arid region and even in areas where total seasonal rainfall is adequate or average (Vaughan *et al.,* 2007). The Rainfall pattern in Maiduguri semi-arid region of Nigeria is characterized by limited and undependable rainfall and the rate of moisture loss into the atmosphere through the process of evapotranspiration is relatively high (Abebe, 2012). Sorghum is the fourth most important world cereal and the second most important cereal after maize in sub-Saharan Africa (Nukenine *et al.*, 2010). Sorghum is grown mainly as a rain fed crop in the semi-arid areas. In these areas, sorghum production is being limited by water stress due to low and variable rainfall between season and within season, and hence sorghum yields vary considerably between years and show a close dependence on also in some highland areas (Yitebitu, 2004). The area of sorghum production is 1.62 million. Moreover, the determination of evaporation in a region with different simple or complex equations required a wide range of meteorological data. This again proved the difficulty of choosing the most appropriate method.However, elevation of organic material level in the soil can promote increased crop yield, stored moisture and enhancing evapotranspiration especially in sandier soil by management of cation exchange avoiding major losses by leaching (Yanfei *et al*, 2006). In addition, organic material is an important way to provide nutrient to plant and may promote greater absorption efficiency resulting in productivity gain (Sendiyama. *et al,* 2009). Moringa Olifera is a tropical crop, grown for its nutritional and medicinal purposes. Furthermore Groundnut haulm has most of the qualities of mulching materials, but is not commonly used in the semi-arid region of Africa (Maduka 2011). Most crops grow best in soil with organic matter content between 2 and 5 percent (Pennsylvania. 2009).Therefore, the current study is under taken to determine the most effective organic materials to be used for improved crop evapotranspiration for growth and yield of sorghum crop and to validate the applicability of ETc model develop by Hargreaves-Samani to the study area.

2.0 MATERIALS AND METHODS

2.1Experimental Site Description

The experiment was conducted at the Ramat Polytechnic Teaching and Research farm Maiduguri during the dry season between Februarys to April, 2018. Maiduguri i.e. on latitude 1 1.4°N and longitude 13.05°E it has the altitude of 354m above sea level Bashir., 2015).The average annual rainfall is around 640mm and the temperature is high ranging between 20-40^{o}C (Dalorima, 2002). The area is highly susceptible to drought with relative humidity of 13% and 65% in dry and rainy season respectively (Bashir, 2014). Also the area is vulnerable to desertification (Dibal, 2002).

Table 1: Soil Characteristics of the Experimental Site (0-30 cm)

Soil type (USDA soil classification)	Sand loamy
Clay (%)	8.0
Silt (%)	11.8
Sand (%)	80.2
P^{h}	6.8
Field capacity (vol. %)	16.2
Wilting point (vol. %)	3.2

Available water content (vol. %)	13.0
Bulk Density (g/cm^3	1.70
Organic matter (%)	3.99

2.2 Experimental design

The field experiment was conducted at the Teaching and Research Farm of the Ramat Polytechnic Maiduguri. The experimental site was15m x 15m. The selected area was divided into 3 plots of 14m x 4m each with a foot path of 1.5m in between the plots. Subsequently, the entire land area was fumigated manually to prevent the crops from pest attack. Drainage type lysimeter of 0.6m height, and 0.3 diameter with cross-sectional area of 0.85m^2 was used for this study. A plastic container (5 liters) was placed at 1m away from the lysimeter to serve as drainage collector. However, 0.02m (2cm) diameter plastic pipe was used to link between the lysimeter and the drain collector. The Installation was accomplished by used of backhoe, forklift, hand shovels, and hand tools. An order of returning excavated soil for the lysimeter. "Last out first in and first out last in" was used to maintain same natural soil structure or arrangement as suggested by Shukla et al., (2007). Furthermore, the lysimeter were set into the soil pebbles and wire mesh was placed at the bottom of the lysimeter to a depth of 5cm in order to facilitate easy drainage and help in preventing blockage of the drain. The organic materials used for this study were Moringa Olifera leaves, Groundnut Haulm and Maize Leaves were grown and incorporated into the soil at 0.45kg/m^2 tonnage to a depth of 8inch beneath the soil in the lysimeter for the all experimental unit, the crop was irrigated as per the design of the treatments. Measured quantity of water was applied. Soil moisture was measured before each irrigation. Since the experiment was carried out in dry season no rainfall part was considered and only change in soil moisture during the period under consideration were subtracted from the applied water to obtain crop evapotranspiration (ET_c).

2.3 Agronomic practices

An improved variety of sorghum developed by (ICRISAT) was obtained from Borno State Agricultural Development Programmed (BOSADP) Maiduguri was planted on the 1st of February, 2018 and to avoid alteration of the treatments, water were applied using a sprinkling irrigation method i.e. using hand watering-can as suggested by (Howell, 2001) .The standard lysimeter spacing of (1m) was used and the sorghum was planted six seed per hole in each lysimeter plots at the depth of 7cm using hoe. It was letter thinned to two seedling per hole on each experiment unit after germination. (De Rouw and Rajot, 2004).Recommended NPK fertilizer50kg of K_2O per hectare for most cereals crop was applied. The first dosage of fertilizer was applied after the first week of planting at a depth of 5-8cm, while the second dosage was also applied four weeks after planting as recommended by (Onyibe et al. 1997). Weeding was carried out manually throughout the growing period to avoid competition for space, water light and nutrients between the crops (James et al., 2000). The first weeding was done two weeks after planting and the second was carried out 5 weeks after planting. At the fully maturity i.e. late stage of growth (80day after sowing) all plants in each lysimeter experiment unit were manually harvested by use of cutlass, sickles were used to separate the panicle /cobs from their stalks, and were dried using sun drying method, while the threshing was accomplished by the use of local conventional procedure.

2.4 Estimation of crop Evapotranspiration (ETc) using lysimeter

The determination of crop evapotranspiration using lysimeter was achieved using Equation (1) below as suggested by (Sharma 1995). However, the moisture available in the soil at the root zone of the crops in each lysimeter was estimated using speedy moisture meter. Nevertheless, the difference between water applied and water drained was determined using measuring cylinder.

$$ET_c = R_w + I_w - QD \pm \Delta S \qquad (1)$$

Where: ET= Evapotranspiration (mm/day), Rw= Rainfall Water (mm) Iw= Irrigation Water (m^3) QD=Quantity of water drained Δs=Surface & Subsurface changes in storage difficulties Involved

2.5 Estimation of Crop Coefficient

Crop coefficient was determined at growth stages of the crop using empirical relation recommended by (Allen *et al*., 1994) shown in equation (2).

$$K_c = \frac{ET_c}{ET_o} \qquad (2)$$

Where, Kc is crop coefficient (-),ETc is crop evapotranspiration in (mm/day) was estimated as stated in equation 1,ET_o is reference evapotranspiration in (mm/day) was estimated using pan method as mentioned in shown in equation 3

$$ET_o = K_{pan} \times E_{pan} \qquad (3)$$

2.6 Determination of Leaf Area Index (LAI)

Leaf area index at all stages of growth was determined using Babiker (1999) formular

$$kc = \frac{\text{max } leaf \times \text{max width} \times \text{no.of leaves}}{\text{plant} \times 0.75 \times \text{no.of plants } /m^2} \qquad (4)$$

Where, 0.75 is the Correction factor for crop

2.7 Determination of the crop yield

The panicle length of the fully matured grain was measured using meter rule and the mean was recorded for each treatment in (cm). Number of panicle per plant was counted and the mean values were recorded. The panicle from each lysimeter in the experiment units were threshed, seeds were counted, and the average seed number per head was recorded.

2.8 Hargreaves-Samani Crop evapotranspiration (ETc) models

The model considered for validation is Hargreaves-Samaniequation for estimating crop ET which doesn’t require wind speed data Presented in FAO - 56 by Allen et al. (1998) Adopted by Abhinaya *et al* (2015). For the validation studies, some meteorological parameters such as daily values of mean minimum and maximum temperature, sunshine, mean daily relative humidity, and evaporation using evaporation pan was collected and considered. These weather parameters were obtained from Ramat Polytechnic and

Maiduguri international airport weather stations (NIMET) and were substituted into models as presented in equation 5 below

$$ET_c = \frac{0.0135Rs\,(T + 17.8)}{2} \qquad (5)$$

Where; $Rs=0.758RaS^{0.50}$, and $S=0.125(100-Rh)$,Rh = daily mean relative humidity (%), T mean is the daily mean air temperature (◦C), and Rs is mean daily sunshine radiation (mm day^{-1})

2.8.1 Model performance evaluation

The validity agreement between the observed and predicted crop evapotranspiration was quantitatively evaluated using the Nash- Sutcliffe efficiency (NSE), the ratio of the root mean square error to the standard deviation of measured data (RSR), and root mean square error (RMSE). The evaluation were rated 'Very Good' (0 ≤ RSR ≤ 0.50 and 0.75 < NSE ≤ 1.00), 'Good' (0.50 < RSR < 0.60 and 0.65 < NSE < 0.75), 'Satisfactory' (0.60 < RSR < 0.70 and 0.50 < NSE < 0.65), or 'Unsatisfactory' (RSR > 0.70 and NSE ≤ 0.50), according to the criteria suggested by Moriasi *et al.* (2007).

$$RSR = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(ET_{cobs-}\,ET_{cal})^2}}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(ET_{cobs-}\,ET_{mean})^2}} \qquad (5)$$

$$RMNS = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(ET_{cobs-}\,ET_{cal})^2} \qquad (6)$$

$$NS = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(ET_{cobs-}\,ET_{cal})^2} \qquad (7)$$

Where; ETc_{cal} = calculated ETc by model, ET c_{obs} = observed ET_C by lysimeter and ETc_{Mean}=average daily ET_{obs} over the season

2.9 Data Analysis

All the data collected on the growth and yield parameters of the millet were subjected to Analysis of Variance (ANOVA) using Statistic 8.0 package. The difference between treatments means were separated using least significant difference (LSD).

3.0 RESULTS AND DISCUSSION

3.1 Influence of Organic Materials on Crop Evapotranspiration (ETc)

The experimental results obtained on influence of organic materials on crop evapotranspiration ET_C, Crop coefficient K_C, leaf area index LAI, Yield and yield attributes of millet are presented in internationally recognized growth stages Initial (10 DAS), development (35 DAS), middle (60 DAS) and late season (80DAS) stages and DAS means (day after sowing) as illustrated in Table 2, 3, 4, 5&6 below.

Table 2 Influence of organic materials on evapotranspiration (ETc) of sorghum crop at different growth stages (mm)

Treatments	Initial	Development	Middle	Late
Maize leave	16.3[b]	62.2[c]	137.6[b]	97.7[a]
Moringa leave	18.2[a]	97.8[a]	148.0[a]	76.6[b]
Groundnut haulm	18.0[a]	79.0[b]	133.3[c]	68.1b[c]
Control	17.6[b]	82.3[b]	137.7[b]	71.6[c]
SE±	2.537	4.04	3.331	5.140

Means within a treatment column followed by similar letter(s) are not significantly different at 5% probability level

The organic materials used had significantly ($P<0.05$) influenced the evapotranspiration of millet (Table 2). The highest evapotranspiration values of 18.2mm, 97.8mm, and 148.0mm at initial, development and middle stages of growth respectively occurred due to the use of Moringa Olifera leaves as an organic material. It was closely followed by Maize leave (97.7mm) at late stage. Also there were significant differences among the organic materials used. Thus, groundnut haulm has the least value (68.1mm) at late stage. Whereas, crop evapotranspiration is less in control lysimeter than all the treatment used. These results are similar to finding of (Irmak, 2009), who reported that the weekly ET_c values for millet ranged from 25.2 to 61.9 mm. Higher ET_c values were recorded from initial and development stages as compared to the values in the initial and end of the crop life cycle.

3.2 Influence of Organic Material on Stage –Wise Crop Coefficient (Kc) of sorghum. The results obtained on the influence of organic materials on crop coefficients of sorghum are presented in Table 3 below.

Table 3: Influence of organic material on stage –wise crop coefficient (Kc) of the sorghum crop at different growth stages.

Treatments	Initial	Development	Middle	Late
Maize leave	0.35[c]	0.79[d]	1.27[a]	0.33[b]
Moringa leave	0.40[a]	1.16[a]	1.38[a]	0.93[a]
Groundnut haulm	0.39[ab]	0.95[c]	1.30[a]	0.69[ab]
Control	0.35[c]	1.06[b]	1.31[a]	0.66[ab]
SE±	0.180	0.093	0.204	0.368

Means within a treatment column followed by similar letter(s) are not significantly different at 5% probability level

Crop co-efficient values for different growth stages of millet crop were significantly ($p<0.05$) influenced by the treatments used Table 3. The highest millet crop coefficient (Kc) values (0.40, 1.16, 1.38 and 0.93) at all the stages growth were occurred as a result of moringa leaves use as an organic material. It was closely followed by groundnut haulm with Kc values range from (0.39, 0.95, 1.30 and 0.69) correspondingly. While, least (Kc) values were recorded from the maize leaves and control plot. The changed in Kc could be attributed to the seasonal variation of leaf area, the results were tallied with the findings of Zhang *et al* (2005). For more detail see Figure 1.

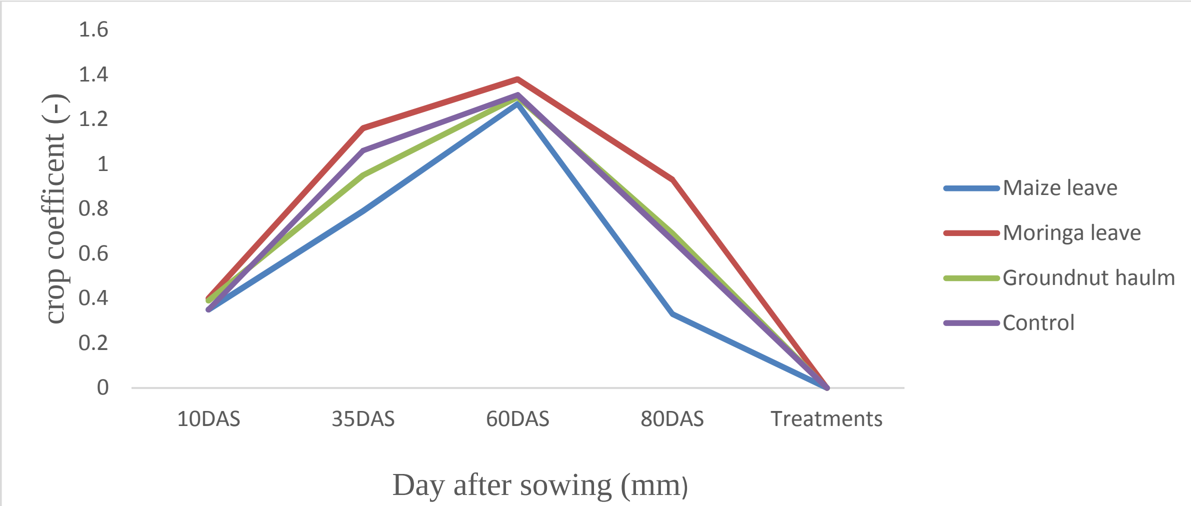

Figure: 1 showing the graph of Kc versus DAS

3.3 Influence of Organic Material on Crop Leaf area Index (LAI) of Sorghum

Results obtained on influence of organic materials on leaf area index of sorghum crop are illustrated in Table 4 below.

Table 4: Influence of organic materials on leaf area index of sorghum crop at different growth stages (m^2)

Treatments	Initial	Development	Middle	Late
Maize leave	0.03^{b}	0.25^{c}	2.40^{b}	1.87^{ab}
Moringa leave	0.04^{a}	0.34^{a}	3.20^{a}	1.50^{b}
Groundnut haulm	0.03^{ab}	0.22^{d}	3.00^{a}	1.93^{a}
Control	0.02^{c}	0.28^{b}	2.50^{b}	1.50^{b}
SE±	0.342	0.126	0.2514	0.321

Means within a treatment column followed by similar letter(s) are not significantly different at 5% probability level

The leaf area index (LAI)) of a sorghum crop were significantly ($P > 0.05$) affected by the treatment used throughout the period of experiment Table 4. Rapid increase in LAI was observed highest with moringa olifera leaves during initial, development and mid- stage of the crop growth with corresponding values of 0.04, 0.34, and 3.20, closely followed by groundnut haulm at mid-stage with LAI of 3.0. Similarly at late stage the highest LAI (1.93 and 1.87) was recorded both in groundnut haulm and maize leave respectively. This could be attributed to leaf droppings at crop full maturity affects the leaf area index. Similar observation was reported by Fasinmirin *et al*. (2015).

3.4. Influence of Organic Material on Yield Parameters and Yield of Sorghum

The experimented results of the yield and its attribute of sorghum crop as influenced by the organic material used as treatments were illustrated in Table 5.

Table 5: Influence of organic material on yield attributes and yields of sorghum crop

Treatment	Panicle length (cm	Panicle diameter (cm)	Number of panicle per plant	No seed per panicle	Panicle weight (Kg)	Yield (kg/ha)
Maize leave	21.17[a]	10.2[ab]	3[b]	2228.7[bc]	0.3690[bc]	2969.5[b]
Moringa leave	21.23[a]	11.2[a]	5[a]	2636.0[a]	0.4190[a]	3663.8[a]
G. haulm	20.33[ab]	10.3[ab]	4[ab]	2390.0[ab]	0.3553[b]	3468.0[ab]
Control	19.00[b]	10.3[ab]	2[c]	1979.0[c]	0.2360[c]	2308.3[bc]
SE±	2.029	1.351	1.793	349.13	0.0850	364.72

Means within treatment and a column followed by similar letter(s) are not significantly different at 5% probability level.

The treatments used were significantly ($P<0.05$) influenced the yield and it parameters sorghum crop as shown in Table 5. Moringa leaves and maize leaves gave highest number of panicle lengths per plant (21.17and 21.23) respectively. It were followed by groundnut haulm (20.333) and control having the least (19.0). Also, the highest panicle diameter and number of panicle per plant were obtained from moringa leaves were 11.2cm and 5cm respectively. Conversely, followed by groundnut haulm with (10.3cm and 4), while the least was recorded from maize leaves and control. The findings were agreed as stated in (Wahome *et al*, 2010). Also the maximum grain yield of 36637.8 kg/ha with total seed per panicle of (2636.0) was obtained from moringa Olifera. It was closely followed by the groundnut haulm and maize leaves with corresponding yield and number of seed per panicle of (3468.0kg/ha, 2969.5kg/ha) and (2390.0 and 2228.7), respectively. The least yield of 2308.3 kg/ha was recorded in control plot and was achieved with (1979.0) number seed per plant respectively. According to FAO (2010) reported that the number of seed per plant are the most important characters that affect seed yield in most cereal crops.

Table: 6 Performance evaluation comparison between crop evapotranspiration observed from (lysimeter) versus predicted from Hargreaves–Samani (ABC model) for sorghum crop at different growth stages.

Growth stages	ETobs (mm)	ETcal (mm)	ΔET	ET mean (mm/day)	RMSE	NSE	RSR	Performance Rating
Initial	17	18.9	-1.9	1.8	0.86	0.99	0.12	VG
Development	82	70.2	11.8	3.0	1.2	0.65	0.60	G
Middle	138.1	135.3	2.8	5.5	0.93	0.69	0.54	G
Late	72.5	78.2	-5.7	3.7	0.38	0.68	0.59	G

RMSE – root mean square error; NSE – Nash-Sutcliffe efficiency; RSR – ratio of the root mean square error to the standard deviation of measured data; S – satisfactory; VG – very good; G – good, and ΔET difference in ETc.

The comparison as presented in Table 6, showed a good agreement between the ETc calculate from ABC model and ETc observed from the lysimeter for the sorghum crop, the model output and the experimental result plotted on the graph Fig 4.1, have yielded the slope and intercept of 10.971x and 3278respectively and with R^2 of 0.977, exhibited a high degree of agreement between the model output and the field observed data. the NSE values of 0.99, 0.65, 0.69 and 0.68 and RSR values of 0.12, 0.60, 0.54 and 0.59 for initial, development , middle and late growth respectively. In addition the RMSE for the same growth stages was found to be (0.86, 1.2, 0.93, and 0.38) and also indicated that model performed 'Very Good' in estimating the seasonal evapotranspiration of millet. However, the agreement between the calculated and measured values as presented in Table 4.9.1 varied from the agreement rated 'very good' for the initial stage, 'good' for development stage, middle stage, and the late stage. Similarly, the observed and predicted millet crop evapotranspiration were analyzed using T-test as shown Table 6 below indicating that there is no significant difference between the predicted and measured crop evapotranspiration at ($P<0.05$), implies that, the applicability of ABC model is a good representation of calculating evapotranspiration to semi-arid region with sandy loam in the study area.

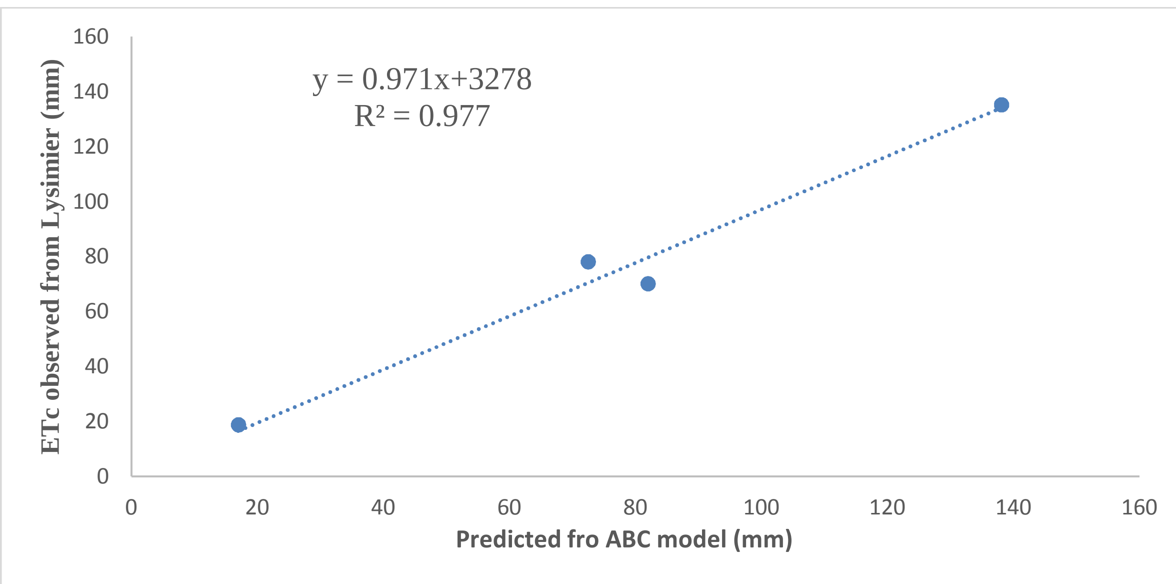

Figure: 2 showing relationship between the predicted and observed ETc

Table 7: Summary of T-Test for comparing ETc by Lysimeter and ABC model at growth stages

Z	*ETc Predicted values (mm)*	*ETc Observed values Millet (mm)*
Mean	75.65	77.4
Variance	2271.63	2459.273333
Observations	4	4
Pooled Variance	2365.452	
Hypothesized Mean Difference	0	

Df	6
t Stat	-0.050
P(T<=t) one-tail	0.480
t Critical one-tail	1.943
P(T<=t) two-tail	0.461
t Critical two-tail	2.446

T Stat < T critical

As presented in table 7 there is no significant difference between the ETc observed from the lysimeter and ETc predicted from fapohunda model. Therefore, ETc predicted from the model and the ETc observed from the field produce the same result. This indicate that the ABC model is a good representation of calculating evapotranspiration to semi-arid region with sandy loam in the study area.

4.0 CONCLUSION AND RECOMMENDATION

The research analyzed the influence of organic materials on crop evapotranspiration of sorghum crop, to determine its influence on the crops. The study employed statistical technics including analysis of variance (ANOVA) and Nash- Sutcliffe efficiency (NSE) and concluded as follows:

1. Analysis of variance (ANOVA) showed a significant difference between the treatments used (organic materials). Moringa Olifera has the highest influence on $ET_{C,}$ Kc, LAI at all stages of growths and significantly influenced the yield of the grain with (3663.8kg/ha) than of all other treatment experimented
2. comparison between the predicted ETc and observed from the lysimeter using Nash- Sutcliffe efficiency (NSE) exhibited a high degree of agreement between the model output and the field observed data with an $R^2 = 0.9779$.
3. The results of comparison the study implies that the applicability of Hargreaves model is a good representation of calculating sorghum crop evapotranspiration to semi-arid region with sandy soil.
4. The statistical analysis (T-test) showed that there is no significant difference between the means of the ETc predicted using the model and that observed from the field using lysimeter
5. Similar experiment are needed to be conducted at different agro-ecological condition in order to confirm the findings

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