Effect of some selected soil properties, moisture content, yield and consumptive water use on two Cassava (TMS 0581 and TME 419) varieties

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Abstract

The increasing demand of Cassava for our dietary needs and shortage experienced going by the burgeoning global population is a cause for concern that requires urgent attention. The study therefore considered the effect of some selected soil properties, nutrients, moisture content, yield and consumptive water use on two selected Cassava varieties TMS 0581 and TME 419 respectively. The design was a randomised complete block design of four treatments and three replicates. Treatment A had fertigation, B used poultry manure, C employed nitrogen-phosphorus-potassium, 15-15-15 while D with no treatment was used as control. Soil properties such as bulk density, particle density, soil classification and nutrients such as cation exchange capacity, organic matter, nitrogen, potassium and others were determined using standard procedures. Penman-Monteith model was used in estimating reference evapotranspiration while its product with crop coefficient produced crop evapotranspiration. Moisture content was measured at depths 10, 20 and 30 cm respectively while water use efficiency (WUE), irrigation water applied and tuber yield were also determined. The findings of this study showed that all the soil properties were within permissible levels to encourage optimum agronomic development of Cassava plant and the class was entirely a loamy soil, which permits well-developed root-tuber configuration. Tuber yields varied from 21.96 kg to 25.13 kg for TMS 0581 variety while TME 419 had 17.04 kg to 31.63 kg in all the treatments. Deficiencies were observed in some of the nutrients, which were replenished with the introduction of the fertilisers among the plots. Moisture content at 30 cm depth is suggestive of adequate water availability sufficient enough to encourage proper tuber development for optimum yield while fertigation technique was adjudged the best as it improved Cassava *Tuberisation* and WUE in all the treatments considered.

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Key words: Cassava; evapotranspiration; nutrients; soil properties; water use efficiency; yield.

Acknowledgements: the authors are grateful to the Federal University of Technology, Akure (FUTA) Nigeria for providing the institution-based research (IBR) TETFund Research Grant with No. TETFUN-DRGC/MAJOR/2014/155 that was used in executing this research. The efforts of the anonymous reviewers are also gratefully appreciated.

Received for publication: 6 November 2018.
Accepted for publication: 1 April 2019.

Journal of Agricultural Engineering 2019; L:919
doi:10.4081/jae.2019.919

Introduction

Cassava (*Manihot esculenta Crantz*) is a tropical root crop of the family *Euphorbiaceae* with a well-developed fibrous root system, which is grown mainly in the tropical region of Africa (including Nigeria), Brazil, Indonesia, Philippines and Thailand (Olukunle *et al.*, 2010). It is normally planted from stem cuttings and thrives in fairly bad weather and poor soils with little or no fertiliser application. Cassava forms a major part of the dietary calorie equivalent of 238 kcal (Agbetoye, 2003). It grows well in areas with annual rainfall of 500-5000 mm and full sun, but it is susceptible to cold weather and frost (Eze and Ugwoke, 2010). A very wide range of Cassava varieties are grown worldwide depending on the locality, but they are broadly classified into the sweet and the bitter varieties based on the level of the poisonous hydrogen cyanide present in the tuber. Nigeria is by far the highest producer of the crop in the world with production level estimated at 49 million tons per year (Uthman, 2011). This is a third more than the production in Brazil (World's second largest producer) and almost double the production of Indonesia and Thailand. They are also classified based on time to maturity. Most of the traditional varieties mature in eighteen months and beyond but, some new improved Cassava varieties have been developed by the International Institute for Tropical Agriculture (IITA), which matures as early as six months after planting (IITA, 2010). They are high yielding, more resistant to pest and diseases, with cyanide contents as low as 3.1 mg/100 g (Uchechi and Nwanchukwu, 2010). Cassava is presently the most important food crop in Nigeria from the point of view of both the area under cultivation and the tonnage produced. This is the fact that it has transformed greatly into high yielding cash crop, a foreign exchange earner, as well as a crop for world food security and industrialisation, as a result of this, there has been an unprecedented rise in the demand for Cassava and its numerous products worldwide for both domestic and industrial applications (Ayoola and Makinde, 2007). Several efforts have been put into improving its production (for example: Odedina *et al.,* 2012; Anju *et al.*, 2014). Oguntunde (2005) concluded that production of drought resistant varieties and increase in land area under cultivation will improve cassava production. Similarly, Akinbile *et al*. (2011) identified efficient adoption of irrigation technology as another major way of ensuring increased Cassava production and therefore precise water application is required to study the behavioural pattern of Cassava during water deficit. The problem of irrigation in Nigeria today is not about lack of abundant water resources but that of efficient utilisation of the resources (Akinbile *et al*., 2011). With the introduction of new technologies, which combined fertiliser application with irrigation (fertigation), the process of growth and development of crops have been simplified as ambiguities associated with poor irrigation and fertiliser application have been eliminated (Liang *et al*., 2014). Drip irrigation with its ability of small and frequent water applications have created interest in view of decreased water requirements, possible increased production, and better product quality. It was reported by Edoga and Edoga (2006) that with drip irrigation, soil is maintained continuously in a condition, which is highly favourable to the crop growth. Studies carried out by Burns *et al*. (2012), Gicheru *et al.* (2003) and Cadavid *et al.* (1998) has shown that it does well on light, sandy loams or on loamy sands, which are moist, fertile and deep. It also does well on soils ranging in texture from sands to clays and on soils of relatively low fertility. In practice, it is grown on a wide range of soils, provided the soil texture is friable enough to allow the development of the tubers. On very rich soils the plant may produce stems and leaves at the expense of tubers. The objective of this study therefore was to determine the moisture content, soil properties and consumptive use of the two Cassava varieties (TMS 0581 and TME 419) within the entire growing season.

Materials and methods

The study was conducted at the experimental farm of Agricultural and Environmental Engineering Department, The Federal University of Technology, Akure, Ondo State between January and November 2016. Akure is located within the humid region of Nigeria on latitude 9°17’N and longitude 5°18’E. It lies in the Rain Forest zone with a mean annual rainfall between 1405 mm and 2400 mm, with two distinct seasons, a relative dry season from November to March and a wet/rainy season from April to October (Akinbile *et al.,* 2011). Average temperature of the area is 27.5°C while relative humidity ranged between 85% and 100% during the rainy season and less than 60% during the harmattan period. Soil at the experimental field is sandy loam, which is an alfisol classified as clayey skeletal oxic-paleustaif (USDA) (Akinbile and Yusoff, 2011). The field experiment was laid out in a randomised complete block design consisting of four treatments and three replicates, making a total of 12 plots (Figure 1) [Treatment A = liquid fertiliser (Plantzyme Agricultural Soluble Fertiliser) administered at 2.0 t ha^{-1}; Treatment B = poultry manure; Treatment C = NPK fertiliser and Treatment D = control]. Each plot was of dimensions 4 m x 4 m and total field dimension was 22×16 m with 2 m alley ways along the length and width of the plots and between the plots and the fence at the four edges respectively. The field was planted with 96 pieces each of TMS 0581 and TME 419 Cassava cuttings, which were obtained from the IITA, Ibadan, Nigeria in March, 2016. Drip emitters were connected to main pipes, which were connected to two reservoirs located at 4 m away from the edge of the experimental field at the upper end (Figure 2). These emitters, in pre- determined drip irrigation frequency were used to convey the mixture into the respective blocks of treatments. Agronomic parameters were measured weekly which began from three (3) weeks after planting (WAP) and ended at 32 WAP. Irrigation water was applied to the crops at

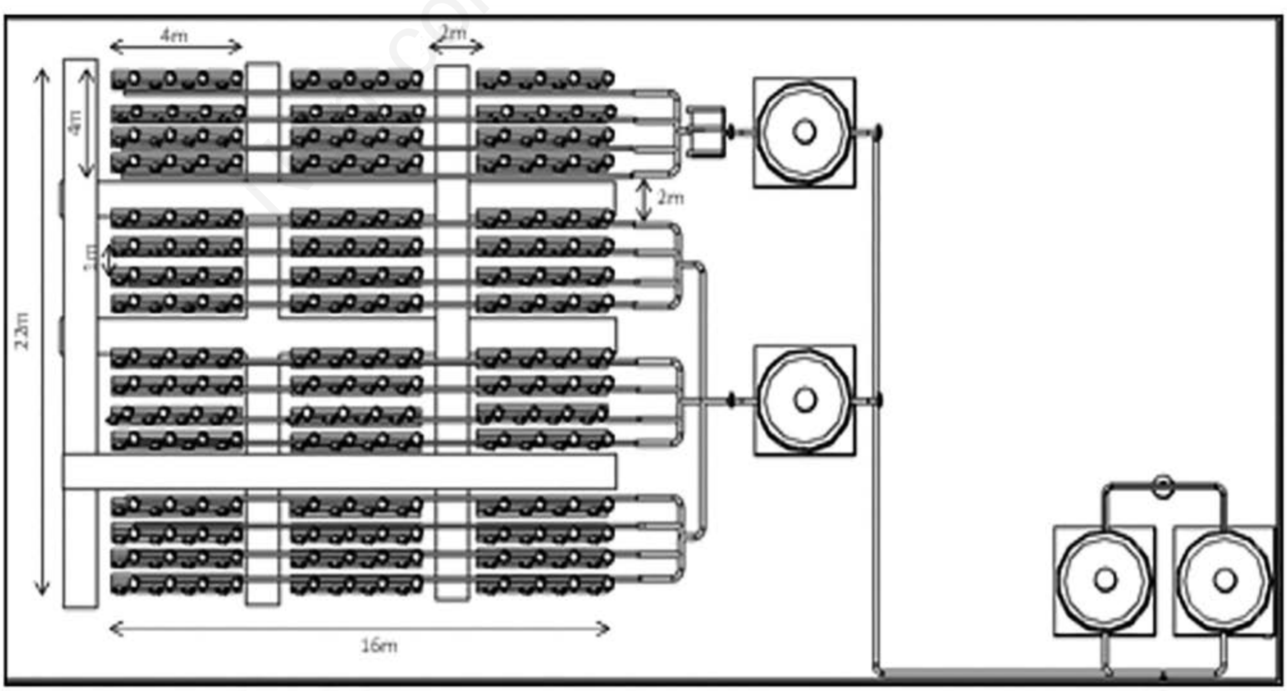

Figure 1. The layout and design of the experimental farm.

three days' interval during the peak of the dry season *i.e.* between 7th March and 18th May 2016. Irrigation water application was reduced to once a week between 18th May and 20th July when rains had begun to stabilise. There was no irrigation from 21st July to 12th November 2016. At this period, adequate rainfall was experienced to wet the soil for optimum crop growth. Soil samples before and after crop establishment was collected and analysed. Soil parameters measured included: bulk density, particle size density, pH, exchangeable acidity, cation exchange capacity (CEC), nitrogen content (N), carbon content (C), potassium content (K), zinc content (Zn), calcium content (Ca), magnesium content (Mg), sodium content (Na) and organic matter content (OM). Soil moisture content was measured weekly at 0.1 m interval up to 0.5 m by gravimetric method. The weekly average reference and crop evapotranspiration (ET_0 and ET_c) was computed using the Penman-Monteith model (Allen *et al.,* 2005). Weather parameters (evaporation, maximum and minimum air temperatures, relative humidity, shortwave solar radiation, and wind speed) were obtained from the FUTA/West African Science Centre on Climate Change and Adapted Land Use (WASCAL) Meteorological Station, which is about 15 m from the experimental site. Results obtained during experimentation were subjected to statistical analysis using SAS 9.1 version while one-way ANOVA and least square difference were performed on all data at 95% significance level.

Results and discussion

Soil physical properties

The results of variations in some selected soil's physical properties and particle size distribution within the four treatments A to D were as presented in Table 1. All the treatments had relative low bulk density with values ranging from 1.41 g/cm^3 in A and 1.44 g/cm^3 in D with no statistical difference across rows. Low bulk density (<1.5 g/cm^3) as recommended by Hunt and Gilkes (1992) is highly desirable and therefore favours Cassava production. In general, soil at the experimental field is considered good due to proper aeration and considerable water retention capacity across the treatments as depicted by the BD values. As for the Particle size distribution analysis, the soil class was determined using the USDA Textural Classification, is predominantly sandy clay loam, with high loam fraction in all the treatments which agreed with the findings of Agele (2003) who reported that the soil around the experimental field is sandy clay loam. The soil has weak surface aggregation but not poor enough to lack adsorptive capacity for basic plant nutrients. The small constituent of clay content, from 25.36% through 31.76% across all the treatments disallowed the soil to be susceptible to erosion menace thereby supporting sustained basic plant nutrients for optimum production. The sandy clay loam texture of the soil with good aeration favours crop growth under drip or sprinkler irrigation system.

Results of some soil properties analysed across the four treatments were as presented in Table 2. From the table, some of the treatments have significant differences in some of the physico-chemical parameters such as C, P, K, Mn, Zn and Mg, while N, Ca and Na showed no significant difference. Total N values were all within the Food and Agricultural Organisation (FAO) maximum permissible limit of 0.5% in all the treatments but closest to the upper limit in treatment D (0.48%), which may be due to the presence of ammonia that existed in the soil that has been previously used for rice cultivation prior to this experiment and in the fertilis-

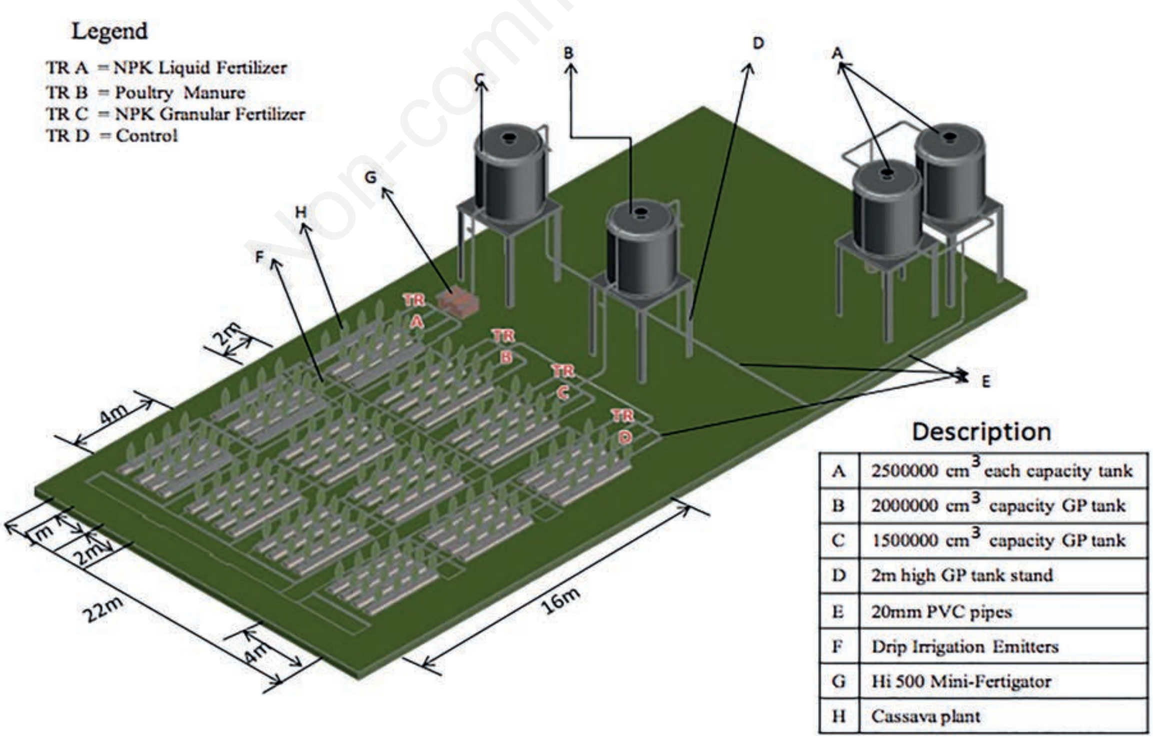

Figure 2. The 3-D orthographic projection of the experimental field.

ers used. This observation has been attributed to poor vegetative growth, fast rate of decomposition, and the high temperature of the ecological zone (Akpan-Idiok *et al.,* 2013). However, the low content of nitrogen that was generally recorded in the study area could be attributed to indiscriminate bush burning by the farmers, leaching and the high rate of organic matter decomposition by microorganisms. Also, attributed to this observation was rapid mineralisation and absorption of nitrogen due to continuous farming, which does not give room for fallow (Odjugo, 2008). Changes in available P were expectedly generally low in all the plots because P is relatively immobile and strongly adsorbed by soil particles. The phosphorus deficiency was caused by heavy precipitation recorded shortly before the commencement of dry season prior to the experiment, which was leached out of the soils. Exchangeable K decreased in all the plots irrespective of the treatment type. This is an essential plant nutrient that is required in large quantities for proper growth of plants. Its deficiency, also known as potash deficiency is associated with a chalky or peaty soil (such as the soil at the study site) with a low clay content (Table 1).

As for the OM, CEC and BS, they all have significant effect on the soil in all the treatments and were all within the FAO permissible limits (Table 2). Treatment C performed better in all the treatments on the OM content of the soil. The incorporation of poultry manure in treatment C has been shown to increase the amount of soluble organic matter which is mainly organic acids that increase the rate of absorption of phosphate and thus improves the available P content in the soil. Considering the CEC content of the soil, treatment D's performance was the best amongst all the treatments with 6.79±3.28 cmol/kg but still within the FAO permissible limit of 10.00 cmol/kg. All the treatments had values higher than the permissible range of 60-80% on BS of the soil. The soil was slightly acidic in all the treatments with values 5.85±0.07^a, 5.81±0.51^a, 6.10±0.03^a and 5.67±0.02^a respectively but slightly below the permissible range of 6.5-8.5 (Table 2). Utsev *et al.* (2014) reported that such pH condition of the soil could be attributed to the high rainfall, as a result of leaching of appreciable quantities of exchangeable base forming cations such as calcium, magnesium, potassium and sodium from the surface layers of the soils and high buffering capacity. This was also observed elsewhere in the Lower River Benue Basin (Izaurralde *et al.,* 2006; Akpan-Idiok *et al.,* 2013). FAO (2005) reported that Cassava tolerates soil within a wide pH range of 4.0 to 8.0 but the best pH range for growing Cassava is 5.5 to 6.5. The pH of the soils of experimental field is therefore suitable for Cassava cultivation.

Moisture content

Table 3 showed the average moisture content at depths 10, 20 and 30 cm respectively in all the four treatments. Significant differences across the different depths in all the treatments were noticed. The soil moisture showed an increasing trend as the depth increases. Treatment A had value of 10.85±0.01^a, 11.40±0.00^a and 11.25±0.01^a when compared with Treatment D that had values

Table 1. Some selected soil's physical properties and particle size distribution analysis in all treatments.

Parameters	Treatments				Standards
	A	B	C	D	
Bulk density	1.41±0.01^b	1.43±0.01^{ab}	1.41±0.01^b	1.44±0.01^a	1.3-1.5 (g/cm^3)
Particle density	2.54±0.01^a	2.57±0.01^a	2.54±0.02^a	2.53±0.01^a	2.65 (g/cm^3)
Sand (%)	33.18	32.35	32.24	32.52	-
Silt (%)	41.47	41.22	38	40.21	-
Clay (%)	25.36	26.43	29.76	27.27	-
Class	Loam	Loam	Loam	Loam	-

Data represent the mean±standard error mean of triplicate readings. Values with different superscripts in the same column were significantly different (P<0.05).

Table 2. Variations in other soil parameters analysed in all the treatments.

	Treatments				
Parameters	A	B	C	D	FAO range
N (%)	0.44±0.01^a	0.54±0.06^b	0.40±0.02^a	0.48±0.01^a	0.2-0.5 (%)
C (%)	4.21±0.01^a	4.21±0.56^b	4.77±0.39^a	4.71±0.10^a	2.0-5.0 (%)
P (mg/kg)	4.34±0.05^b	4.08±0.69^c	4.80±0.39^a	4.54±0.08^b	5.0-20.0 (mg/kg)
K (cmol/kg)	0.51±0.01^a	0.19±0.04^b	0.26±0.04^b	0.48±0.80^a	0.6-1.2 (cmol/kg)
Mn (cmol/kg)	0.02±0.00^b	0.60±0.03^a	0.08±0.06^b	0.03±0.01^b	0.02-2.0 (mg/kg)
Zn (mg/kg)	10.30±0.71^b	11.05±0.50^{ab}	12.82±0.83^a	10.94±1.00^{ab}	10-20 (mg/kg)
Ca (cmol/kg)	2.12±0.01^a	2.06±0.11^a	0.31±0.01^a	0.43±0.15^a	10-20 (cmol/kg)
Mg (cmol/kg)	0.31±0.01^a	0.31±0.00^b	0.31±0.01^a	0.43±0.15^a	3.0-8.0 (cmol/kg)
Na (cmol/kg)	1.18±0.02^a	1.31±0.48^a	1.07±0.85^a	1.20±0.19^a	0.7-1.2 (cmol/kg)
pH	5.85±0.07^a	5.81±0.51^a	6.10±0.03^a	5.67±0.02^a	6.5-8.5
OM (%)	7.23±0.04^b	7.25±0.96^b	8.22±0.11^a	8.12±0.17^a	2-10 (%)
CEC (cmol/kg)	4.56±0.01^b	4.26±0.29^c	4.16±0.23^c	6.79±3.28^a	10.00 (cmol/kg)
BS (%)	90.87±0.01^b	90.79±1.43^b	91.33±0.95^b	95.23±3.35^a	60-80%$^{+++}$

Data represent the mean±standard error mean of triplicate readings. Values with different superscripts in the same column were significantly different (P<0.05).

8.80±0.14[c], 9.45±0.01[c] and 8.65±0.01[c] at 10, 20 and 30cm depths respectively. This result showed that available moisture for optimum growth was adequate for the cassava tubers at depth below 20 cm. Adequate water was supplied promptly through drip irrigation system and the moisture's availability for the Cassava optimal performance was however supplemented through intermittent rainfall, especially during the second half of the research when water supply was considerably reduced due to changes in weather pattern. The effect of soil moisture among the treatments became clearer after the crop had reached the vegetative stage, that is, between 12 and 90 days after planting (DAP) when distinct agronomic features were obvious. It should be noted however, that water requirement of Cassava is at its highest demand at the mid-season period when true leaves began to expand and photosynthesis began. This is dependent on the amount of nutrient reserved in the soil for its initial leaf and root formation. *Tuberisation* started between 30 and 40 DAP (4 to 6 WAP). At 60 DAP (8 WAP), when the fibrous and tuber roots were present, first fertilisation was carried out. Above 90 DAP (12 WAP), moisture requirement of the Cassava decreased since features indicating that the crop has reached early maturity stage began to be visible. This may be due to the maximum growth of the leaves and the stems and the corresponding maximum light interception with large dry matter allocation to the leaves and the roots. The soil moisture level obtained was adequate for the optimal growth of Cassava. This finding was confirmed by FAO (2013), which reported that Cassava, once it is established can grow in regions that receive just 400 mm of average annual rainfall.

Crop water use pattern

Table 4 contained results on applied irrigation water and the estimated values of water use efficiency (WUE) in treatment plot for the two Cassava varieties, TMS 0581 and TME 419 respective-

Table 3. Soil moisture content distribution at various depths in all the treatments.

Treatments	Depth (10 cm)	Depth (20 cm)	Depth (30 cm)
A	10.85±0.01[a]	11.40±0.00[a]	11.25±0.01[a]
B	10.35±0.01[b]	10.85±0.49[b]	11.02±0.21[a]
C	10.40±0.14[b]	10.65±0.01[b]	10.50±0.14[b]
D	8.80±0.14[c]	9.45±0.01[c]	8.65±0.01[c]

Data represent the mean±standard error mean of triplicate readings. Values with different superscripts in the same column were significantly different (P<0.05).

Table 4. Water use efficiency in all the treatment plots for TMS 0581 and TME 419 Cassava varieties.

Cassava variety	Treatments			
Parameters TMS 0581	A	B	C	D
Applied irrigation water (mm)	250	170	400	190
Effective rainfall (mm)	871	871	871	871
Total water used (mm)	1121	1041	1271	1061
Applied water (%)	22.3	16.3	31.5	17.9
Yield (kg/ha)	23,169	22,669	25,125	21,956
Water use efficiency (kg/ha/mm)	26.47	22.26	19.77	20.69
Parameters TME 419	A	B	C	D
Applied irrigation water (mm)	290	210	350	250
Effective rainfall (mm)	871	871	871	871
Total water used (mm)	1161	1081	1221	1121
Applied water (%)	25.0	19.42	28.7	22.3
Yield (kg/ha)	31,625	17,044	25,081	17,331
Water use efficiency (kg/ha/mm)	29.82	15.77	20.54	15.46

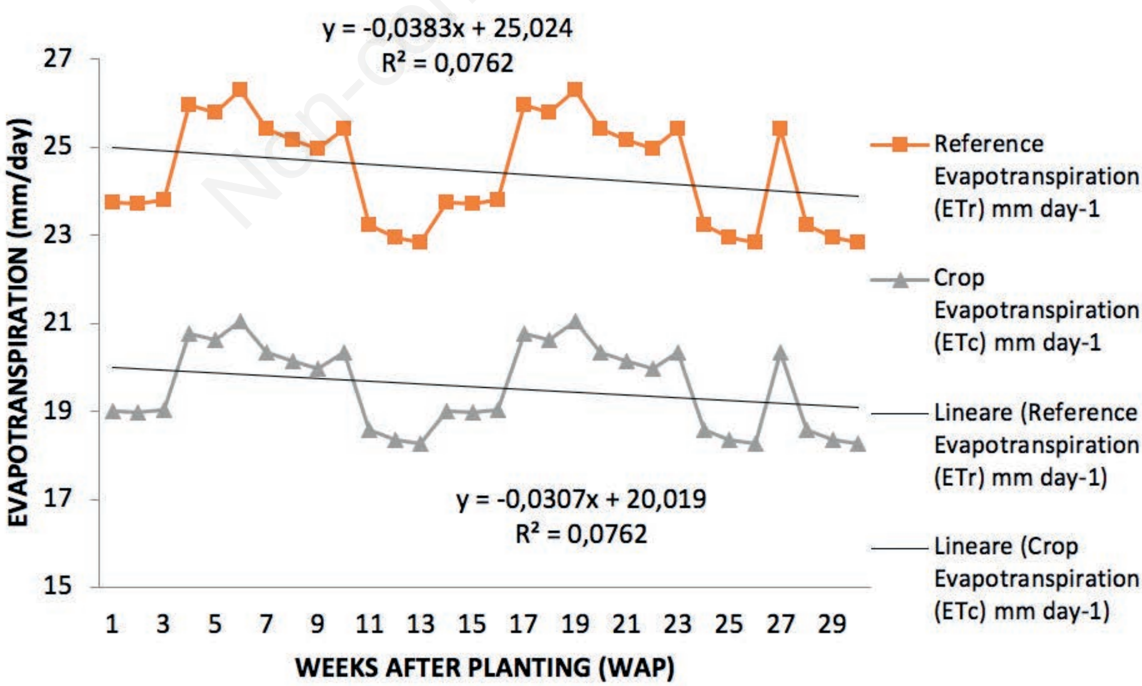

Figure 3. Trend analysis of the average weekly reference and crop evapotranspiration (ET_r and ET_c).

ly. In TMS 0581, Treatment C had the highest irrigation water applied and expectedly had highest yield of 25, 125 kg/ha but lowest WUE of 19.77 kg/ha/mm. for the same variety, even though Treatment B had lowest applied water, the yield was not substantially different from that of C that had the highest while treatment A had the highest WUE of 26.47 kg/ha/mm despite having received just 250 mm of irrigation water. The implication of these findings is that increased water application does not translate to increased WUE while there is a linear correlation between increased water application and yield from the study. Other factors apart from water were also responsible for the Cassava (TMS 0581) yield behaviour such as fertilisation application. While plot A received fertigation treatment, plot B received poultry manure but NPK (15-15-15) fertiliser was administered to plot C and D received nothing (control). For the second variety TME 419, a slightly different scenario played out (Table 4). Plot A (fertigation) though received second highest applied water (1161 mm) when compared with Plot C (NPK) with 1221 mm, still had maximum total yield (31, 625 kg/ha) and highest WUE (29.82 kg/ha/mm). This defiled the linear relationship between applied water and yield and may therefore be responding to other factors apart from water and fertiliser application. Such factors could be climatic such as solar radiation, temperature and relative humidity agreed with the findings of Akinbile and Yusoff (2011). However, in both varieties, highest WUE was recorded in treatment A which inferred that a relationship exists between the fertigation technique and WUE. Fertigation agriculture has become globally acceptable due to the reduced cost of practicing precision agriculture (Anu and Habeeburrahman, 2014). The technique was used in this study and conforms with the prediction of Ramniwas *et al.* (2012) in identical circumstances.

Average weekly reference and crop evapotranspiration (ETr and ETc)

The results of average weekly reference and crop evapotranspiration (ET_r and ET_c) throughout the entire planting season of the two cassava varieties were as presented in Figure 3. It was observed that the highest ET_r and ET_c were 25.96 mm day^{-1} and 20.77 mm day^{-1} at 6 WAP and 19 WAP respectively. The lowest values were 22.83 mm day^{-1} and 18.26 mm day^{-1} at 15 WAP, 28 WAP and 32 WAP respectively. This result agreed with the assertions of Ayoola and Makinde (2007) that from 15 – 90 DAP or (2 WAP – 12 WAP), Cassava's development and response in water and nutrient absorption were clearly evident. Similarly, from 3-6 months after planting or (12 WAP – 24 WAP), maximum growth of leaves and stems (most active vegetative growth) were also achieved. During these metabolic activities, ET_r and ET_c were high because the Cassava plant water uptake was high to enable well development. The lowest ET_r and ET_c recorded at 15 WAP and 28 WAP was as a result of low water intake, low temperature and high humidity recorded during those periods as indicated in the climatic information from WASCAL GRP-WACS, FUTA meteorological station, hence consumptive water use by the Cassava was low. At 32 WAP, growth responses were at the lowest point, hence low ET_r and ET_c were recorded. These observations agreed with the findings of Ayoola and Makinde (2007).

Conclusions

The study was carried out to determine the effects of some selected soil properties, moisture content, yield and consumptive water use on two cassava varieties TMS 0581 and TME 419 respectively under standard planting and environmental conditions. Results from this study confirm that fertigation technique is the best as it improves both the cassava yield and its WUE in all the treatments considered. The moisture amount at 30 cm depth is suggestive of adequate water availability that is sufficient enough to encourage proper tuber development (*Tuberisation*) for optimum yield. The soil nutrients and parameters considered were within the permissible limits to advance healthy development of cassava plants under standard condition. The crop water use's behaviour at different periods of low water availability affirms that Cassava can adapt to different physiological stress and still produce yield that are not entirely different from expected output in well-watered situations. Subjecting cassava crop to alternate wetting and drying and long-term monitoring of changes in soil nutrients to determine its responses to these scenarios are suggested.

References

Agbetoye L.A.S. 2003. Engineering challenges in developing indigenous machinery for cassava production and processing. pp 80-86 in Proceedings of the Annual Conference of the Nigerian Society of Engineers, Ibadan, Nigeria.

Agele S.O. 2003. Response of sunflower to weather variations in a tropical rainforest zone. Afr. Crop Sci. Conf. Proc. 6:1-8.

Akinbile C.O., Abd-El-Latiff K.M., Yusoff M.S., Abdullah R. 2011. Rice production and water use efficiency for self-sufficiency in Malaysia: a review. Trends Appl. Sci. Res. 6:1127-40.

Akinbile C.O., Yusoff, M.S. 2011. Effect of tillage methods and fertiliser applications on Amaranthus curentus in Nigeria. Int. J. Agric. Res. 6:280-9.

Akpan-Idiok M.E., Ukabiala A.U., Amhakhian O.S. 2013. Characterisation and classification of River Benue flood plain soils in Bassa Local Government Area of Kogi State, Nigeria. Int. J. Soil Sci. 8:32-46.

Allen R.G., Walter I.A., Elliot R.L., Howell T.A., Itenfisu D., Jensen M.E., Snyder R. 2005. The ASCE Standardised Reference Evapotranspiration Equation. ASCE and American Society of Civil Engineers.

Anju L., Ambily P.G., Gopikrishna V.G., Amalraj M. 2014. A study on the scope and importance of tuber crops with special reference to Cassava as resilient crop towards climate change. J. Earth Sci. Climat. Change 5:202-13.

Anu V., Habeeburrahman P.V. 2014. Fertigation and plastic mulching in tomato and Brinjal - a review. Department of Irrigation and Drainage Engineering, KCAET, Tavanur-679 573, India.

Ayoola O.T., Makinde E.A. 2007. Fertiliser treatments effects on performance of Cassava under two planting patterns in a Cassava-based cropping system in South West Nigeria. J. Agric. Biol. Sci. 3:13-20.

Burns A.E., Gleadow R.W., Zacarias A.M., Cumbana C.E., Miller R.E., Cavagnaro T.R. 2012. Variation in the chemical composition of Cassava (Manihont esculenta, Crantz) leaves and roots as affected by genotypic and environmental variation. J. Agric. Food Chem. 60:4946-56.

Cadavid L.F., EL-Sharkawy M.A., Acosta A., Sa´nches T. 1998. Long term effects of mulch, fertilisation and tillage on Cassava grown in sandy soils in Northern Colombia. Field Crops Res. 57:45-56.

Edoga R.N., Edoga M.O. 2006. Design of drip irrigation set for small vegetable gardens. Notulae Botan. Hortic. Agrobot. Cluj-Napoca 34:1842-4309.

Eze S.C., Ugwuoke K.I. 2010. Evaluation of different stem portions of Cassava (Manihot esculenta) in the management of its establishment and yield. J. Agric. Biol. Sci. 6:181-5.

FAO (Food and Agricultural Organisation). 2005. Trade yearbook. Food and Agricultural Organisation, Rome, Italy.

FAO (Food and Agricultural Organisation). 2013. A guide to sustainable production intensification. Food and Agriculture Organisation, Rome, Italy.

Gicheru P.T., Gachene C., Mbuvi J., Mare E. 2003. Effects of soil management practices and tillage systems on soil surface, soil water conservation and crust formation on a sandy loam in semi-arid Kenya. Soil Tillage Res. 75:173-81.

Hunt N., Gilkes B. 1992. Farm monitoring handbook. University of Western Australia, Land Management Society and National Dry Land Salinity Programme, Australia.

IITA (International Institute for Tropical Agriculture). 2010. Cassava plant research guides. 33pp.

Izaurralde R.C., Malhi S.S., Nyborg M., Solberg E.D., Jakas M.C.Q. 2006. Crop performance and soil properties in two artificially eroded soils in North-Central Alberta. Agron. J. 98:1298-311.

Liang X., Gao Y., Zhang X. Tian Y., Zhang Z. 2014. Effect of optimal daily fertigation on migration of water and salt in soil, root growth and fruit yield of Cucumber (Cucumis sativus L.) in solar-greenhouse. PLoS One 9:e86975.

Odedina S.A., Odedina J.N., Ogunkoya M.O., Ojeniyi S.O. 2012. Agronomic evaluation of new cassava varieties introduced to farmers in Nigeria. J. Life Sci. 6:939-44.

Odjugo P.A.O. 2008. The impact of tillage systems on soil microclimate, growth and yield of Cassava in Midwestern Nigeria. Afr. J. Agric. Res. 3:225-33.

Oguntunde P.G. 2005. Whole-plant water use and canopy conductance of Cassava under limited available soil water and varying evaporative demand. Plant Soil J. 278:371-83.

Olukunle O.J., Ogunlowo O.S., Sanni L. 2010. The search for effective Cassava Peeler. West Indian J. 32:42-47.

Ramniwas R.A., Kaushik D.K., Sarolia S.P., Singh V. 2012. Effect of irrigation and fertigation scheduling on growth and yield of Guava (Psidium guajava L.) under meadow orcharding. Afr. J. Agricult. Res. 7:6350-6.

Uchechi A., Nwanchukwu I. 2010. Averting household food insecurity through adoption of improved Cassava varieties by farmers in Abia State. pp 192-196 in Proceedings of the 44th Annual Conference of the Agricultural Society of Nigeria held in Ladoke Akintola University of Technology, Ogbomosho, Osun State.

Uthman F. 2011. Design and fabrication of Cassava lump breaking and sieving machine. Oasis J. Res. Develop. 1:42-50.

Utsev J.T., Ajon A.T., Ugama T.I. 2014. Irrigation soil analysis in River Katsina - Ala catchment areas of North-Central Nigeria. Int. J. Engine. Technol. 4:387-93.