*FUDMA Journal of Sciences (FJS)*
*ISSN online: 2616-1370*
*ISSN print: 2645 - 2944*
*Vol. 6 No. 3, June, 2022, pp 243 - 247*
*DOI: https://doi.org/10.33003/fjs-2022-0603-977*

# MODELING THE ONION YIELD RESPONSE TO DEFICIT IRRIGATION AND MULCH USING MULTIPLE REGRESSION MODEL IN SEMI-ARID NIGERIA

**[*1]Shanono, N. J. and [1,2]Abba B. S.**

[1]Department of Agricultural and Environmental Engineering, Bayero University Kano, Nigeria.
[2]Department of Agricultural Engineering Technology, Ramat Polytechnic Maiduguri, Borno State, Nigeria

*Corresponding authors' email: **njshanono.age@buk.edu.ng;** Phone: +2348038443863

## ABSTRACT

The effect of deficit irrigation, mulch practices, crop growth and water use parameters on the Onion yield was modelled using multiple linear regression model. The crop evapotranspiration, number of leaves, leaf height and canopy cover of the Onion were used as the independent variables. Onion bulb yield was the dependent variable under four mulching materials (rice straw, RM; wood shaving, WM; white synthetic plastic, SM and no mulch, NM) in the semi-arid region, of Nigeria. The regression analysis revealed that the independent variables in the model predicted the Onion bulb yield significantly ($p < 0.05$) under mulching conditions, while no mulch plots yielded no significance as indicated by the ANOVA statistic. The overall model degree of determination ($r^2$) of the dependent variable of 0.97, 0.97, 0.98, and 0.81 were obtained under SM, WM, RM, and NM respectively indicating that the multiple regression model predicted the dependent variable satisfactorily. The co-efficient values show that the highest coefficient was obtained at the number of leaves (0.56) followed by crop evapotranspiration (0.33). It was observed that among the four multiple regression models developed, the model obtained with white synthetic plastic mulch produce a better yield. Thus, white synthetic plastic mulch conserved soil moisture thereby improving Onion bulb yield. When the models were tested, a slight overestimation of the Onion bulb yield at both mulched and no mulched regression models was observed as compared with the yield obtained from the field. Therefore, the model obtained with white synthetic plastic mulch produces a better yield.

**Keywords:** Deficit irrigation, Mulch, Onion yield, Regression model, Semi-arid Nigeria

## INTRODUCTION

Improving crop water use productivity is an issue with global concern for sustainable crop production, particularly in the water-stressed region of the world. The water use productivity is a strategy by which the yield per unit of water applied can be maximized (Shanono et al., 2012; Zakari et al., 2012). For example, the concept of deficit irrigation (DI) coupled with mulching has been considered one of the most affordable agricultural management practices in water-stressed regions (Sabo et al., 2022). By applying DI, the crop is exposed to a certain level of water stress but significant water savings could be attained (Fereres & Soriano 2007; Shanono & Ndiritu, 2020). The reduction of soil evaporation, when the soil surface is covered with mulches, more water remains potentially available for the crop and consequently, irrigation requirements could be decreased. Moreover, using a sufficient mulching layer could control both weed growth and soil temperature fluctuations. Yield can also increase under mulching by improving soil's physical properties and fertility (Khaledian et al. 2010; Zakari et al., 2022a).

Mulch material can be synthetic black/white polythene or biological products such as plant residues such as rice straw and millet chaps (Zakari et al., 2022b). Depending on the type of mulch and the fraction of the soil surface covered by mulch, the reduction in soil evaporation might be more or less considerable. Many studies have been carried out regarding Onion water requirements and the effects of DI and mulch on yield (Igbadun et al. 2012; Patel & Rajput 2013; Shanono et al., 2015; Zakari et al., 2015; Tsegaye et al. 2016). For instance, Tsegaye et al. (2016) found that DI given at 75% of crop water requirement was economically recommended in southern Ethiopia. Patel and Rajput (2013) reported that with 40% DI throughout the growing season, crop water productivity (WP) can be significantly ameliorated with a saving which may be used to irrigate the additional cropped areas. Nagaz et al., (2012) observed that applying 60% of crop evapotranspiration (ETc) caused significant decreases in fresh yield, dry matter, bulbs per hectare, and bulb weight of Onion, compared to those under full irrigation (100% ETc) and DI (80% ETc). Igbadun et al., (2012) determined the Onion yield response under DI and different mulch covers in north-western Nigeria. The study revealed that the water consumption of the Onion crop was reduced by about 20% when a DI of 50% was applied. Also, they reported that the proportional decrease in yield under the mulch condition was much lower than under the no-mulching condition. For different covers cover, the proportional reduction in yield in the polyethene materials was found to be 10% lower than the rice straw.

In this study, regression analysis is a statistical technique for estimating the relationship between two or more variables having correlations to make predictions among the variables for the existing relations. The regression analysis using one independent variable is called single regression analysis, while the analysis using more than one independent variable is called multiple regression analysis (Buyukozturk, 2002; Moore et al., 2013). Multiple regression analysis was first used by Karl Pearson in 1908 and is a useful extension of simple linear regression that use several quantitative variables in combination rather than just one to predict the value of the quantitative dependent variable. Most researchers believe that using more than one variable can give more details on how the model can work effectively than is permitted by single linear regression. Behavioural scientists believe that behaviour and feelings are determined by multiple variables rather than just one (Shanono, 2019). Through multiple regression analysis, the relationship between a dependent variable and the independent variable can be analyzed and an equation representing the linear relation is formulated. The regression model with one dependent variable and more than one independent variable is known as the multiple regression model. In multiple analyses, an attempt is made to account for the variation of independent variables in the dependent variable synchronically (Crossman and Ashley, 2021). Therefore, the main objective of this research is to determine the impact of deficit irrigation and mulch management on Onion bulb yield using a multiple linear regression model. The independent variables used include actual crop evapotranspiration, number of leaves, leaf height, and canopy cover of the Onion whereas Onion bulb yield was used as the dependent variable under four mulching materials (rice straw mulch, RM; wood shaving mulch, WM; white synthetic plastic mulch, SM and no mulch, NM).

## MATERIALS AND METHODS

### Site location and experimental design

This study was conducted at Dala Alamderi Irrigation Project, Maiduguri, Borno State, north-eastern Nigeria. Dala Alamderi Irrigation Project is located between Latitudes 11$^o$05\` and 11$^o$55'N, Longitudes 13$^o$02\` and 13$^o$16'E and altitude 345 m above mean sea level. The mean annual rainfall of the study location is about 625 mm and the temperature range of 28.5 $^o$C – 40.5 $^o$C (Adeniji et al., 2013). The climate of Maiduguri is generally semi-arid with moderate variation in temperatures. The soils in the study location are predominantly sand to sandy loam having low moisture retention and high permeability, and few places with clay to clay loam. The field experiments consisted of two factors (water application depth and mulch practice) each at four levels. The four levels of water application depths are 100, 85, 70, and 55% of weekly reference evapotranspiration (WRET), while the four levels of mulch practice consisted of no mulch (NM), rice straw (RM), Wood shaving mulch (WM) and white synthetic plastic mulch (SM). The treatments were replicated 3 times making 4 × 4 × 3 = 48 experimental plots. The experiment was lout aid using a split-plot design (SPD). The block was separated by a distance of 0.5 m and the basins in each block were also separated by a distance of 0.5 m. Such separation aims to minimize the lateral movement of water from one basin to another.

### Land preparation, agronomic operations and water application

A land area of 36 m by 15 m was cleared and prepared into levelled basins of 2.0 m x 2.0 m and Onion seedlings were transplanted on 1$^{st}$ December 2020. The variety of Onion used was a Red Creole, which is commonly grown in the study area. Transplanting was done at crop spacing of 20 cm between plants and 25 cm between rows resulting in a crop density of 80 plants per plot. The mulch materials were placed two weeks after transplanting. All other operations were conducted according to the standard agronomic procedure (Igbadun et al., 2012; Sen et al., 2006). The surface irrigation method which is not uncommon in the study location was used. The major source of water in the study area is tube wells. During the early growth stage, all experimental plots were irrigated at full irrigation to ensure proper plant establishment. Different irrigation water levels were applied to the developmental, mid and late growth stages. The amount of water applied at every irrigation event was observed throughout the crop growing season and was based on the reference evapotranspiration amount for the days of irrigation and the experimental treatment plots. The average weekly reference evapotranspiration for December, January, February and March were 25 mm, 37 mm, 53 mm and 58 mm, for treatment Irrigated at 100% respectively. The seasonal water applied for the treatments irrigated at 100%, 85%, 70%, and 55% WRET were 577, 490, 404, and 317 mm respectively throughout the crop growing season. Reference evapotranspiration (ETo) 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 ETo was obtained from Meteorological Station (NIMET) situated in Maiduguri International Airport, Maiduguri. The crop consumptive use (CWU) of the treatments irrigated at 100% WRET ($I_{100}$), was regarded as actual consumptive use (ACWU) while the CWU of the deficit irrigated treatments ($I_{85}$, $I_{70}$, $I_{55}$) was regarded as deficit consumptive use (DCWU).

### Crop data collection

To ascertain the Onion crop response to deficit irrigation and mulch, plant height and number of leaves per plant were measured at 2, 4, 6, 8 and 10 weeks after transplanting. The canopy cover, leaf area, crop biomass, and harvest index were computed at 2, 4, 6, 8 and 10 weeks after transplanting using equations 1, 2, 3 and 4 respectively.

$$CC = \frac{LA_m N}{A} \times 100 \qquad 1$$

$$LA = 0.000199 + 1.277L \times A_{25} \qquad 2$$

$$CB = BB + LB \qquad 3$$

$$HI = \frac{Y}{B} x100\% \qquad 4$$

where; CC is the canopy cover in %, $LA_m$ is the average leaf area in m$^2$, N is the number of leaves and A is the area occupied by crop in m$^2$. L is total leaf length and $A_{25}$ is leaf width taken from a distance of 25% from the leaf base. HI is the harvest index, Y is the onion yield in Kg/ha, CB is the crop biomass, BB is the bulb biomass, LB is the leaves biomass and B is the total onion biomass in Kg/ha.

The Onion bulb yield was computed for each of the experimental plots using equation 5.

$$Y = \frac{W}{A} \qquad 5$$

where; Y = Onion bulb yield in kg/ha, W = crop weight in kg and A = experimental plot in ha.

### Multiple regression model description

The regression equation representing the prediction model is the most straightforward expression of the general linear model that was introduced by Andrien Marie Legendrie in 1805. In the model, a weighted linear composite of a set of variables is used to predict the value of some variables. In multiple regression analysis, what is predicted is a single variable (predict the value) which is a weighted linear composite of other sets of variables. In this study, multiple linear regression was used to produce a model that identifies the best weighted linear combination of independent variables (number of leaves, leaf height, canopy cover and actual crop evapotranspiration) to optimally predict the dependent variable (Onion bulb yield) for different mulch materials. Typically, the multiple regression analysis models take the form as expressed in equation 6.

$$Y_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_2 X_3 + \ldots\ldots + \beta_n X_n \qquad 6$$

where; $Y_i$ = dependent variable, $\alpha$ = intercept t, $\beta_i$ = co-efficient of variability and $X_i$ = independent variables.

### Data analysis

The data collected from the experimental field were subjected to regression analysis using a Microsoft Excel toolpak 2013 software package.

## RESULTS AND DISCUSSIONS

### Multiple regression analysis

The regression analysis was performed with the data obtained from the experimental field at the Dala Irrigation Project during the 2020/2021 irrigation season and was subjected to multiple regression analysis using the Microsoft Excel Toolpak 2013 software package. The independent variables include actual crop evapotranspiration, the number of leaves, leaf height and canopy cover of the Onion crop and the yield of the Onion is the dependent variable under different mulching materials. The result obtained from the analysis of the independent variables in the model predicted significantly the dependent variable in the experimental plot under mulching conditions, while experimental plots with no mulch were not significantly predicted as shown in the ANOVA statistics (Table 1). This result contradicts the finding by Shanono et al (2022) that the Crop model has perfectly predicted both the Onion bulb yield and biomass at both full and deficit irrigation irrespective of the mulching conditions. Whereas the overall model degree of determination of the dependent variable was recorded as $r^2 = 0.97$, 0.97, 0.98 and 0.81 for SM, WM, RM and NM respectively. Thus, the multiple regression model predicted the dependent variable satisfactorily irrespective of mulching materials.

**Table 1: multiple linear regression results**

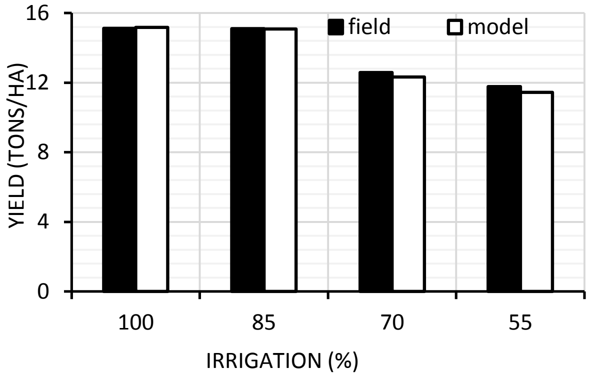
| | | | | Regression co-efficient (β) | | | | |
|---|---|---|---|---|---|---|---|---|
| **Treatment/variables** | **α** | **$L_H$** | **$C_C$** | **$N_L$** | **$ET_C$** | **$r^2$** | **f(4,3)** | **P(0.05)** |
| SM | -0.640 | 0.044 | 0.172 | 0.049 | 0.041 | 0.97 | 25.11 | 0.012 |
| WM | -5.557 | 0.027 | 0.011 | 0.556 | 0.322 | 0.97 | 25.28 | 0.012 |
| RM | -4.667 | 0.074 | 0.219 | 0.003 | 0.033 | 0.98 | 48.81 | 0.004 |
| NM | -16.729 | 0.542 | 0.017 | 0.501 | 0.032 | 0.81 | 3.18 | 0.184 |

Where; $L_H$ = leaf height, $C_C$ = canopy cover, $N_L$ = number of leaves and $ET_C$ = crop evapotranspiration; no mulch (NM), rice straw (RM), Wood shaving mulch (WM) and white synthetic plastic mulch (SM)

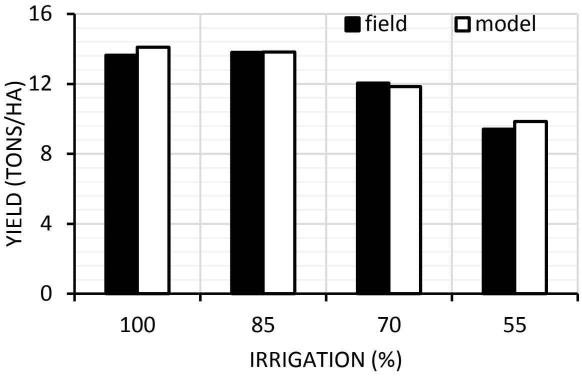
The absolute co-efficient (β) values shown in Table 1 indicate the order of importance of the independent variables to the models. The variables with the highest co-efficient values are the most important variable in the model. The contribution made by the individual independent variables to the general model under mulching conditions indicates that wood shave mulch recorded the highest co-efficient values of 0.556 for the number of leaves, then followed by co-efficient values of 0.322 recorded at crop evapotranspiration. While the least co-efficient value of 0.003 was also observed for the number of leaves ($N_L$) for rice straw mulch. The experimental plot with no mulch recorded the highest co-efficient value of 0.542 at leaf height and the lowest value of 0.017 at crop canopy cover. The generated multiple linear regression models for predicting Onion bulb yield ($Y_n$) for SM, WM, RM and NM are presented in equations 7, 8, 9 and 10 respectively. It is observed that among the four multiple regression models, the model obtained with the independent variables with white synthetic plastic mulch produces a better yield. This was proved when the independent variables recorded at both mulched and no mulch plots were substituted into the regression equations and compared with the yield from the field. The yield recorded with white synthetic mulch gave a closer yield value to that from the field compared to the value recorded with other mulch materials. This is in assertion with a report by (Shanono et al, 2022) that irrespective of the irrigation level and mulch materials, the values recorded for both Onion bulb yield and biomass were underestimated by the Crop model except at 100% irrigation with white synthetic mulch. It was also observed that the regression model with white synthetic mulch recorded the highest intercept value compared to the intercept values obtained with other mulched materials.

$$\mathrm{Y_{SM}} = -0.64 + 0.041\mathrm{ET_c} + 0.05\mathrm{N_l} + 0.04\mathrm{L_H} + 0.17\mathrm{C_C} \quad (7)$$
$$Y_{WM} = -5.56 + 0.32ET_C + 0.56N_l + 0.03L_H + 0.01C_C \quad (8)$$
$$\mathrm{Y_{RM}} = -4.68 + 0.03\mathrm{ET_C} + 0.003\mathrm{N_L} + 0.07\mathrm{L_H} + 0.219\mathrm{C_C} \quad (9)$$
$$Y_{NM} = -16.73 + 0.03ET_C + 0.50\,N_L + 0.54L_H + 0.02C_C \quad (10)$$

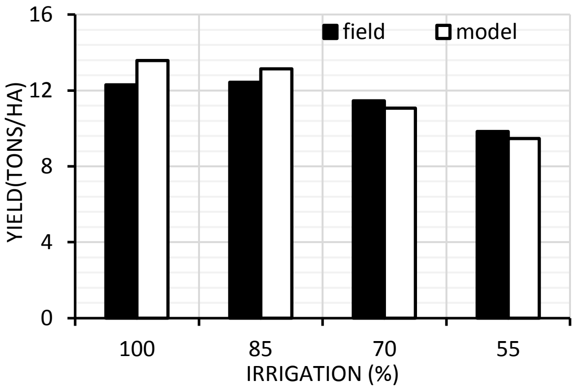
The comparative analysis between the Onion bulb yields obtained from the field and that of regression models due to the effect of independent variables at both mulch and no mulch plots are presented in Figure 1. The result generally indicates that there was a slight overestimation of the Onion bulb yield at both mulched and no mulched by the regression models as compared with the yield obtained from the field, especially at 100% and 85% levels of irrigation (Shanono et al., 2022). This is in line with a report by (Agbemabiese et al 2017) that Crop yield and biomass were overestimated for 100 % irrigation water regime and underestimated for deficit irrigation regimes However, among the mulched materials, the highest overestimation value of Onion yield was recorded in regression models obtained at rice straw mulch with the corresponding overestimation value of 9.4%.



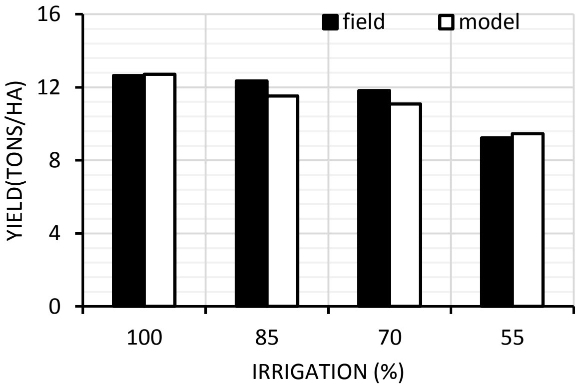

**a)** White synthetic mulch




**b)** wood shave mulch




**c)** Rice straw mulch




**d)** No mulch

Figure 1: Comparative effect of independent variables on Onion yield at different mulch materials for field and regression models

## CONCLUSIONS

An analysis of whether or not the independent variables (number of leaves, leaf height, canopy cover and actual crop evapotranspiration) can optimally predict the dependent variable (Onion bulb yield) using the regression model was conducted. The dependent and independent variables were collected from the experimental field carried out at Maiduguri, semi-arid Nigeria. The result of regression analysis indicated that the independent variables predicted the dependent variable significantly under mulching conditions only. However, the overall model degree of determination ($r^2$) of the dependent variable was recorded as 0.97, 0.97, 0.98 and 0.81 for SM, WM, RM and NM respectively. Thus, the model predicted the dependent variable satisfactorily irrespective of mulching materials. The co-efficient values (the contribution made by each independent variable to the general model) shows that the highest co-efficient values of 0.556 of the number of leaves were recorded at wood shave mulch. While the least co-efficient values of 0.003 were also observed with the number of leaves ($N_L$) in rice straw mulch. For the plots with no mulch, the highest co-efficient value of 0.542 was obtained at leaf height and the lowest value of 0.017 at crop canopy cover. Thus, among the 4 models developed, the model obtained with white synthetic plastic mulch produces a better yield which is similar to the yield obtained in the field. The yield recorded with white synthetic mulch gave a closer yield value to that from the field when compared to the yield value recorded with both mulch and no mulch plots on the Onion yield shows a slight overestimation as compared with the yield obtained from the field.

## REFERENCES

Adeniji, F.A., B.G. Umara, J.M. Dibal, and A.A. Amali (2013). Variation of infiltration rate with Soil texture. International Journal of Engineering and Innovative Technology (IJEIT) Vol. 3. Issue 2. pp. 454-455.

Buyukozturk, S (2002). Sosyal bilimler Icin Veri analiza el Kitabi. Ankara Pegem Yayincilk. ISBN 978-975-6802-74-8 DOI 10.14527/9789756802748, Ankara.

Crossman, Ashley. (2021). Linear Regression Analysis. Retrieved from https://www.thoughtco.com/linear-regression-analysis-3026704.

FAO, 1977. Guidelines for predicting crop water requirements by J. Doorenbos & W.O. Pruitt. FAO Irrigation and Drainage Paper No. 24. Rome.

Fereres E., M.A. Soriano (2007). Deficit irrigation for reducing agricultural water use. *Journal of Experimental Botany*, Volume 58, Issue 2, January 2007, Pages 147–159, https://doi.org/10.1093/jxb/erl165

Igbadun H. E., A. A. Ramalan and E. Oiganji (2012). Effects of regulated deficit irrigation and mulch on yield, water use, and crop water productivity of onion in Samaru, Nigeria. Agric Water Mgt. 109:162–169.

Khaledian, M.R., J .C. Mailhol, P. Ruelle, I. Mubarak, and S. Perret (2010). The impacts of direct seeding into mulch on the energy balance of the crop production system in the SE of France. Soil and Tillage Research s106(2): 218–226. DOI: 10.1016/j.still.2009.10.002.

Moore, D. S., W. I. Notz, & M. A. Flinger, (2013). The basic practice of statistics (6th ed.). New York, NY: W. H. Freeman and Company

Nagaz, K., M. M. Masmoudi and N. Ben Mechlia (2012). Yield Response of Drip Irrigated Onion under Full and Deficit Irrigation with Saline Water in Arid Regions of Tunisia. ISRN Agronomy Volume (2012), Article ID 562315, 8 pages http://dx.doi.org/10.5402/2012/562315.

Patel, N. and T. B. Rajput (2013). Effect of Deficit Irrigation on Crop Growth, Yield and Quality of Onion in Subsurface Drip Irrigation. *International Journal of Plant Production 7 (3), ISSN: 1735-6814 (Print), 1735-8043* (Online) www.ijpp.info Pelter

Sabo, A.A., M.S. Abubakar, M.D. Zakari, N.J. Shanono, A.N. Jibril, and U.K. Adamu (2021). Effect of organic materials on soil physio-chemical properties at Bayero University, Kano-Nigeria. Agricultural Engineering International: CIGR Journal, 23(3): 52-59. https://cigrjournal.org/index.php/Ejounral/article/view/6893/3669

Sen, R., A.T. Mondal, R. Brahma, and M. S. Khan (2006). Effect of different soil moisture regimes on the yield and yield components of onion, Bangladesh J. Sci. Ind. Res., 41 (1- 2), 2006, 109-112.

Shanono, N.J., M.K. Othman, N.M. Nasidi and H. Isma'il (2012). Evaluation of Soil and Water Quality of Watari Irrigation Project in Semi-Arid Region, Kano, Nigeria. Proceedings of the 33rd National Conference and Annual General Meeting of the Nigerian Institute of Agricultural Engineers (NIAE) Bauchi. pp. 181 – 186.

Shanono, N. J. (2019). Assessing the Impact of Human Behaviour on Reservoir System Performance Using Dynamic Co-evolution - *A PhD Thesis Submitted to University of the Witwatersrand, Johannesburg.* https://doi.org/http://wiredspace.wits.ac.za/handle/10539/29043

Shanono, N. J., Adamu, M. S., Nasidi, N. M., Zakari, M. D., Isma'il, H., & Halilu, A. G. (2015). Evaluation of Soil Water Characteristics-Hydraulic Property Calculator (SWC-HPC) Model at Thomas.pdf. *Proceedings - 2nd Int'l Interdisciplinary Conf. On Global Initiative for Integrated Dev. (IICDIID) 2015, Chukwuemeka Odumegwu University, Nigeria.*, 1158–1169.

Shanono, N. J., & Ndiritu, J. (2020). A conceptual framework for assessing the impact of human behaviour on water resource systems performance. *Algerian Journal of Engineering and*, *02*(35–44). https://doi.org/http://dx.doi.org/10.5281/zenodo.3903787

Shanono, NJ, Abba, BS, Nasidi, NM (2022). Evaluation of Aqua-Crop Model Using Onion Crop under Deficit Irrigation and Mulch in Semi-arid Nigeria. *Turkish Journal of Agricultural Engineering Research (TURKAGER)*, 3(1), 131-145. https://doi.org/10.46592/turkager.1078082

Tsegaye B., T. Bizuayehu, A. Wolde Michael Michael, and A. Mohammed (2016). Yield and yield components of onion (Allium cepa L.) as affected by irrigation scheduling and nitrogen fertilization at Hawassa area districts in Southern Ethiopia. *Journal of Agricultural Science and Food Technology 2(2): 15–20.*

Zakari, M.D., M.M. Maina, M.S. Abubakar, N.J. Shanono, I. Lawan, M.A. Tadda and N.M. Nasidi (2012). Design, Construction and Installation of Sprinkler Irrigation System. *Bayero J. of Eng. and Tech.* Vol. 7 (1 & 2) pp. 109 – 117. https://www.bayerojet.com/wpcontent /uploads/journal/published_paper/volume-7/issue-1/bjet_OH4ednaS.pdf

Zakari, M. D., Audu, I., Shanono, N. J., Maina, M. M., Abubakar, M. S., & Mohammed, D. (2015). Sensitivity analysis of crop water requirement simulation model (CROPWAT (8.0) at Kano River Irrigation Project, Kano Nigeria. *Proceedings for International Interdisciplinary Conference on Global Initiatives for Integrated Development (IICGIID 2015 Chukwuemka Odumegwu University, Igbariam Campus Nigeria)*, 502–510.

Zakari, M.D., N.N. Sani, A.A. Sabo, N.J. Shanono, D. Mohammed, S.E. Ahmadu, A. Ibrahim and N.M. Nasidi (2022a). Effect of Millet Chaff as Organic Amendment on Rice Yield in Sodic Soil - A Case Study of Thomas Irrigation Scheme in Kano, Nigeria. FUDMA Journal of Sciences 6(1), 68-80. https://doi.org/10.33003/fjs-2022-0601-820

Zakari, M.D., S. Auwal, A.A. Sabo, N.J. Shanono, A. Ibrahim, D. Mohammed, S.E. Ahmadu and N.M. Nasidi (2022b). Cumulatıve Effect of Rıce Straw Ash on Soıl Physıcochemıcal Propertıes and Yıeld of Cucumber. *Bayero J. of Engıneerıng and Technology* 17(2) pp 1 – 9. https://www.bayerojet.com/wp-content/uploads/journal/published_paper/volume-17/issue-2/bjet_4LLUprC7.pdf