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Assessment of Furrow Irrigation Variables on Growth Performance and Yield of Millet in Borno State

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Abstract: *Furrow irrigation is a widely practiced irrigation method often characterized by low water application requirement efficiency caused by poor design and/or unskillful operation and management. Frequent evaluation of furrow performance parameters is one of the key parameter for precise furrow irrigation especially in regions with limited water resources. This study was conducted to determine the influence of some furrow irrigation variables and its performance parameters on growth and yield of maize in semi-arid region of Borno state, Nigeria. The experiment was performed between February to March 2019. Furrow irrigation variables considered in the study were furrow lengths and stream sizes each at three levels namely; FL10m, FL20m, FL30m and SS0.5 l/s, SS1.0 l/s, and SS1.5 l/s respectively. The variables were laid in Randomized Complete Block Design (RCBD). The growth and yield parameters measured included plant height, stem diameter and number of leaves per plant and yield. Collected data was subjected to Analysis of variance (ANOVA) using Statistic 8.0. at ($p \leq 0.05$) probability level. The results of the analysis indicated that furrow length 20m and streams size 1.0 l/s was significantly influenced the performance parameters of the furrow than other furrow irrigation variables experimented and gave better application efficiency 93%, distribution efficiency 89% and total water distribution efficiency 87% respectively. Likewise, highest grain yield of 3.9563 t/hac and 4.3463 t/hac were recorded between FL2 and SS2 respectively. Furthermore, correlation studies among some growth and yield parameters established strong positive significant association of averagely 89% at ($p \leq 0.05$) probability level.*

Keywords: *Furrow, Irrigation , Yield, and Growth*

1.0 INTRODUCTION

Furrow irrigation is one of the extensively used means of irrigating crops in many developing countries. It is especially recommended for growing row crops on medium to heavy textured soils and is preferred over other surface irrigation methods due to its simplicity and low capital cost (Dibal *et al* 2015). Furrow irrigation requires precisely graded fields with furrows or small ditches formed between crop rows for the water to flow by gravity from one side of the field to the other Eshetu (2007). Its efficient application and distribution of water by furrow irrigation is dependent on furrow parameters such as inflow, soil texture, field slope, soil infiltration, plant coverage, roughness coefficient, field shape and irrigation management (Holzapfel, 2010). The optimal design of furrow irrigation methods can be an important way to maximize net returns and to use water most efficiently. Well-designed methods can increase the water application efficiency to levels of 60-80 % compared with typical efficiencies of 20-40% reported by Clyma, *et al.* (2001). Poor performance of furrow irrigation system suggests a need for better system design and management. Improved designs of furrow irrigation systems would result in more effective and efficient use of water resources Rice et al (2001). Determining flow rate is a critical step in designing furrow irrigation systems for maximum net return. Earlier methods were developed to optimally design furrow systems for maximization of net returns from farm, assuming infiltration characteristics do not change during the season and not considering deep percolation losses (Zehirun,.*et al* 2001). Mekonen (2006) investigated 0.3, 0.4 and 0.5 lit/s flow rates against 24, 35 and 50 m furrow length design at Batu Degaga and found that average application efficiency of 28.9, 33.6 and 40.46% for furrow lengths of 24, 35 and 50 m, respectively. Regarding flow rates, the average values of application efficiency became 32.9, 32.8 and 36.9% for the flow rates of 0.3, 0.4 and 0.5 lit/s, respectively. Therefore, the present study was undertaken in order to analyse influence of some furrow irrigation variables (inflow discharge and furrow length,) on growth and yield maize, as well as furrow performance parameters. Irrigation efficiency is a crucial aspect for irrigated agriculture and a key factor due to the competition for water resources (Hsiao *et al*., 2007). Furrow irrigation variables are the most sensitive engineering problem most affecting farmers in the region. Basic requirement is to adequately select furrow irrigation variables (furrow length, and stream flow), with the view to improve irrigation scheduling, and improve water management of the field which will also potentially reduce over-irrigation and deep percolation of applied water. Therefore, the current study is undertaken to determine the influence of some furrow irrigation variables with the view to ascertain its performance on irrigation performance parameters, growth and yield of maize crop in Maiduguri.

2.0 MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was conducted at the Teaching and Research Farm of the Ramat Polytechnic, Maiduguri. The site lies between latitude $11^{0}5$ N and longitude $13^{0}09$E (Kyari, *et al* 2014). The area is about 335m above sea level and lies within the lake Chad Basin formation, which is an area formed as a result of down –warping during the Pleistocene period (Waziri, 2007). The average annual rainfall is around 640mm and the temperature is high ranging between 20-40°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). However, the soil texture in the farm is predominantly sandy loam with an aggregates proportion as shown in table 1 below.

2.2 Model Performance Evaluation

Wilmot (1982) suggested that bias and root mean square error (RMSE) are among the "best" overall measures of model performance.

$$Bias = \frac{1}{N}\sum_{i=1}^{N}(P_i - M_i) \tag{3.11}$$

Where P and M are predicted and observed values of the variable of interest, respectively, and N is the number of observations.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_i - M_i)^2} \tag{3.12}$$

Mean Square deviation (MSD) and square bias (SB) and lack of correlation weighted by the standard deviation (LCS), is calculated using Kobayashi and Salam, (2000) equations

as:

$$MSD = \frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2 \quad (1)$$

$$SB = (-\bar{P}\bar{O})^2 \quad (2)$$

$$LCS = 2 \times SD_P \times SD_O \times (1 - r) \quad (3)$$

Where

$\bar{P}$ and $\bar{O}$ = average predicted by the model and measured values. SD_P and SD_O = standard deviations of predicted and observed values, respectively; r = the correlation coefficient between predicted and observed values. Model performance was quantified by calculating the standard error (SE) and average absolute deviation (AAD) as in Yusuf, 2001):

$$SE = \sqrt{\frac{\sum(y_m - y_p)^2}{n}} \quad (4)$$

Where y_m and y_p represent measured and predicted values, respectively and n is the number of observations. Coefficient of efficiency (Legates and McCabe, 1999, Krause *et al.,* 2005)

2.3 Furrow Irrigation Model for Validation Studies.

The validation studies, some furrow irrigation performance parameter model develop by Zerihun *et al.* (2001) such as water application efficiency, requirement efficiency, requirement distribution efficiency, and total distribution efficiency, were used in the study area by substituting the measure discharge (q), and furrow length (L) were used, because the model have the best correlation with the furrow irrigation variables

3.0 Result and Discussion

The millet yield dependent and independent variables such as; dry cobs weight, cobs length, number cobs per plant, thousand seed yield, and number of seed per plant on yield as shown in table 1 were analyzed using regression and the result of the analysis is presented in table 2.The regression relationship among the millet growth attributes on the yield of millet were analyze at ($p \leq 0.05$) and presented in table 2 above exhibited an $R^2 = 0.98345$ which indicate high positive relationship among the yield attribute, Conversely, hundred seed yield of the millet had highest regression coefficient of (146.26) indicate strong influenced on the millet yield produced, it was closely followed by number seed per cob with regression coefficient of (36.11) respectively. Correspondingly dry cob weight and cob length have not strongly influenced yield of maize, because they have exhibited less coefficients. Result is agreed with the findings of (Hsiao *et al.,* 2007)

Table 1: independent and dependent variable of millet

Independent variable	Regression coefficient
Dry cob weight	0.01298
Cob length	2.156
Number of seed per cob	36.11019373
100-seed yield	146.2657652
R^2	0.98345
Adjustable R^2	0.86212
Multiple R^2	0.74364
SE±	0.01562

Table 2: Showing the regression analysis result

DRY COB WEIGHT KG	COB LENGTH CM	NSPC	100-SEED (G)	YIELD T/H
0.34	22.4	528	21.93	2967.4
0.45	27.8	736	26.4	3956.3
0.64	25.7	636	25.73	3697.2

3.1 Furrow Irrigation Performance Parameters Model Performance Evaluation

In order to assess the degree of its accuracy, the model performance was simulated using the model (eqn 3.7, 3.8 3.9 and 3.10). The verification was achieved by subjecting the furrow irrigation performance parameters data such as furrow length (L), stream size (Q) and furrow width (W) considered from field were substituted to model develop by Zerihun *et al*. (2001). Because the model has the best correlation with the furrow irrigation variables to the study area. An excel computer package was used to compare the observed and predicted furrow irrigation performance parameters to the study area using Wilmot (1982) equation for standard error (SE) and root mean square error (RMSE) are among the "best" overall measures of model performance suggested by Yusuf, 2001

Table 3: Performance Evaluation Comparison between furrow irrigation water Application Efficiency (WAE) observed from (field) versus predicted from (model)

Application Efficiency Observed From the field	Application Efficiency Values Predicted using model	Residuals	Squared Residuals	RMSE	SSE	SSR	SST
85.34	65.23	20.11	404.41	10.51	552.40	103.45	44.44
87.25	75.12	12.13	147.14				
78.3	79.22	-0.92	0.85				

As illustrated in table 3. The performance evaluation comparison between the observed and predicted performance parameters i.e (WAE) were critically compared using RMSE, SSE, SSR and

ST values were computed as specified in eqn 3.7, 3.8 3.9 and 3.10). The values obtained were (10.51, 552.40, 103.45 and 44.44) respectively. The small values of these evaluation parameters between the predicted and measured values indicates a better model because it shows that there exist but a little deviation between the predicted and measured values. The relationship between the field observed data and the model prediction is as presented in fig. 4.1 below. The model output and the experimental result plotted on the graph yielded the slope and intercept of 0.51599 and 0.00 respectively and R^2 of 0.9112 exhibited a high degree of agreement between the model output and the field observed data. Hence the null hypothesis is upheld that the slope is not statistically different from 1.0 and the intercept is equal to zero at ($P<0.05$) level, using the Duncan's multiple range test (DMRT). This showed that there is a very high agreement between the predicted and measured water application efficiency implies that the developed model is a good representation of furrow irrigation performance parameter on a sandy loam soil in the study area.

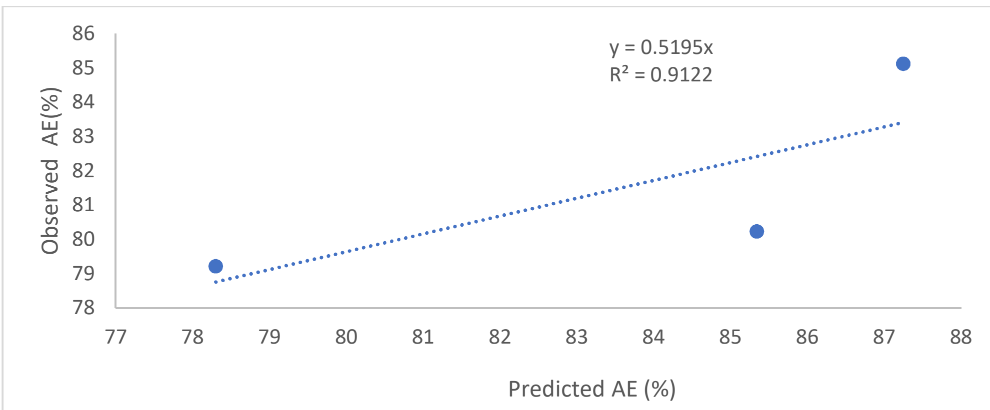

Figure. 1: Plot of predicted against observed values of Water Application Efficiency

Table 4: Performance Evaluation Comparison between furrow irrigation water Distribution Efficiency (WDE) observed from (field) versus predicted from (model)

Distribution Efficiency Observed From the field	Distribution Efficiency Values Predicted using model	Residuals	Squared Residuals	RMSE	SSE	SSR	SST
78.58	69.12	9.46	89.49	6.55	214.68	34.13	20.33
83.33	81.23	2.10	4.41				
79.2	68.21	10.99	120.78				

As presented table 4. The performance evaluation comparison between the observed and predicted. (WDE) were critically compared using RMSE, SSE, SSR and ST values were computed. The values obtained were (6.55, 214.7, 34.13 and 20.13) respectively. The small values of these evaluation parameters between the predicted and measured values indicates a better model because it shows that there exist but a little deviation between the predicted and measured values. The model output and the experimental result plotted on the graph yielded the slope and intercept as in (figure 2) of 2.7 68x and 149.61 respectively and R^2 of 0.9669 exhibited a high degree of agreement between the model output and the field observed data.

This showed that there is a very high agreement between the predicted and measured furrow irrigation water distribution efficiency (WDE) implies that the developed model is a good representation of furrow irrigation performance variables on a sandy loam soil in the study area.

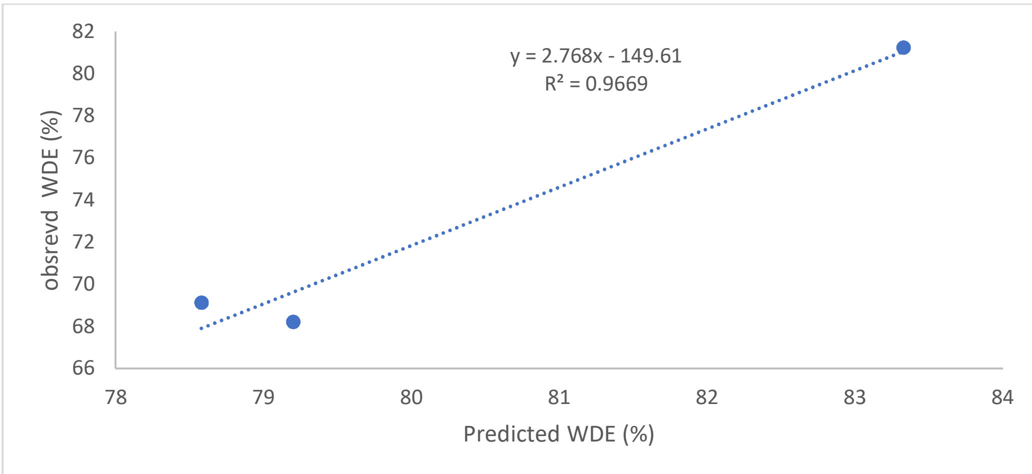

Figure. 2: Plot of predicted against observed values of water distribution efficiency

Table 5: Performance Evaluation Comparison between furrow irrigation Total Distribution Efficiency (TDE) observed from (field) versus predicted from (model)

Total Distribution Efficiency Observed From the field	Total Distribution Efficiency Predicted using model	Residuals	Squared Residuals	RMSE	SSE	SSR	SST
78.58	81.24	-2.66	7.08	4.80	1.17	59.59	1.57
80.33	70.34	9.99	99.80				
79.2	76.32	2.88	8.29				

As presented table 5. The performance evaluation comparison between the observed and predicted. (TDE) were critically compared using RMSE, SSE, SSR and ST values were computed. The values obtained were 4.40, 115.17, 59.59 and 1.57) respectively. The small values of these evaluation parameters between the predicted and measured values indicates a better model because it shows that there exist but a little deviation between the predicted and measured values. The relationship between the field observed data and the model prediction is as presented in fig. 4.3 below. The model output and the experimental result plotted on the graph yielded the slope and intercept of 6.1143x and 561.26 2respectively and R^2 of 0.9878 exhibited a high degree of agreement between the model output and the field observed data. This showed that there is a very high agreement between the predicted and measured furrow total distribution efficiencies implies that the developed model is a good representation of furrow irrigation performance variables on a sandy loam soil in the study area.

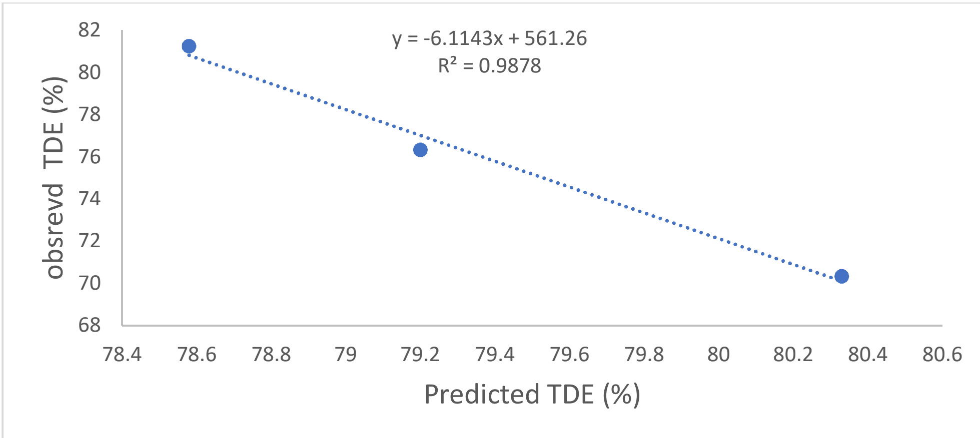

Figure. 3: Plot of predicted against observed values of total distribution efficiency

4.0 CONCLUSION AND RECOMMENDATIONS
4.1 CONCLUSION

The research was carried out to determine the influence of furrow irrigation variables on furrow performance parameter was carried out at the Agricultural engineering research and teaching farm of Ramat Polytechnic Maiduguri during the dry season from 12 January to 12 April 2018. The result of the studies was analyzed using statistic 8.0 as follows.

I. Based on the findings of results, regression analysis of the independent variable on the yield showed that number of cobs length and the number seed per cob emerge as highest yield parameters that remarkably influencing the yield of the Millet than all other yield attribute in the study area

II. The regression relationship among the millet growth attributes on the yield of millet were analyze at ($p \leq 0.05$) exhibited an $R^2 = 0.98345$ which indicate high positive relationship among the yield attribute, Conversely, hundred seed yield of the millet had highest regression coefficient of (146.26)

4.2 Recommendations

(i) Since this experiment is season study in a single environment, further research over seasons are required so as to develop reliable values.

(ii) Different furrow irrigation variables should be should be repeated in similar agro-climatic condition in order to confirm the findings.

(iii) Further research need to be carried out at different soil type, millet varieties and farm practice.

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