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Influence of Some Furrow Irrigation Variables on Irrigation Performance Parameters, Growth and Yield of Maize 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 for the period of four months. 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 were found best and had significantly influenced the performance parameters of the furrow than any other furrow irrigation variables experimented which 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.*

Key words: *Furrow, Irrigation, Stream size, Furrow length and performances Parameter*

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^{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). However, the soil texture in the farm is predominantly sandy loam with an aggregates proportion as shown in table 1 below.

Table: 1 Soil characteristics at the experimental site (0-40 cm)

Soil type (USDA soil classification)	Sand loamy
Clay (%)	8.0
Silt (%)	11.8
Sand (%)	80.2
P^{h}	7.8
Field capacity (vol. %)	17.2
Wilting point (vol. %)	4.2
Available water content (vol. %)	13.0
Bulk Density (g/cm^{3}	1.70
Organic matter (%)	3.99

Source : Agrcultural Research Farm Rampoly (2019)

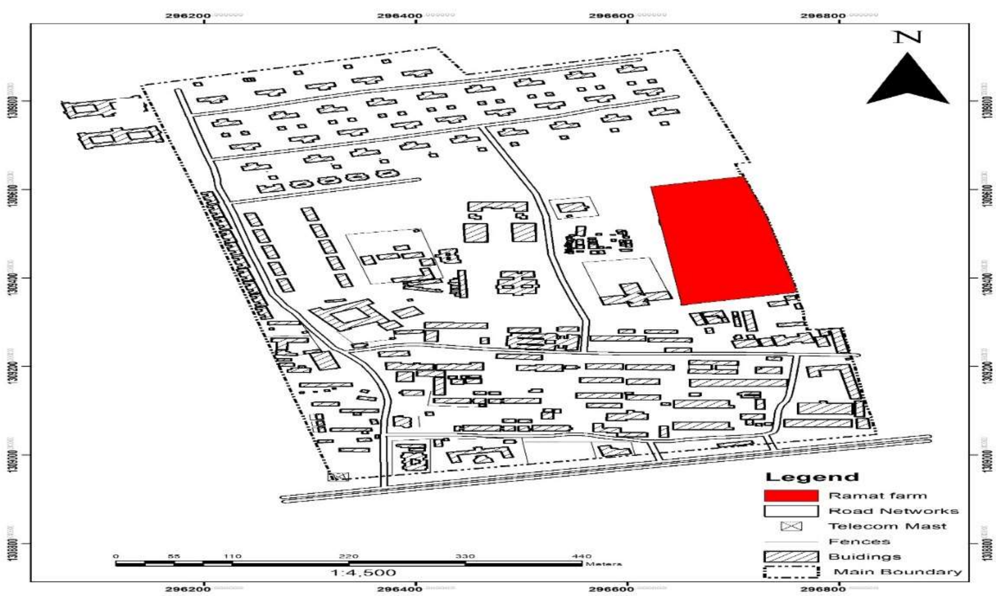

Fig: 1 Map showing the experimental site

2.2 Treatment and Experimental Design

The experimental factor considered in this work were furrow Length and stream size at three level each, and replicated three times to make total of 27 treatments. The stream size were 1.5, 1.0 and 0.5l/s ; while the furrow length were 30, 20 and 10 that were laid in a Randomized Complete Block Design (RCBD).

2.3 FIELD EXPERIMENTATION

2.3.1 Furrow Geometry

2.3.2 Furrow Stream Flow Measurement

The stream flow in each furrow was measured by volumetric method as suggested by Zerihun *et al*. (2010). A drum having capacity of 100 litres was filled completely with water flowing out of the pipe at the head end of the furrows and time taken by the water flow to fill the drum was noted with the help of a stop watch. The capacity of drum divided by the time gave the stream flow.

2.3.3 Furrow Cross Section Area

Trapezoidal shaped furrows were made by using a tractor drawn ridges. The depth of furrow was measured by installing a hook gauge at every 5m distance along the furrow length and the average depth was found to be 0.25 m. Top width and bottom widths were also measured at the same distances. With a side slope of 1.5:1, the top width was measured as 0.6 m against the bottom width of 0.15 m.

2.3.4 Furrow-Bed Slope

The bed or bottom slope of furrow was maintained as 0.2 per cent with the help of dumpy level and levelling staff.

2.3.5 Measurement of Infiltration in Experimental field

In the experiment, furrow infiltration was determined by volume balance method. The furrow was completely filled with water up to the top width and immediately, the water depths at different distances along the furrow length were measured. At the end, the furrow was blocked so that no water is allowed to escape as runoff. Then at different time intervals, the flow depths were measured at the same distances as was measured when the furrow was completely filled with water at the beginning. The difference of the two depths gave the depth of water infiltrated.

Table 2: Geometric details of experimental plot

Expereiment plot area	**752.5 m^2 =35×21.5**
Furrow length	At 3 level = 30m, 20m and 10m
Furrow stream size	At 3 llevel=1.5m, 1.0m and 0.5m
Furrow width	0.35m
Furrow topwidth	0.6m
Furrow bottonwidth	0.15m
Furrow depth	0.25m
Side slope	2:1
Bed slope percentage	0.2%
Row to row spacing	0.60 m
Plant to plant spacing	0.45m

2.4 Estimation Application efficiency (Ea %)

The application efficiency of the furrow irrigation system for each of the treatments was determined using the formula suggested by Hart, *et al* (1979):

$$Ea = \frac{(Ws)}{Wf} \times 100 \qquad (1)$$

Where, Ea % = water application efficiency, as percent

Ws = the average depth of irrigation water stored in the root zone during irrigation

Wf = the average depth of irrigation water deliver to the farm

2.4.1Estimation Distribution efficiency (Ed %)

Expresses the extent to which water were uniformly distributed along the run. This index was determined as following

$$Ed = \frac{(1-\acute{y})}{d} \times 100 \qquad (2)$$

Where, Ed% = water distribution efficiency, as percent, d = Average depth of water stored along the run during the irrigation, y = Average numerical deviation from (d).

3.0 Results and Discussions

There were several parameters which are used as real indicators of the hydraulic performance of an irrigation system. In this study Water application, Water distribution efficiencies, Requirement efficiencies and Total distribution efficiencies were considered as influenced by furrow lengths and stream sizes at three different irrigation levels.

3.1 Influence of Furrow lengths (FL) and Stream Sizes (SS) on Furrow Water Application Efficiency (WAE)

Table 3 shows the water application efficiency of furrow irrigated raised bed system as influenced by treatments i.e. (30m, 20m, 10m) furrow lengths and (0.5l/s, 1.0l/s and 1.5l/s) stream sizes.

The furrow lengths and stream sizes had significantly ($p<0.05$) influenced WAE of the furrow irrigation. The highest efficiencies values of 86.23%, 88.44% and 87.09% for the 1st, 2nd and 3rd irrigation was remarkably recorded with FL2 treatment, was closely followed by FL1 with efficiencies value of 82.01% 85.34% and 80.67% respectively, in addition the lowest (WAE) values for the 1st , 2nd and 3rd irrigation was obtained in FL3 with corresponding values of 67.22% , 71.34% and 78.30 respectively. Conversely, highest WAE was obtained with SS2 for 1st , 2nd and 3rd irrigation with corresponding WAE values of 89%, 86.22% and 89.90%, respectively, followed by SS1 and the least WAE values of 71.24%, 76.32% and 74.22% was affected by SS3. Interestingly the interactions between the furrow lengths and different stream sizes were significant. The result is similar to the findings of (Esfandiari *et al* 2001).

Table 3 Influence of furrow lengths and stream sizes on Furrow WAE

Treatment	1st irrigation	2nd irrigation	3rd irrigation	Average
Furrow length (m)				
FL1(10)	82.01[b]	85.34[b]	80.67[c]	85.34[b]
FL2(20)	86.23[a]	88.44[a]	87.09[a]	87.25[a]
FL3(30)	67.22[c]	71.34[c]	76.35[b]	78.30[c]
Significance	Ns	Ns	*	*
SE±	1.45	2.40	0.27	0.10
Stream sizes (L/s)				
SS1 (0 .5)	88.02[b]	85.63[b]	87.29[ab]	76.98[c]
SS2 (1.0)	89.00[a]	86.22[a]	89.90[a]	79.37[a]
SS3 (1.5)	71.24[c]	76.32[c]	74.22[c]	77.92[b]
Significance	*	*	*	*
SE±	0.02	0.99	2.10	0.124
Interaction				
FL x SS	*	*	*	*

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

3.2 Influence of Furrow Lengths and Steam Sizes on Furrow Water Distribution Efficiency (WDE)

Table 4 shows the influence of furrow lengths and different stream sizes on water distribution efficiency of furrow irrigated raised bed system as influenced by treatments i.e. (30m, 20m, 10m) furrow lengths and (0.5l/s, 1.0l/s and 1.5l/s) stream sizes on maize experimented farm. Furrow lengths and stream sizes were significantly ($p<0.05$) influenced the water distribution efficiencies of 1st, 2nd and 3rd irrigation. The highest WDE values of 79.23%, 92.41% and 89.36% for 1st, 2nd and 3rd irrigation was remarkably recorded with FL 2. It was closely followed by FL3 at 1s and FL2 at 2st irrigation with corresponding WDE efficiencies values of 77.12% and 82.76% respectively. In addition, the lowest WDE were detected with FL1 at 1st and 3rd irrigation, and FL3 at 2nd irrigation with corresponding efficiencies values of (74.81% a, 74.18% and 79.39%), respectively. This could be due to lack of antecedent moisture in the soil prior to the irrigation. Similarly, stream sizes variation induced WDE. The highest WDE was observed in at 1st 2rd and 3nd irrigation were remarkably induced by SS2 than other treatments experimented with corresponding efficiencies values of 84% 91.23% and 90.10% respectively, it was closely followed by SS3 with efficiencies values (79.24%, 78.32% and 89.32%), respectively. Whereas, the least WDE was affected by SS1 used as treatment at 1st and 2nd irrigation. However, the interactions between the furrow lengths and different stream sizes were not significant, which is in line with the result obtained by (El-Halim, 2013).

Table 4 Influence of Furrow Lengths and Stream Sizes on Furrow Water Distribution Efficiency

Treatment	1st irrigation	2nd irrigation	3rd irrigation	Average
Furrow length (m)				
FL1(10)	74.81c	82.76b	74.18c	78.58c
FL2(20)	79.23a	92.41a	89.36a	83.33a
FL3(30)	77.12b	79.39c	80.11b	79.20b
Significance	*	*	*	*
SE±	0.141	2.10	0.04	0.897
Stream sizes (L/s)				
SS1 (0 .5)	78.12c	87.60c	89.19b	81.63c
SS2 (1.0)	84.00a	91.23a	90.10a	83.78a
SS3 (1.5)	79.24b	78.32b	89.32b	80.29b
Significance	*	*	*	*
SE±	0.023	0.012	0.181	0.071
Interaction				
FL x SS	NS	NS	NS	NS

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

3.3 Influence of Furrow Lengths and Stream Sizes on Furrow Requirement Efficiency (RE) and Total Distribution Efficiency (TDE)

Table 5 shows the influence of furrow lengths and stream sizes on furrow 1st 2nd and 3rd irrigation water requirement efficiency and total distribution efficiency in the study area. The result showed that both furrow lengths and stream sizes significantly ($p<0.05$) influenced the RE and TDE of the furrow at 1st, 2nd and 3rd irrigation. As affected by furrow length, the highest RE and TDE values of 98.34% and 77.12% were distinctly recorded with FL2 and FL3 at 1st irrigation, was closed by FL1 at same irrigation with corresponded RE and TDE values of 83.12% and 74.81% respectively. Also, at 2nd and 3rd irrigation, highest RE and TDE were induced by FL2 in comparison to other treatments experimented with efficiencies values (90.31% and 92.41%) and (89.11% and 89.36%), respectively. In addition, mostly the least RE and TDE was recorded between FL1 and FL3. Similarly stream sizes variation significantly ($p<0.05$) influenced the requirement efficiency and total distribution efficiency of the furrow. The highest RE and TDE of (88.34 and 92.41%), (92.18 and 91.23%), (89.11 and 90.10%) were remarkably induced by SS2 than other treatment used. It was closely followed by both SS1 at 3rd irrigation with RE and TDE values of 84.91% and 89.19% respectively. Whereas the least RE and TDE was only affected by SS1 used as treatment and the result was similar to the finding of (Holzapfe, 2012). In addition, the interaction between the furrow lengths and different stream sizes were not significant.

Table 5 Influence of furrow lengths and stream sizes on Furrow Requirement Efficiency and Total Distribution Efficiency

Treatment	1st irrigation		2nd irrigation		3rd irrigation		Averages	
Furrow length (m)	RE	TDE	RE	TDE	RE	TDE	TDE	RE
FL1(10)	83.12c	74.81c	87.21b	82.76b	84.91b	74.18c	78.58b	84.11c
FL2(20)	98.34a	76.23b	90.31a	92.41a	89.11a	89.36a	82.33a	90.10a
FL3(30)	88.23b	77.12a	81.41c	79.39c	80.62c	80.11b	70.20b	85.21b
Significance	*	*	*	*	*	*	*	*
SE±	0.123	0.141	2.10	0.234	1.02	0.04	0.897	0.021
Stream sizes (L/s)								
SS1 (0 .5)	80.31c	78.12b	86.22b	87.60c	84.91b	89.19b	81.63c	83.44b
SS2 (1.0)	88.34a	84.00a	92.18a	91.23a	89.11a	90.10a	83.78a	87.23a
SS3 (1.5)	86.21b	79.24b	81.11c	78.32b	80.62c	89.32b	80.29b	82.71c
Significance	*	*	*	*	*	*	*	*
SE±	0.891	0.023	0.012	1.201	2.10	0.181	0.071	1.00
Interaction								
FL x SS	Ns	*	*	Ns	Ns	Ns	Ns	Ns

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

3.4: Influence of Furrow Lengths and Stream Sizes on Maize Yield and Yield Parameter

Table 6 shows the results of yield and it attribute as influenced by the furrow length and stream size in the study area. All the furrow lengths variation was significantly ($P<0.05$) influenced cob length of the maize. FL3 gave the highest cobs length of (27.8 cm) which was closed by FL3 with cob length of (25.8 cm), while least cobs length (21.833 cm) was produced from FL1. Similarly, (FL2) produced superlative dry cob weight, number of seed per plant, hundred seed yield and grain yield with corresponding values (0.45kg, 736, 26.40 g and 3.9563 t/ha) respectively. And, also was closed by other furrow length and FL1 produced the least grain yield and it attributes as shown in Table 5 Similarly, the different stream sizes used had significantly influenced the yield and yield attribute of the maize crop as presented in the (Table 4.9). Correspondingly, stream size use as treatment significantly affected yield and it parameters, maximum cob dry weight of (0.59kg) was recorded with SS2 treatment, it was closely followed by SS3 with cob dry weight values of (0.44kg) and least of (0.33kg) was counted with SS1. The grain weight per plant increased with the increasing of irrigation water discharge levels. Also the highest number of plant per seed of (596 and587) were remarkably produced from SS2 and SS3 respectively. Whereas SS1 gave the least seed number per plant. Equally, highest grain yield of (4.3463t/h and 3.812t/ha) were still recorded with SS2 and SS3 than all other treatment experimented. In addition, SS1 produced the least grain yield of (2.8828 t/ha) which is in line with those obtained from Hanson *et al.* (2007). Whom further reported that deficit irrigation water discharge decreased the number of grain yield, which was in agreement with findings of this study. The interactions between the furrow lengths and stream sizes were not significant.

Table 6: Influence of furrow lengths and stream size on yield attributes and yield of maize

Treatments	Cob Length (cm)	Cob Dry weight (kg)	NSPC	100 Seed weight (g)	Yield t/h
Furrow length (m)					
FL1(10)	22.4[c]	0.34[c]	528[c]	21.93[c]	2.9674[c]
FL2(20)	27.8[a]	0.45[b]	736[a]	26.40[a]	3.9563[a]
FL3(30)	25.7[b]	0.64[a]	636[b]	25.73[b]	3.6972[b]
Significance	Ns	*	*	*	*
SE±	0.12	0.34	0.07	0.14	0455
Stream sizes (L/s)					
SS1 (0 .5)	25.4[c]	0.33[c]	518[c]	20.23[c]	2.8822[c]
SS2 (1.0)	29.8[a]	0.59[a]	596[a]	29.10[a]	4.3463[a]
SS3 (1.5)	26.8[b]	0.44[b]	587[b]	27.73[b]	3.8122[b]
Significance	Ns	*	*	*	*
SE±	0.03	0.16	0.161	0.021	0.144
Interaction					
FL x SS	Ns	Ns	Ns	Ns	Ns

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

3.5 Matrix Correlation Studies

Table 7 and 8 shows the correlation results as among some growth and yield parameter in the study area. the parameters considered were days to 50% silking and girth, leaf area index, stem diameter, plant height, cob length and dry cob weight of the maize was analyzed at ($p<0.05$). As shown in Table 4.10. Days to 50% Silking showed a significant positive association with days to 50% girth (0.997**) followed by plant height at 10WAS (0.966**), steam diameter (0.762**), cob dry weight (0.626**) and cob length exhibited negative association (-0.386). However, it was not significant. Similarly, the parameter days to 50% girth was positively and significantly associated with cob length and dry cob weight with corresponding values (0.852** and 0.868**), respectively. It was closed by LAI at 10 WAS (0.836 **), whereas steam diameter at 10WAS (-0.815**) showed significant negative association. However, plant height at 10WAS (-0.119) showed non-significant negative association as in Table 4.10. Equally, the character leaf area index at 10 WAS, showed a highly significant positive association with plant height (0.993**) and stem diameter (0.7029**) at same WAS and significant negative association was also observed with cob dry weight (-0.688**) respectively. However, leaf area index exhibited a non-significant negative association with cob length (-0.309). In addition, stem diameter revealed a positive and highly significant association with cob dry weight (0.673**), plant height at 10WAS (0.7424**) and showed non-significant negative association with cob length (-0.389). likewise, plant height at 10WAS showed significantly positive association with cob length (0.8920**) and exhibited significant negative association with cob dry weight (-0.597), respectively. The results are in line with the finding (Egharevba 1999)

LAI=leaf area index, SD=stem diameter, PH= plant height, WAS= week after sowing

Table 7: Correlation matrix coefficient among some growth parameter and yield parameter as influenced by furrow length.

	50% silking	50% girth	LAI 10WAS	SD10 WAS	PH10 WAS	Cob length	Cob dry wet
50% Silking	1						
50% Girth	0.156	1					
LAI(10WAS)	0.997	0.836	1				
SD(10WAS)	0.762	-0.815	0.756	1			
PH(10WAS)	0.966	-0.119	0.993	0.673	1		
Cob length	-0.386	0.851	-0.309	-0.389	0.419	1	
Cob dry weight	0.626	0.868	-0.688	0.995	-0.597	0.478	1

As shows in Table 8 Days to 50% Silking showed a significant positive association with cob dry weight (0.995**), followed by days to 50% girth (0.891**), plant height at 10WAS (0.846**), leaf area index (0.756**) and the cob length exhibited negative association (-0.386) which was not significant. Correspondingly, the character leaf area index at 10 WAS, showed a highly significant positive association with days to 50% silking and girth with corresponding values (0.756** and 0.971**) and significant negative association was also observed with cob dry weight (-1.000**) respectively. However, plant height exhibited a strong positive significant association leaf area index (0.848**), stem diameter (0.959**). In addition, cob dry weight revealed a positive significant association with days to 50% silking (0.995**), days to 50% girth, leaf area index (0.818**), cob length (0.993**) than stem diameter (-0.138) which gave non-significant negative association which is in line with (Iyanar *et al*., 2001)

Table 8 : Correlation matrix coefficient among some growth parameter and yield parameter as influenced by stream sizes.

	50% silking	50% girth	LAI (10WAS)	SD (10WAS)	PH (10WAS)	Cob length	Cob dry wet
50% silking	1						
50% girth	0.891	1					
LAI(10WAS)	0.756	0.971	1				

SD(10WAS)	0.037	0.486	0.682	1			
PH(10WAS)	0.846	0.720	0.848	0.959	1		
Cob length	-1.000	0.983	0.745	-0.020	0.263	1	
Dry cob weight	0.995	0.932	0.818	-0.138	0.147	0.993	1

LAI=leaf area index, SD=stem diameter, PH= plant height, WAS= week after sowing

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 conducted 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. The findings revealed that furrow variables between 20 to 30m with stream sizes 1.5l/s and 1.0 have greatly improved growth and yield production in the study area. However, correlation studies revealed that positive and significant associations of averagely 89% was established among some growth and yield attributes

II. The finding testified that adoption of furrow length and stream size between (20-30 m and 1.0-1.5 L/ s) could be a good variable strategy to improve furrow irrigation performance parameters in the study region.

4.2 Recommendations

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

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

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