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Impact of Sowing Methods and Intra-row Spacing on Yield and Yield Components of Three Varieties of Maize (*Zea mays* L.) at Gash Scheme, Sudan.

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Abstract

Two experiments were conducted at Kassala Research Station, Experimental Farm at Takroof, Gash Irrigated Scheme, Kassala State, Sudan, during two successive winter seasons of (2015and 2016), to study the effect of three Sowing methods (Ridge, Flat and Local Farmer's Method), three Intra-row spacing (20, 30 and 40 cm) on yield and yield components of three maize (Zea mays L.) varieties namely Hudeiba-1, Hudeiba-2 and Variety113. The treatments of the experiment were conducted by using split plot arrangements based on a randomized complete block design with three replications, sowing methods were assigned as the main plots, the intra-row spacing as the subplots and the varieties as the Sub-subplots. The data were recorded for nine yield and yield components. Results revealed that sowing methods significantly affected most of the studied characters during both seasons. Ridge sowing method scored the higher rates of ear number/plot and number of seeds/row. Intra-row spacing also significantly affected most of the studied characters and 20 cm intra-row spacing gave higher levels of ear number/plot, number of seeds/ear, seed yield and hay yield. The varieties significantly affected ear length, ear diameter, number of rows/ear and number of seeds/row in the first season, ear number/plot was significantly affected by the varieties during both seasons, variety113 scored higher rates of ear/length, ear diameter, ear number of rows/ear and number of seeds/ear. In addition, the variety113 scored the higher rates of grain yield during 2015 and 2016 which amounted 1683 and 1766 Kg/ha, respectively. Grain yield was significantly affected by intra-row spacing of 20 cm and scored (1767 Kg/ha) during the first season, while 30 cm inter-row spacing scored higher levels of grain yield during the second season which amounted (1687Kg/ha). Accordingly, Variety113, grown on ridge and with intra-row spacing of 20 or 30cm gave the highest maize grain yield in Gash Scheme.

Key words: Sowing Methods, Intra-row Spacing, Variety, Maize, Yield, Yield components.

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I. INTRODUCTION

Maize (*Zea mays* L.) is one of the three most important globaly cereal crops after wheat and rice. Maize is grown in a wide range of environments more than wheat and rice because of its greater adaptability, it is grown at latitudes varying from equator to slightly north and south of latitude 50°, from sea level to over 3000 meters elevation, under heavy rainfall to semi arid conditions and cool to very hot climates. Maize is a basic food grain in many areas and several cultures(Abuali, *et al.,* 2011). According to USDA- FAS (2016), USA leads the World in both maize tonnage (341 million tons) and acreage (88 million acre). According To FAO (2007), about 158 million hectares of maize are harvested worldwide. Maize is desired for its multiple purposes as human food, animal feed, pharmaceutical and industrial manufacturing of many substances like: cornflakes, corn syrup and oil, the crop can also be used to produce starch, ethanol, plastics, and as a base for antibiotic production. A major shift in global cereal demand is underway, and by 2020, demand for maize in developing countries is expected to exceed demand for both wheat and rice. (Sabo *et al.,* 2016).

In Sudan Maize is of minor importance, it is only grown in River Nile Banks in small batches, in local farming system called Jobraka around houses, in limited areas in irrigated schemes, and in modern irrigation systems in Khartoum and River Nile States **(**Daboka, 2019). In Sudan grain yield of maize is very low compared to other growing countries, the demand for maize is increasing due to the increasing poultry production, establishments of many poultry and dairy plants (Salih *et al*., 2008). Abuali *et al.,* (2011) reported that, in the Sudan, the total cultivated area of maize increased from 17000 hectares in 1971 to 37000 hectares in 2010 and the average grain yield of maize (1.9 T/ha) is far below that of the world (6 T/ha). The low grain yields can be attributed to a number of constraints which include biotic stress (diseases, pests and lack of suitable varieties), a biotic stresses (low soil fertility and lack of capital to purchase farm inputs), this makes it imperative to boost the area and yield per unit area of maize and to explore the optimum cultural practices of the crop to meet the increasing demand (Idris and Abuali, 2011). Gash Irrigated scheme at Kassala State, East of the Sudan, with its most fertile soil in the world constitute a high potential to satisfy the needs for this crop. Hence, more researches should be carried out to determine the optimum growing techniques for the crop. Therefore, this study was conducted to determine the suitable sowing method, intra-row spacing and variety for optimum output, higher yield and yield components of maize in the Gash Scheme, Sudan.

II. MATERIALS AND METHODS

2.1 Experimental site, plant materials, design and cultural Practices

Three released open pollinated varieties of grain maize (*Zea mays* L.), obtained from Agricultural Research Corporation (ARC), Wad Medani, Sudan, were used in this study. Two experiments were conducted at Kassala Research Station Experimental Farm, at Takroof location latitude 15° 43' N and longitude 36° 38' East, elevation 596 m above sea level. The Gash soil analysis is presented in table, 3. The field experiments were carried out under irrigation system in the winter season for two consecutive seasons from September 2015 to January 2016 and from September 2016 to January 2017. (The climatic data of these periods are presented in table, 4). The experiments were carried to study the effect of sowing methods, intra-row spacing on grain yield and yield components of three varieties of maize. The three sowing methods used in the study were ridging method (RM), flat method (FM) and farmer local method (FLM). The three intra raw spacing were 20, 30 and 40 cm between holes. The three grain maize varieties were Hudeiba-1, Hudeiba-2 and variety113. The treatments of the experiments were conducted by using split plot arrangements based on a randomized complete block design with three replications, sowing methods were assigned as the main plots, the intra-row spacing as the subplots and the varieties as the sub-subplots. Land preparation was done according to ARC packages**.** The whole land of the experiment was ploughed using disc plough, disc harrow then leveled.

For the sowing method treatment, three sowing methods were used included: the ridging method in which the space was 0.8 m between ridges, the flat method in which the land was leveled and divided into plots 3X3 meters area and the farmer local method (which is called the farmers' method in all Gash area) in which the plough was used to convert any three ridges to one area with 1 m apart. For the intra-row method, the three varieties were sown in (20, 30 and 40 cm) spacing between holes. After emergence of plants, seedlings were thinned to one plant per hole, resulting in about (62500, 41670 and 31250) plants per hectare. All cultural practices were applied during both seasons as recommended by ARC. No fertilizer and/or pesticides were applied. Hand weeding was executed at 2nd, 6th and 8th weeks after planting to keep plots free of weeds. The irrigation was scheduled every two weeks interval. At harvest time (when the plants reached physiological maturity) nine yield and yield components traits were measured included: ear length, ear diameter, number of ears/plot, number of rows/ear, number of seeds/row, number of seeds/ear, seed yields Kg/ha, 100 Seed weight (gm) and hay yield Ton/ha,.

2.2 Statistical analysis for the collected data:

All compiled data of each season were analyzed separately, using Statistics10 Computer based program. Analysis of variance for each variable was obtained and means were separated using Least significant Difference (LSD) Test, according to (Gomez and Gomez, 1984).

III. RESULTS and DISCUSSION

3.1 Effect of Sowing Methods on means of yield and yield components

The effect of sowing methods (SMs) on means of yield and yield components are presented in tables 1 and 2. Statistical analysis of variance showed that ear length, ear diameter, ear number/plot, number of seeds/row, number of seeds/ear and hay yield ton/ha during the first season in addition to ear number/plot during the second season were significantly affected by sowing methods (tables,1 and 2). However, farmers' local method scored the highest levels of ear length, ear diameter, while ridge SM scored higher rates of ear number, number of seeds/ear, number of seeds/row and hay yield as shown in tables 1and 2, Flat SMs scored higher levels with respect to grain yield at both seasons and number of rows/ear as shown in table 2. Attia *et al.*, (2012) reported that sowing maize on ridge 80 cm apart was associated with significant increase in ear length, number of seeds/row, 100 seeds weight and grain yield. Sharifai, *et al.*, (2012) and Leilah, *et al.*, (2013) showed that increase in intra-row spacing from 20 cm to 25 cm significantly increase number of row/ear, 100 seed weight and grain yield. Anjum, *et al.*, (2014) concluded that maize grown on ridges under deep tillage gave maximum income ie. grain yield, while flat gave minimum income i.e. minimum grain yield. Mohammed *et al.*, (2006) reported that maize grain yield improved by planting methods, seed density and fertilizer level.

Table 1: Effect of SMs and Intra-row Spacing on Yield and Yield Components of three varieties of Maize (Zea mays L.) on Ear length, Ear Diam., Number of Ears/ plot., Number of rows/ear, Number of Seeds/row

Parameter	Ear Length		Ear Diam.		Number of Ears /Plot		Number of rows/ear		Number of Seeds/row	
Treatment	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
SM										
Ridge	18.2	15.6	4.66	2.3	29.3	33.8	14.0	12.9	31.0	22.9
Flat	18.7	16.1	4.75	2.0	22.9	20.1	14.4	13.4	28.8	18.9
F.L.M.	19.0	16.6	4.82	3.4	24.7	26.1	15.0	12.6	30.0	25.1
LS	*	NS	*	NS	*	*	NS	NS	*	NS
LSD0.05	0.633	3.909	0.194	2.447	0.194	9.763	1.162	2.467	2.053	7.52

Intra.R.S.										
20 cm	17.7	15.4	4.61	2.3	25.6	21.9	14.1	13.0	27.7	23.3
30cm	18.4	16.1	4.73	2.2	27.4	33.4	14.6	13.1	31.3	20.8
40cm	19.7	17.1	4.89	3.2	23.9	24.5	14.7	12.8	31.2	21.3
LS	***	NS	***	NS	*	**	NS	NS	**	NS
LSD	0.912	1.197	0.199	1.412	2.285	6.696	0.921	0.934	2.564	3.20
Varieties										
Hud-1	17.0	15.7	4.7	3.2	24.0	18.9	14.1	13.0	31.2	22.5
Hud-2	18.4	16.1	4.74	2.2	25.6	28.6	14.6	13.1	27.5	20.7
Vari113	20.2	17.3	4.79	2.4	27.4	32.5	14.7	12.8	31.6	21.9
LS	*	NS	**	NS	**	*	**	NS	*	NS
LSD0.05	1.267	1.581	0.282	1.648	2.48	11.46	0.702	0.944	2.744	3.15
Interac.										
R*V	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
LSD	0.912	2.738	0.488	2.412	4.304	19.84	1.248	1.634	2.053	5.51
R*S	*	*	NS	NS	*	*	*	NS	*	*
LSD	1.579	1.073	0.345	2.211	3.958	1.073	1.595	1.618	4.441	5.51
V*S	*	*	NS	NS	*	*	*	NS	*	NS
LSD	1.579	1.073	0.345	2.211	3.958	1.073	1.595	1.618	4.441	5.51
R*V*S	**	*	**	NS	*	*	NS	NS	NS	NS
LSD	2.735	3.591	0.597	3.829	6.857	3.591	2.763	2.805	7.871	9.54

Kg/ha= Kilogram/ hectare, F.L.M.=Farmer' Local Method, LS=Level of significant ns=not significant, *,**,*** significant to highly significant, LSD 0.05= Least significant difference at (P=0.05), SM*V=interaction between sowing method and variety, SM*S= interaction between sowing method and spacing, V*S= interaction between variety and spacing, SM*V*S= interaction between sowing method , spacing and variety.

3.2 Effect of Intra-row Spacing on yield and yield components:

The effect of intra-row spacing on means of yield and yield components are presented in tables 1 and 2. The statistical analysis showed that, Ear length, ear diameter, number of seeds/row during the first seasons, while ear number/plot during both seasons were significantly affected by intra-row spacing as presented in table, 1. The statistical analysis revealed that seed yield kg/ha, 100 seed weight and hay yield ton/ha during the first season and number of seeds/ear during the second season were significantly affected by intra-row spacing as shown in table, 2. The space of 20 cm intra-row spacing resulted in higher rates of seeds/ear, seed yield and hay yield (Tables 1 and 2), while 40 cm intra-row spacing scored higher rates with respect to ear length, ear diameter and 100 seeds weight (tables 1 and 2). The high yield scored by 20 cm spacing may be due to the increasing of the plants subjected their surfaces to sun radiation which led to more dry matter production and more seeds/ear. Fahad *et al.,* (2016), reported that grain yield of maize was more affected by variation in holes spacing than other member of grass family, holes spacing affected flowering, agronomic characters and grain yield. Sharifai, *et al.*, (2012) and Attia *et al.*, (2012) described that highest grain yield and harvest index were obtained at 10 plants/m^2 ie.(12.5 cm intra-row spacing). The highest number of grains/ear, stem diameter and ear length were recorded at 8 plants/m^2 i.e. 16 cm intra-row spacing.

3.3 Effect of varieties on means of yield and yield components:

The effect of varieties on means of yield and yield components are shown in tables 1 and 2. The statistical analysis of variance revealed that ear length, ear diameter, number of rows/ear and 100 seed weight and hay yield ton/ha during the first season were significantly affected by the varieties, in addition, ears number/plot and number of seeds/ear at both seasons were also significantly affected by the varieties (tables 1 and 2). Variety 113 significantly scored higher levels with respect to ear length, ear diameter, ears number/plot, number of rows/ear, number of seeds/row, number of seeds/ear, 100 seed weight and hay yield (tables 1 and 2). Kandil,et al., (2017), reported that maize hybrids ie. Varieties have different response to agronomic characters and grain yield. Alias, *et al.*, and El-Motwally *et al.*, (2011) showed a significant differences between plant height, number of ears/plant, LAI, number seeds/row, grain weight/ear and grain yield. Similarly variety113 has more adaptability to the environment of the experimental site (Gash Scheme, Takroof), which may be stimulated by the large inter-row spacing which results in better solar radiation interception with the crop canopy and increase photosynthetic processes as reported by Darwish (2009).

Table 2: Effect of SMs, Intra-row Spacing on yield and yield components of three varieties of Maize (Zea mays L.): for No. of Seeds/Ear, Seed Yield, 100 Seeds weight and hay Yield

Parameters	No of Seeds/Ear		Seed Yield Kg/ha		100 Seeds weight gm		Hay Yield Ton/ha	
SMs	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Ridge	437.8	299.3	1547	1578	18.0	17.9	9.62	11.82
Flat	309.7	281.1	1732	1740	17.4	17.2	10.0	9.96
F.L.M.	484.9	298.8	1626	1578	17.3	16.0	8.03	8.03
LS	*	NS	NS	NS	NS	NS	*	NS
LSD0.05	27.07	94.34	212.1	541.4	1.297	3.76	1.157	5.062
Intra.R.S.								
20 cm	384.6	311.2	1767	1595	17.1	16.5	9.81	9.8
30cm	459.4	260.8	1640	1637	17.2	18.2	8.91	8.9
40cm	456.4	307.2	1500	1684	18.4	17.0	8.94	11.07
LS	NS	*	**	NS	*	NS	*	NS
LSD	45.69	38.08	155.91	267.9	0.903	2.018	0.843	3.702
Varieties								
Hud-1	437.8	324.9	1568	1525	17.4	16.4	8.0	10.13
Hud-2	399.1	274.9	1654	1625	18.8	16.7	8.62	8.56
Vari113	458.6	279.5	1683	1766	16.5	18.6	11.03	11.04
LS	*	*	NS	NS	***	NS	***	NS
LSD0.05	39.11	41.58	164.3	319.2	0.903	2.311	0.592	3.669
Interac.								
SM*V	NS	*	NS	NS	*	NS	*	NS
LSD	67.73	70.29	284.5	551.1	1.025	4.004	1.026	6.702
SM*S	NS	NS	*	NS	*	NS	*	NS
LSD	69.13	65.95	270.0	468.9	1.563	3.494	1.459	6.411
V*S	NS	NS	*	NS	*	NS	*	NS
LSD	69.13	65.95	270.0	468.9	1.563	3.494	1.459	6.411
SM*V*S	NS	NS	*	NS	NS	NS	***	NS
LSD	137.8	114.2	467.7	809.6	3.074	6.411	2.528	11.105

F.L.M.=Farmer' Local Method, LS=Level of significant ns=not significant, *,**,*** significant to highly significant difference , LSD 0.05= Least significant difference at (P=0.05), SM*V=interaction between sowing method and variety, SM*S=interaction between sowing methods and spacing, V*S= interaction between variety and spacing, SM*V*S= interaction between sowing method, spacing and variety.

3.4 Effect of the interaction on means of yield and yield components:

The interaction between SMs*V was significantly affected ear number/plot. The interaction between Variety*Intra-row spacing was significantly affected ear length, ear number/plot, number of row/ear and number of seeds/row. The SM*V*Intra R Spacing interaction was significantly affected ear length, ear diameter and ear number/plot, seed yield and hay yield. The combinations of interaction of SM2* IR2 * V3 spacing (Flat SM* 30cm Intra spacing * V113) scored the highest yield during the first season and the second season, therefore, it could be selected as the best combination.

IV. CONCLUSION

From the above obtained results, it could be concluded that, among the three sowing methods ridge method scored the highest rates of the majority of the measured characters. As far as the Intra-row spacing 30 cm and 40 cm scored the highest levels of almost all measured characters. Within the three varieties used, the variety113 gave highest levels of all measured attributes. The combination of Flat*40cm *V113 and Flat*30cm * V113 of the interaction between the three treatments during the first season and the combination of Flat* 20cm* V113 during the second season gave highest levels of yield in Kg/ha.

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Table 3: Gash Soil Analysis

Soil name	PH	EC Dl/m-1	SAR %	ESP %	OC %	N ppm	P Ppm	K ppm	Sand ppm	Clay ppm	Silt Ppm
R1	8.1	o.83	1.2	1.9	0.20	340	2.4	37.5	9	37	54
R2	7.8	o.80	1.6	2.3	0.05	215	2.3	31.3	11	35	54
F1	7.9	1.1	2.1	3.0	0.05	401	2.3	37.3	12	39	49
F2	7.5	0.84	2.1	3.0	0.73	211	2.3	12.5	7	41	52

EC-Electrical conductivity, SAR=Sodium Absorption Ratio, ESP=Sodium exchangeable %, OC=Organic Carbon

Table 4: Climatic Data from September to January for 2015 and 2016 Season: min., maxi and mean temperature, R.H.%, Evaporation (Piche mm), R.F mm, Sunshine/day, Hours of Sunshine, Wind direction and speed.

Month	Maxi. Temp.	Mini. Temp.	Mean Temp.	Mean RH%	Evap Piche mm	Rain Fall mm	Sun shi -ne D.	Sunsh Hours /day	Wind Direct ion	Wind Speed Knots
Sept 2015	38.3	25.1	31.7	47	10.1	2.5	79	9.7	S	0.3
Sep. 2016	35.7	23.8	29.8	59	-	2.0	-	-	S..SW	03
Oct 2015	39.9	26.0	33.2	37	13.0	2.5	79	10.1	A.D.	03
Oct 2016	39.1	24.9	32.1	41	-	13.9	-	-	A.D	03
Nov 2015	38.1	23.5	30.9	37	12.9	0	92	10.5	N. N	03
Novr2016	38.1	23.0	30.8	33	-	Nil	-	-	E	03
Dec 2015	32.9	18.3	25.5	45	10.1	0	86	09.6	N.NW	03
Dec 2016	36.3	21.3	28.7	45	-	Nil	92	10.5	N.,NE	03
Jan 2016	34.1	16.9	26.0	42	11,4	Nil	90	10.1	N.	0.3
Jan 2017	33.4	16.6	29.8	42	10.7	Nil	86	9.8	NW	0.3

