Journal of Agriculture & Forestry Research
Volume no.2, Issue no. 1, Year 2023
www.sarpo.net

Research Article

Open access

Performance of Maize (*Zea mays*) Under Different Sowing Methods and Intra-Row Spacing

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ARTICLE INFORMATION

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Keywords:

Maize
Intra-row spacing
Hudeiba I
Grain yield
Leaf area index

ABSTRACT

The experiments were conducted to investigate the effects of sowing methods and intra-row spacings on some agronomic characteristics of the crop, including plant height, stem diameter, leaf area index, number of rows/ear, number of seeds/ row, number of grains per Ear, 1000-grains weight and grain yield (t.ha^{-1}), were conducted using the cultivar Hudeiba I, seasons 2019/20 and 2020/21. The experimental design was a randomized complete block design in a split plot arrangement with three replications. The main plot was sowing methods (drilling, ridging, and terrace). Subplots were intra-row spacing of (10, 15, 20, 25, and 30 cm). Sowing methods and intra-row spacing had significant effects on plant height, number of seeds per ear, and grain yield. Row spacing had non-significant effects on stem sickness, number of rows per cob, and 1000-grain weight. Intra-row spacing at 20 cm gave the highest grain yield (6.99 t.ha-1) and the same intra-row spacing 20 cm combined with the ridging sowing method gave the maximum grain yield, so they achieved (8.33 t.ha^{-1}), and intra-row spacing 10 cm with drilling sowing method were gave the highest plant height in both two seasons, they were achieved 190.13 cm. It's clear that plant height increased with the decrease in intra-row spacing. Stem diameter decreased with the decrease in intra-row spacing. Intra-row spacing (10 cm) in combination with the terrace sowing method produced the lower grain yield (3.53 t.ha^{-1}).

INTRODUCTION

Determination of the optimum plant density and in combination with appropriate agronomic practices is an important component of crop production package for maximizing productivity. Maize (Zea mays L.) is a member of the grass family, Poaceae (Gramineae); it's the world's widely grown highland cereal and primary staple food crop and animal feed in many developing countries (Kandil, 2014). It is the third most important staple food crop both in terms of area and production after wheat and rice in the world (Yearbook, 1995). Maize demand is projected to increase by 50% worldwide` and by 93% in sub-Saharan (FAO, 2015, Temesgen, 2019). In the many countries becoming the main food crop, especially in part of Africa and Asia countries. Maize has become a staple food in many parts of the world, with total production surpassing that of wheat or rice (Ali, 2019). Maize is also known as corn, domesticated by the indigenous people of South Mexico before 10,000 years ago (Ali, 2019). The rapidly increase demand for maize is driven by increase demand for direct human consumption in the world as a staple food crop (Ghimire et al. Kandil, 2014), this made many researchers, research centers and countries focus on this crop in order to fill any potential food gap in the world, whether through direct consumption or through animal and poultry feed. Where increasing grain yield per unit area and increasing the corn are the best solution to decrease the gap between consumption and production from feed and forage. Among the good agricultural practice to achieve this goal is to define the best row and intra-row spacing. Decreasing intra-row spacing decreased the number of inflorescences per plant, leaf area, shoot dry weight and grain yield per plant but increased plant height (Kandil, 2014). In other crops, early sowing dates with low density and high irrigation levels increased growth period and reduced competition, so increased production potential of Amaranth (Kandil, 2014, Yarmia et al. 2011).

Although maize was a non-major crop in Sudan, but in the past few years the need for it has grown, as it is used in livestock and poultry feed, in addition to use it in other food industry and biofuel (ethanol). Maize optimum cultural practices should be determined to satisfy increasing demand for the crop. Also, its production is greatly affected by varying planting density than other members of the grass family because of its monoecious floral organization, its low tillering cognition to fill the gap among plants, and the presence of synopsis ontogeny punctuation (Ali et al. 2017).

In fact, Sudan has great potential for animal production, ranking first in the Arab World. In Sudan, area cropped with maize amounts to 126 thousand acres (121,500 Feddan), about 51000 ha-1, which is 82% of that of 2013 (FAOSTAT, 2016). It's becoming the fourth most important, after wheat, sorghum, and millet. It is grown mainly as a food and feed crop (both forage and grain). Also it's of minor importance; it is only grown on in River Banks, in small batches, and in the "Jobraka" system of farming around houses in rural areas, in irrigated schemes, and in modern irrigation systems in Khartoum and River Nile States (Ali, 2019).

The establishment of an adequate plant density is critical for the utilization of available growth factors such as water, light, nutrients, and carbon dioxide and to maximize grain yield. Decreasing the distance between neighbor rows at any particular plant population has several potential advantages. It reduces competition among plants within rows for light, water, and nutrients due to a more equidistant plant arrangement (Tesfaye, 2020).

Growth and grain yield of maize is more affected by variations in hill spacing than other members of the grass family. Too wide spacing leads to low plant density per unit area and reduces ground cover, whereas too narrow spacing is related to intense competition between plants for growth factors (Tesfaye, 2020). The low yield of crops has been partly attributed to inappropriate plant density, planting time, and pest pressure (weeds, diseases and insect pests) (Gobeze et al, 2012). Determination of optimum plant population, adapted varieties and appropriate agronomic practices are important components of the maize production package for maximizing productivity. Successful production of any crop depends on the application of production inputs that will support the environment as well as agricultural production, these inputs include; adapted varieties, plant population, soil tillage, fertilization, weed, insect and disease control, harvesting, marketing and financial resources. Maize crops are characterized as low tillers, this poses that population density should be manipulated to compensate for the spaces created by the low tillering character; therefore, studying plant densities will be of vital importance. Many cultural practices like optimum sowing methods, intra-row spacing, and suitable varieties which achieve economical yield are also crucial for farmers and producers to increase their returns, change lifestyles, and increase the investment capital of producers and investors. The increase in maize crop yield adds up to the satisfaction of the growing demand of the increasing livestock and poultry industry.

The experiments were conducted to adapt the best cultural practices that increase maize production in Sudan, especially in Khartoum north area. Therefore, the overall objective of this study investigated a new cash and food crop, test the effects of sowing methods, and intra-row spacing on a variety of maize (Hudeiba I) for the growth, yield, and yield components of the crop.

MATERIALS AND METHODS

Description of the experiment

Two experiments were conducted at the experimental farm of the College of Agricultural Studies, Sudan University of Science and Technology, Shambat, Khartoum North, Sudan, to investigate the effects of three sowing methods (drilling, ridging, and terrace), and five intra row spacing's (10, 15, 20, 25 and 30 cm) on some agronomic characters of plants using the cultivar Hudeiba I, seasons 2019/20 and 2020/21. The area suited in the low land, River Nile, which lies between Latitude 15° 40̀ N and longitude 32°32̀ E, evaluated 380 m above Sea level (Gol, 2018). During two consecutive seasons (2019/20 and 2020/21) to investigate the proper sowing method with the relation of intra-row spacing of maize, variety (Hudeiba I), using a Randomized Complete Block Design in a split-plot arrangement, keeping sowing methods as main plots and intra-row spacing as sub-plots, plant populations of these intra-row spacings at all sowing methods are (10.0, 6.67, 5.0, 4.0 and 3.33 plants m-1) respectively (Table 1), the plot measuring size is 12 m2 (4 rows× 3 m) with three replications (Table 1), (drilling sowing method was leveled the four ridges and seeds were sown in four lines, the terrace sowing method was combined every two ridges together to compose one terrace and seeds were sown at the sides of any terrace). The spacing of 1.0 m and 1.5 m were left between plots and blocks, respectively.

Table 1: Combination of Treatments and Descriptions

No	SM× Intra-row spacing	Plot area (m^2)	Plant density/ m^{-1}
1	SM1 IRSP1	12 m^2	10.0
2	SM1 IRSP2	12 m^2	6.67
3	SM1 IRSP3	12 m^2	5.00
4	SM1 IRSP4	12 m^2	4.00
5	SM1 IRSP5	12 m^2	3.33

SM= Sowing Methods (1= Drilling (Flat), 2= Ridging, 3= Terrace), IRSP = Intra-row Spacing (1= 10, 2= 15, 3= 20, 4= 25 and 5= 30 cm).

Climate

The climate according to Shambat Metrological station, is described as tropical semi-arid, with the maximum annual rainfall ranging between 160- 180 mm, occurring from July to September. Relative humidity ranges between 31- 51% during the wet season and 12-27% during the dry season. Mean maximum and minimum temperatures in Khartoum North are 41.7˚C and 15.3˚C respectively. Winter season from Nov. – Mar. and is relatively cool and dry. The summer season is hot and dry.

Sowing methods and time

The experiments were sown on the 4th week of Nov. during both seasons. Sowing was done manually. Pumping water thefrom river Nile is common; in addition, underground water is used as supplementary irrigation the when river pump station was failed, especially in the second season. First irrigation was given after 15 days after the sowing in the first season and 7 days in the second season. For the 1st month field was shallowly irrigated at 7 interval days, while after a month till to tasselling and silking irrigation 10 days intervals were applied deeply by a furrow system, and at a critical time at tasselling and silking stage field was irrigated by 5 days interval to initiate flowering and silking, most of the time irrigation has been done after noon to avoid loses of water from the field by evaporation.

Land preparations

Land was well prepared (soil was plowed with a disc plow to uproot the previous crop, followed by disc harrow, cross harrow, and leveling and finally ridging operation), all these operations were done by a tractor. After that, the field was divided into plots. Drilling, and terrace were done manually after dividing the soil and then two seeds per hole were sown manually the last end-Nov, thinning to a single plant per each hole was done when seedlings produced four real leaves.

Plant material

The open-pollinated variety of grain maize (Zea mays L.) used in this study was obtained from Agricultural Research Corporation (ARC), Hudeiba station. The experiments were conducted to study the effects of sowing methods, and intra-row spacing on maize variety namely: Hudeiba I.

Soil classification

Soil of Shambat is well-drained loamy clay, non-saline, non-sodic, and classified predominantly as arid sols with pockets of Vertisols formed on old alluvium deposits, and Entisols on recent alluvium and aeolian deposits, with pH ranging from 7.71 to 7.91 (Gol, 2018, Hamadtou, 2016, Osman, 2021).

Fertilization

Phosphorus fertilizer in the form of DAP (Diammonium phosphate 18% N and 46% P2O5) at the recommended dose of 100.0 kg. ha-1 this equivalent (9 kg N and 46 kg P2O5) and half of the recommended dose of Nitrogen fertilizer in the form of Urea 46% N 250.0 kg ha-1, this equivalent (115.0 kg N) were added uniformly to all plots manually at the time of the sowing and the rest half of N-fertilizer was added after 35 days (5 weeks) from the first irrigation during both seasons.

Herbicides

Herbicide 2-4-D (2-4-dichloro-phenoxyacetic acid) 4.0 L. ha-1 was applied manually by Knapsack to protect the crop from broad leaves in the second season only.

Insecticides

Amidocloprid (N-{1-[(6-Chloro-3-pyridyl) methyl]-4, 5-dihydroimidazol-2-yl} nitramide) 1.50 L/ha-1 was applied manually by Knapsack, to control the Armyworms

Mythimna Spp. (Lepidoptera: Noctuidae) appeared during both seasons.

Plant height (cm)

Plant height was measured from six randomly pre-tagged plants from the net plot area and then their height was measured from the soil surface to the point where the tassel starts to branch with a meter rod at physiological maturity.

Stem diameter (mm)

Stem diameter was measured at 30 cm over the soil surface using the vernier caliper to determine the plant thickness and effects of sowing methods and intra-row spacing.

Leaf area

Leaf area per plant and leaf area index was recorded at 50% milk stage by measuring the leaf length and maximum leaf width of three leaves (top, middle, and bottom) per plant from six randomly pre-tagged plants from each net plot, the average of the three leaves was multiplied by the total number of leaves per plant and the area was adjusted by a correction factor 0.75 (i.e. 0.75× leaf length× maximum leaf width) as described by (Francis et al. 1969). The leaf area index was determined as the ratio of leaf area per plant divided by the respective ground area occupied by the plant.

Ear length

Ear length was recorded from six pre-tagged plants and measured their ear height from the attached of stalk level to the node bearing the top useful ear with a meter rod at physiological maturity.

Ear diameter

Ear diameter was recorded also from the same six ears taken from the net plot area (The same ears from which the length was taken), and then their diameter was measured at the middle of the ear with an vernier caliper; the mean was recorded as an ear diameter.

Number of rows/ear

The number of rows per ear was counted with the average number of rows in six ears from the same six pre-tagged plants, where the number of rows from six ears was counted and divided by their number.

Number of kernels/ row (KR)

Number of kernels per Ear (KR) was recorded from the six pre-tagged plants.ears taken from the same six pre-tagged plants.

Number of kernels/ ear

Number of kernels per ear were recorded by multiplying the total number of rows per ear and the number of kernels per row was recorded from the same six ears taken from the net plot area (The same ears from which the lengths and thickness were taken) in the net plot area after harvest and the average was recorded.

1000-kernels weight (GW)

Thousand kernels were counted from randomly taken ears after shelling by (manual counted). Then, thousand kernels weight was recorded from weighed thousand kernels using sensitive balance and adjusted to 12.5% moisture level.

Grain yield (GY)

Grain yield per plot was recorded using electronic balance and then adjusted to 12.5% moisture and converted to hectare basis.
The trend of data collected during two seasons was found similar, so the data was averaged.

Statistical analysis

The data was subjected to analysis of variance (ANOVA) using Statistical Analysis System (Statistix10, 2013) version 10.0.1.5 Software using proc GLM procedure. Duncan's multiple range tests and LSD was used to separate significantly differing treatment means after treatment effects were found significant at P≤ 0.05.

RESULTS AND DISCUSSIONS

Analysis of variance showed a significant differences among sowing methods, intra-row spacing and interactions of both variables were obtained from leaf area index (LAI), number of kernels per row, and grain yield in the combined results of two years, all results were shown in (Tables 2- 4).
Plant height (cm):
Analysis of variances of plant height showed no significant affected due to the main effects of sowing method, but highly significant at (P>01) of intra-row spacing and significant at (P>05) of combined analysis of sowing methods with intra-row spacing, the highest plant height (190.13 and 181.73 cm) were obtained from an interactions of drilling and ridging sowing methods with 10 cm intra-row spacing, respectively, while the lowest (139.20 and 134.20 cm) were recorded from interactions

of terrace sowing method combined with 25 cm intra-row spacing followed by interactions of drilling sowing method combined with 30 cm intra-row spacing, (Table 2).

Plant height was increased with decreased of intra-row spacing (increase in plant population from 3.33 to 10.0 plants.m-1), and these might be due to competition among plants about growth factors (moisture, nutrients, solar radiation and wind), these results agreed with (Gondal et al. 2017), they found that plant height was increased with increasing seed rate and decreasing row spacing. (Snider et al, 2012), reported that the effects of seeding rate on the plant height to be significant but contrasting effects at different sites. The intra-row spacing of 10 cm resulted in the highest plant height among all intra-row spacings and interactions among sowing methods; the lower plant height (134.20 cm) was obtained from drilling sowing method and interaction with 30 cm intra-row spacing. Also (Azam, 2007), reported that various varieties of maize have genotypic differences for plant height where the tallest plant height (145 cm) was recorded for variety Cargill 707 and the shortest plant height (134 cm) was recorded for variety Baber.

Stem diameter (mm)

Analysis of variances of stem diameter showed significantly (p>01) affected by intra-row spacing but sowing methods and interaction between sowing methods and intra-row spacing had no significant effects. The highest stem diameter (20.3 mm) was determined at interaction of drilling sowing method with 30 cm intra-spacing, while the lowest stem diameter (15.3 mm) was recorded at interaction of drilling and ridging sowing methods with 15 cm intra-row spacing, terrace sowing method was achieved the highest stem diameter (17.3 mm), while the sowing methods, and both were get 17.1 mm stem diameter, also 30 cm intra-row spacing was resulted the maximum (19.9 cm) stem thickness over the all other intra-row spacings (Table 2). These results may due to the fact that higher seed rate directly results in higher stems density and a higher stem density resulting in decrease in stem diameter due to the obvious interplant competition due to narrower of holes between plant to plant. These results were in line with (Schmitt and Wulff, 1993, Werf et al 1995) they reported that increase in seed rate from 5 kg ha-1 to 15 kg ha-1 resulted in a significant decrease in stem diameter while increased the stem density. Higher plant density produces thin stemmed plants that tend to lodge Kashiwagi et al, 2008; Venuto and Kindiger, 2008).

Table 2: Effects of sowing methods and intra-row spacing on growth parameters (PH, SD and LAI) of maize

Treatments	Plant height (cm)	Stem diameter (mm)	LAI (cm)
IRSP1 (10 cm)	179.76a	1.57c	4.74d
IRSP2 (15 cm)	170.62ab	15.6c	5.70c
IRSP3 (20 cm)	164.30b	16.1c	6.99b
IRSP4 (25 cm)	151.31c	18.5b	5.07ab
IRSP5 (30 cm)	145.96c	19.9a	4.86a
L. S.	*****	*****	***
LSD (0.05)	***4.19***	***0.04***	***0.07***
SM1 (drilling)	165.11a	17.1a	3.63ab
SM2 (ridging)	171.28a	17.1a	3.99a
SM3 (terrace)	150.77a	17.3a	3.28b
L.S.	***N.S.***	***N.S.***	*****
LSD (05)	***10.86***	***0.06***	***0.14***
SM1 IRSP1	190.13	15.7	5.13
SM1 IRSP2	166.40	15.3	5.93
SM1 IRSP3	181.10	16.3	7.27
SM1 IRSP4	153.73	17.7	4.80
SM1 IRSP5	134.20	20.3	5.03
SM2 IRSP1	181.73	15.7	5.57
SM2 IRSP2	180.20	15.3	6.40
SM2 IRSP3	172.33	1.60	8.33
SM2 IRSP4	161.00	18.7	4.83
SM2 IRSP5	161.13	19.7	5.60
SM3 IRSP1	167.40	15.7	3.53
SM3 IRSP2	165.27	16.0	4.77
SM3 IRSP3	139.47	16.0	5.37
SM3 IRSP4	139.20	19.3	4.57
SM3 IRSP5	142.53	19.7	3.93
L. S	***	***N.S.***	***
LSD (0.05)	***7.74***	***0.06***	***0.13***

IRSP = Intra-row Spacing (10, 15, 20, 25 and 30 cm), SM= Sowing Methods (1= Drilling (Flat), 2= Ridging, 3= Terrace), L. S= level of significant. * Significant at 0.05%, ** significant at 0.01%., N.S. Not significant, LSD: Least Significant Different.

Leaf area index

Analysis of variance showed a highly significant at (P < 0.01) affected by way of sowing methods and significant at (P> 0.05) affected by two ways (intra-row spacing and interactions of sowing method with intra-row spacing). Therefore, analysis and combined analysis of variance depicted that the maximum leaf area index (8.33 and 6.99) were obtained from interactions of the intra-row spacing 20 cm× ridging sowing method and intra-row spacing 20 cm, respectively (5.0 stalk. m-1 plant density), whereas the minimum leaf area index (3.53 and 3.28) were attained from combination of the terrace sowing method× 10 cm intra-row spacing (10.0 stalk. m-1 plant density) and terrace sowing method, respectively (Table 2).

In this study, it's clear that leaf area index was increasing with increasing the intra-row spacing till to 20 cm intra-row spacing and decreasing again, the possible reasons for the highest leaf area for ridging sowing method at the medium intra-row spacing (20 cm) might be due to the optimum conditions and ability of plant to uptake its sufficient needs from soil solution and solar radiation interception. These results were agreed with (Ngugi et al, 2013), he mentioned that lower plant population got more nutrients and water compared to higher population, thus contributed increased leaf area unlike high plant population density that reduced that reduced low leaf area of maize decreased. Similarly (Tesfaye, 2020), reported that the main effects of both intra, inter-row spacing and their interactions on leaf area were significant (P < 0.05), also he found that the leaf area per plant was increased with increasing inter and intra-row spacing.

Ali et al., 2017; Zhang et al. 2007 and Borra's et al. 2003 reported that a less leaf area index (LAI) duration could have resulted in response to increased plant population in the field due to more leaf senescence rate during grain filling. (Ali et al. 2017) mentioned that photosynthetic efficiency, growth and development in maize are greatly related to the effect of canopy architecture on the vertical distribution of light within the plants canopy. The optimum plant density is one of the ways of increasing the capture of solar radiation within the canopy. However, the efficiency of the conversion of intercepted solar radiation decreases with a high plant population density because of mutual shading in the plants in the field (Ali et al. 2017; Zhang et al. 2006).

Number of rows per Ear

The effects of sowing methods (SMs) and intra-row spacing on the means of number of the rows per ear were presented in (Table 3). Statistical analysis showed no significant differences among the number of rows per ear affected by sowing methods and intra-row spacing. However, the ridging sowing method (SM2) scored a higher level of rows per ear and achieved 13.49 over the drilling and terrace sowing methods and they scored 13.40 and 13.15 respectively.

The maximum number of rows/ear (14.27) was recorded from the interactions of the ridging sowing method with 20 cm intra-row spacing, followed by the interaction of the terrace sowing method with 30 cm intra-row spacing, was achieved (14.07 cm). These results were agreed with (Ibrahim et al. 2019), they found that the ridging sowing method scored higher rates of ear number , number of seeds/ ear, number of seeds per row and hay yield, also mentioned that the increase in intra-row spacing from 20 cm to 25 cm significantly increase number of row/ ear, 100 seed weight and grain yield.

Table 3: Effects of sowing methods and intra-row spacing on yield components (RE, KR and KE) of maize

Treatments	Number of rows/ear	Number of kernels/row	Number of kernels/ Ear
IRSP1 (10 cm)	13.50a	26.98bc	363.86b
IRSP2 (15 cm)	12.96a	27.44b	355.81b
IRSP3 (20 cm)	13.51a	30.52a	414.22a
IRSP4 (25 cm)	12.91a	26.36cd	339.98b
IRSP5 (30 cm)	13.87a	25.93d	359.40b
L. S.	***N.S.***	********	********
LSD (0.05)	***0.25***	***0.33***	***10.15***
SM1 (drilling)	13.40a	26.78a	358.26
SM2 (ridging)	13.49a	29.35b	397.05
SM3 (terrace)	13.15a	26.21b	344.65
L.S.	***N.S.***	********	*******
LSD (05)	***0.33***	***0.33***	***10.51***
SM1 IRSP1	13.00	27.20	353.27
SM1 IRSP2	12.67	27.67	350.90
SM1 IRSP3	13.40	29.77	399.03
SM1 IRSP4	13.93	25.27	351.90
SM1 IRSP5	14.00	24.00	336.20
SM2 IRSP1	13.60	27.87	379.03
SM2 IRSP2	13.47	28.33	381.23
SM2 IRSP3	14.27	33.93	484.14
SM2 IRSP4	12.60	28.07	354.20
SM2 IRSP5	13.53	28.53	386.63
SM3 IRSP1	13.87	25.87	359.27
SM3 IRSP2	12.73	26.33	335.30
SM3 IRSP3	12.87	27.87	359.47
SM3 IRSP4	12.20	25.73	313.83
SM3 IRSP5	14.07	25.27	355.37
L. S	***N.S.***	********	***N.S.***
LSD (0.05)	***0.56***	***0.50***	***18.21***

IRSP = Intra-row Spacing (10, 15, 20, 25 and 30 cm), SM= Sowing Methods (1= Drilling (Flat), 2= Ridging, 3= Terrace), L. S= level of significant. * Significant at 0.05%, ** significant at 0.01%., N.S. Not significant, LSD: Least Significant Different.

Number of kernels per row

The effects of sowing methods and intra-row spacing on number of kernels per row were presented in (Table 3). Statistical analysis showed highly significant differences among the mean of number of kernels per row and it was affected by three ways of sowing methods, intra-row spacing and interactions of SMs with intra row spacings. However, 20 cm intra-row spacing was achieved the highest number (30.52) of kernels per row while the 30 cm intra-row spacing was scored the lowest number of kernels per row (25.93). Moreover ridging sowing method (SM2) scored the higher level of kernels per row and achieved the 29.35 over the drilling and terrace sowing methods and they were achieved 26.78 and 26.24 respectively. The interaction effects of these cultural practices, ridging sowing methods with 20 cm intra-row spacing were achieved the highest number of kernels per row, achieved 33.93 while the lowest number of kernels per row were achieved by drilling and terrace sowing method methods with (25 and 30 cm) intra-row spacing respectively, they were scored 25.27 number of kernels per row. These results may due to the optimum conditions of the 20 cm intra-row spacing with ridging sowing method, crop was uptake the sufficient required from the soil nutrients and moisture and optimum distance between plants to intercepts their needs from solar radiation for good photosynthetic.

Number of kernels per ear

Number of kernels per ear contributes to the economic yield and represents the productive efficiency of any cereal crop or crop variety (Kebede, 2019).

Number of kernels per ear was highly significant ($p < 0.01$) affected by the main effects of intra-row spacing, significant ($P > 0.05$) affected by sowing methods (SMs) and there were no significant effects by interactions among the experimental variables. The highest number of kernels per year (484.14, 414.22) was recorded at interactions of ridging sowing with 20 cm intra-row spacing followed by the 20 cm intra-row spacing, while the lowest number of kernels per ear (313.85, 335.30) was recorded under interactions of terrace sowing method with 25 cm and 15 cm intra-row spacing respectively (Table 3). This variation might be due to the fact that widely spaced plants encountered less interplant competition than closely spaced plants and thus exhibited better growth that contributed to more number of kernels per ear. These results agreed with (Mukhtar et al., 2012) reported that wider spacing (17.50 cm) produced higher number of kernels per ear (717.00) while narrower spacing (10 cm) gave lower number of grains (540.30). In same line also (Eskandarnejada, 2013) reported that wide inter-row spacing of 30 cm produced more number of kernels per ear than that 20 cm plant spacing.

1000-kernels weight

The effects of sowing methods and intra-row spacing on means of 1000-kernel weight were shown in (Table 4). The main effects of intra-row spacing were highly significant ($P < 0.01$) on thousand kernel weight. However, the sowing methods and their interactions were not significant with increase intera-row spacing, thousand kernels weight increased, where the highest thousand kernels weight (325.72 g) was recorded at the 20 cm intra-row spacing, whereas, the lowest (235.0 g) was recorded at the 25 cm intra-row spacing. The highest 1000-grain weight 358.0 g was recorded at interaction of 20 cm intra-row spacing combined with ridging sowing method. The parameter of increase in 1000-grain weight was reflected in the grain yield increase confirming its contributive factor for grain yield.

Thousand kernel weights were increased with increasing of intra-row spacing till to 20 cm and decreased again, this might be due to the optimum condition to assimilate partitioning between higher numbers of kernels used in connection with the decreased interplant competition that lead to increased plant capacity, for utilizing the environmental inputs (solar radiation interception, wind and soil aeration) addition to agronomic practices with additives like fertilizers and water in building a great amount of metabolites to be used in developing new tissues and increasing its yield components. These results were agreed with (Kandil et al., 2017), reported that maize hybrids i.e. Varieties have different response to agronomic characters and grain yield. Also (Alias et al., 2010; El-metwally, 2011) showed a significant difference between plant heights, number of ears/ plant, LAI, number of seeds/ row, grain weight/ ear and grain yield. (Fernandez et al., 2012) reported that single-row planting at low plant populations produced the highest grain weight.

Grain yield

Grain yield was shown in (Table 4). Statistical analysis showed a significant ($p > 0.05$) affected by the interactions of the sowing method with intra-row spacing. Accordingly, the highest grain yield (8.33 ton. ha-1) was obtained in a combination of the ridging method with 20 cm intra-row spacing, while the lowest grain yield (3.53 ton. ha-1) was obtained from the terrace sowing method in combination with the narrowest intra-row spacing 10 cm.

The possible reason for the lowest grain yield at the narrowest spacing might be due to the presence of competition of plants per unit area for solar radiation interception, moisture, available nutrients and other sources in the soil. This indicated that high plant population per unit area that could not get better available growth factors like moisture, nutrients, light, and space could not offset the grain yield obtained from high plant population per unit area.

Table 4: Effects of sowing methods and intra-row spacing on yield components (1000 Kernels weight and grain yield) of maize

Treatments	1000-Kernels. wt (g)	Yield. T.ha^{-1}
IRSP1 (10 cm)	236.7b	4.74c
IRSP2 (15 cm)	242.44b	5.70b
IRSP3 (20 cm)	325.72a	6.99a
IRSP4 (25 cm)	235.00b	5.07c
IRSP5 (30 cm)	243.00b	4.86c
L. S.	********	********
LSD (0.05)	***8.22***	***0.15***
SM1 (drilling)	252.90a	5.63b
SM2 (ridging)	265.20a	6.35a
SM3 (terrace)	251.60a	4.43c
L.S.	***N.S.***	********
LSD (05)	***7.39***	***0.07***
SM1 IRSP1	237.67	5.13
SM1 IRSP2	245.33	5.93
SM1 IRSP3	324.50	7.27
SM1 IRSP4	218.33	4.80
SM1 IRSP5	238.67	5.03
SM2 IRSP1	240.67	5.57
SM2 IRSP2	240.67	6.4
SM2 IRSP3	358.00	8.33
SM2 IRSP4	245.33	5.83
SM2 IRSP5	241.33	5.60
SM3 IRSP1	231.67	3.53
SM3 IRSP2	241.33	4.77
SM3 IRSP3	294.67	5.37
SM3 IRSP4	241.33	4.57
SM3 IRSP5	249.00	3.93
L. S	***N.S.***	*******
LSD (0.05)	***12.79***	***0.26***

IRSP = Intra-row Spacing (10, 15, 20, 25 and 30 cm), SM= Sowing Methods (1= Drilling (Flat), 2= Ridging, 3= Terrace), L. S= level of significant. * Significant at 0.05%, ** significant at 0.01%., N.S. Not significant, LSD: Least Significant Different.

Previous research reveals indicated that plants grown on wider spacing absorb more nutrients and solar radiation for improved photosynthesis and hence produce better grain yield on an individual basis, but yield per unit area reduced due to a thin and low plant stand on unit area. (Ibrahim and Elhassan, 2019), mentioned in the conclusion study 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 (drilling) Flat× 40 cm× V113 and (drilling) Flat ×30 cm× V113 of the interaction between the three treatments during the first season and the combination of (drilling) Flat× 20 cm V113 during the second season gave the highest levels of yield in Kg.ha-1.

Conclusion and Recommendation

From these findings, we are recommending the following ridging sowing method and 20cm intra-row spacing in this area and variety.

ACKNOWLEDGEMENT

The authors gratefully acknowledge to the management team of the College of Agricultural Studies, Sudan University of Science and Technology for their unlimited support in accomplishing this work over two consecutive years.

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