Effects of Sowing Methods and Intra-Row Spacing on Grain Yield and Some Agronomic Characters of Maize (*Zea mays*)

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Abstract

Effects of sowing methods and intera-row spacing on grain yield and some agronomic characters of maize was investigated at the Demonstration Farm, Sudan University of Science and Technology, College of Agricultural Studies, Shambat, Khartoum North, during two consecutive seasons of 2019/20 and 2020/21 to study the effects of three sowing methods and five intra-row spacings on some agronomic characters of plants including; plant height, stem diameter, leaf area index, number of rows/ear, number of kernels/ row, number of kernels per Ear, 1000-kernels weight and grain yield, Hudeiba II cultivar was used.

The experimental design was a randomized complete block design in split plot arrangement with three replications. Main plot were sowing methods (drilling, ridging and terrace) and subplots were intra-row spacing (10, 15, 20, 25, and 30 cm), plant densities of intra-row spacings are (10, 6.67, 5.0, 4.0 and 3.33 plants m^{-1}) respectively.

Significant effects of interaction of sowing methods and intra-row spacing were observed at plant height and stem diameter, for other traits, effects of sowing methods was highly significant at number of kernels per row, and significant at leaf area index, number of rows per ear, intra-row spacing was highly significant at all parameters under investigation. The highest grain yields (3.53 and 3.20 $t.ha^{-1}$.) were obtained from two ways (interaction of SM2 ×20 cm and 20 cm intra-row spacing) and interaction of SM1× 20 cm respectively, while the lowest (2.07 and 2.0 $t.ha^{-1}$) grain yield were obtained from SM3× 10 cm and SM3× 30 cm, respectively.

Key words: Maize, intra-row spacing, Hudeiba II, grain yield, leaf area index.

1. Introduction

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 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 indigenous people of South Mexico before 10,000 years ago (Ali 2019). The rapidly increasing demand of maize is driven by increased in demand for direct human consumption in the world as a staple food crop (Ghimire *et al.* 2007; Kandil 2014). 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 (Kandil 2014). Decreasing intra-row spacing decreased the number of inflorescence per plant, leaf area, shoot dry weight and grain yield per plant but increased plant height (Kandil 2014). Early sowing dates with low density and high irrigation levels increased growth period and reduced competition, so increased production potential of Amaranth (Kandil 2014; Yarnia *et al.* 2011).

Although it 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. Maize 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 a great potential for animal production, ranking first in the Arab World. In Sudan, area cropped with maize amount to 126 thousand acre (121,500 Feddan) about 51000 ha^{-1}, which is 82% of that of 2013 (FAOSTAT 2016). Maize in the Sudan is the fourth in importance, after wheat, sorghum and millet. It is grown mainly as food and feed crop (both forage and grain). In Sudan also maize is of minor importance, it is only grown in River Banks, in small batches and in "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 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 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 including; adapted varieties, plant population, soil tillage, fertilization, control of (weed, insect and disease), harvesting, marketing and financial resources. Maize crop characterized as low tillers, this poses that population density should be manipulated to compensate the spaces created by the low tillering character; therefore, studying plant densities will be 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 life style, and increase the investment capital of producers.

The increase of 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 the Sudan, especially in Khartoum north area. Therefore, the overall objective of this study is to investigating a new cash and food crop, and testing the effect of sowing methods, intra-row spacing on variety of maize (Hudeiba I I) for growth, yield and yield components of the crop.

2. Material and Methods

Two experiments were conducted at experimental farm of college of Agricultural studies, Sudan University of Science and Technology, Shambat, Khartoum North, Sudan. The area suited in the low land, River Nile, which lies between Latitude 15˚ 40' N and longitude 32˚ 32' E, evaluation 380 m above Sea level (Gol 2018). During two consecutive seasons (2019/20 and 2020/21) to investigate the proper sowing method with relation of intra-row spacing of maize, variety (Hudeiba II), using a Randomized Complete Block Design in a split plot arrangement, keeping sowing methods (drilling, ridging and terrace) as main plots and intra-row spacing (10, 15, 20, 25 and 30 cm) as sub-plots, plant densities of the intra-row spacings at all sowing methods are (10, 6.67, 5.0, 4.0 and 3.33 plants ha^{-1}) respectively, the plot measuring size is 12 m^{2} (4 rows× 3 m) with three replications (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 10 cm from the sides of any terrace). The spacing of 1.0 m and 1.5 m were left between plots and blocks, respectively.

The climate according to Shambat Metrological station, described as tropical semi-arid, the maximum annual rainfall ranges about 260-280 mm, occurring during June to September. Relative humidity ranges between 31-51% during wet season and 12-27% during dry season. Mean maximum and minimum temperature in Khartoum North are 41.7˚C and 15.3˚C respectively. Winter season from Nov. – Mar. and is relatively cool and dry. Summer season is hot and dry.

The experiments were sown on 4th week of Nov. during both seasons. Sowing was done manually. Pumping water from River Nile is common; in addition, underground water used as supplementary irrigation when River pump was failed, especially in the second season. First irrigation was given after 15 days (two weeks) from the sowing in the first season and 7 days (1 week) in the second season. For the 1st month field was shallow irrigated at 7 interval days, while after a month till to tasselling and silking irrigation 10 days interval applied deeply by furrow system, and at 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 was well prepared (soil was ploughed with disc plough to uproot the previous crop, followed by disc harrow and reharrawing, leveling and then ridging), all these operations were done by tractor. After that, field was divided into plots, drilling and terrace were done manually after divided the soil. The area of each plot was (4 rows× 3 m length), and then two seeds per hole were sown manually in the last end-Nov, thinning to a single plant per each hole was done when seedlings produced four leaves.

2.1. 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, intra-row spacing on the maize variety Hudeiba II.

2.2. Soil:

The soil of Shambat is well drained loamy clay, non-saline and non-sodic, and classified as predominantly as arid sols with pokets 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).

2.3. Fertilization:

Phosphorus fertilizer dose in the form of DAP (Diammonium phosphate 18% N and 46% P_2O_5) at the recommended dose of 100.0 kg. ha^{-1} this equivalent (9 kg N and 46 kg P_2O_5) and half of recommended dose of Nitrogen fertilizer in the form of Urea 46% N 250.0 kg, 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.

2.4. Herbicides:

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

2.5. 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 insecticide applicator, to control the Armyworms Mythimna Spp. (Lepidoptera: Noctuidae) appeared during both seasons.

2.6. Plant height (cm):

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

2.7. Stem diameter (mm):

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

Table 1: Combination Treatments and Descriptions

No	SM× Intra-row spacing	Plot area (m^2)	Plant density m^{-1}
1	SM1 IRSP1	12 m^2	10.00
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).

2.8. Leaf area index:

Leaf area plant^{-1} 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) plant^{-1} 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 plant^{-1} divided by the respective ground area occupied by the plant.

2.9. Ear length:

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

2.10. Ear diameter:

Also was recorded 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 ear with vernier caliper; the mean was recorded as an ear diameter.

2.11. The number of rows/ear:

The number of rows per ear were 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.

2.12. Number of kernels/ row (KR):

Number of kernels Ea-1 (KR) was recorded from the six ears taken from the same six pre-tagged plants.

2.13. Number of kernels/ ear:

Number of kernels row^{-1} were recorded by multiplying the total number of rows ear^{-1} and the number of kernels row^{-1} 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.

2.14. 1000-kernels weight (GW):

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

2.15. 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. Stand count was recorded from the net plot area after thinning and at harvest.

The final plant stand percentage (final plant stand counted at maturity/ population established after thinning× 100) of the respective treatments was used to determine the stand loss due to competition.

Above ground, fresh and dry biomass yield was weighed after entire plants harvested from the net plot area, weighed using field balance (Model-T8 weighing platform scale), and recorded biomass yield at harvest. Harvest index was calculated as the ratio of grain yield to the total aboveground dry biomass yield per plot × 100.

2.16. 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 were used to separate significantly differing treatment means after treatment effects were found significant at P≤ 0.05.

3. Results and Discussion:

3.1. Evaluation performance of maize under different sowing methods and intra-row spacings:

Analysis of variance showed highly significant differences (p≤0.01) among intra-row spacing variables from all parameters under study, included; plant height, stem diameter, leaf area index, number of rows/ear, number of kernels/ row, number of kernels per Ear, 1000-kernels weight and grain yield (Tables 2-4), sowing methods showed a significant differences among leaf area and number of rows cob^{-1} (p≤0.05), and highly significant (p≤0.01) in the number of kernels per rows (Table 3), the combined results of combined two years, were shown in (Tables 2-4), analysis of variance showed significant differences at the plant height and stem diameter.

3.2. Plant height (cm):

The effects of intra-row spacing on plant height was highly significant (P <0.01), while the interaction with sowing methods was significant (P≤0.05) and there had no significant effects of sowing methods (Table 2). The tallest plants were recorded at interaction of terrace sowing method with 10 cm intra-row spacing and 10 cm intra-row spacing (165.07 cm, 158.82 cm) respectively and the lowest plant height (127.0 and 124.23 cm) were recorded at interaction of drilling sowing method with 25 and 30 cm intra-row spacing respectively (table 2). It’s clear that plant height was increasing by decreased intra-row spacing, , this results might be due to the competition of plant to light interception and soil sources (water and nutrients) available. These results were in line with (Gozubenli *et al.* 2003; Sener *et al.* 2004), they found that Plant height was significantly affected by maize hybrids and intra-row spacing. In contrast of these results (TURGUT 2000) found there were no effects of intra-row spacing on plant height.

3.3. Stem diameter (mm):

Stem diameter was significantly (p<0.05) affected by interaction of sowing methods and intra-row spacing, highly significant (p<0.01) by intra-row spacings and not significant affected by sowing methods, the highest stem diameter (25.0 mm) was obtained at interaction of drilling sowing method with 30 cm itra-row spacing, while the lowest stem diameter (17.67 mm) was registered at the combined of drilling sowing method with 10 cm intra-row spacing (table 2).

These results might be due to interplant competition on environmental conditions like solar radiation interception and soil sources (nutrients and moisture) and wind affected on growth factors. These results were agreed with (Sener et al. 2004) they found that the stem diameter was strongly influenced by environmental conditions and intra- row spacing. Also (Konuskan 2000) mentioned that stem diameter were lower in higher plant densities as a consequence of interplant competitions.

Table 2: Effects of Sowing Methods and Intra-row Spacing on Plant Height of Maize

Treatments	Height (cm)	Thickness (mm)	LAI
IRSP1 (10 cm)	158.82a	18.00e	3.26c
IRSP2 (15 cm)	151.17b	19.33d	3.49c
IRSP3 (20 cm)	141.09c	21.22c	4.20a b
IRSP4 (25 cm)	131.74d	22.44b	3.97b
IRSP5 (30 cm)	129.13d	23.94a	4.24a b
L. S.	******	*******	*******
LSD (0.05)	***2.61***	***0.60***	***0.13***
SM1 (drilling)	140.05	21.43a	3.71a b
SM2 (ridging)	143.71	21.40a	4.25a
SM3 (terrace)	143.57	20.13a	3.53b
L.S.	***ns***	***ns***	*****
LSD (05)	***3.58***	***0.67***	***0.25***
SM1 IRSP1	158.27	17.67	3.30
SM1 IRSP2	151.53	19.83	3.30
SM1 IRSP3	138.93	21.67	3.93
SM1 IRSP4	127.00	23.00	3.83

SM1 IRSP5	124.23	25.00	4.20
SM2 IRSP1	153.13	18.33	3.47
SM2 IRSP2	149.80	19.83	3.83
SM2 IRSP3	144.40	21.67	4.73
SM2 IRSP4	135.00	23.00	4.47
SM2 IRSP5	136.20	24.17	4.47
SM3 IRSP1	165.07	18.00	3.00
SM3 IRSP2	153.07	18.33	3.33
SM3 IRSP3	139.93	20.33	3.93
SM3 IRSP4	133.13	21.33	3.60
SM3 IRSP5	126.67	22.67	3.80
L. S	*****	*****	***ns***
LSD (0.05)	*5.38*	*0.35*	*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.

3.4. Leaf area index:

Leaf area index was significantly (P< 0.01) affected by intra-row spacing, significant (P<0.05) affected by sowing methods and no significant effects was recorded by interactions of sowing method× intra-row spacing (table 2). Therefore, analysis of variance depicted the maximum leaf area index (4.73) was obtained from interactions of of ridging sowing method× 20 cm intra-row spacing, whereas the minimum leaf area index (3.00) was attained from the interaction of terrace sowing method with thinner intra-row spacing 10 cm (Table 2). The reasons for the wider leaf area index at interaction of ridging sowing method× 20 cm might be due to the optimum environmental growth conditions and interplant competition to receipt the solar radiation interception, and easy to uptake the nutrients and moisture from the soil solution. These results were partial agreed with (Tesfaye 2020), he reported that leaf area per plant was increased with increasing inter and intra-row spacing, and also mentioned; the higher leaf area plant^{-1} in the wider inter and intra-row spacing might be due to more availability of growth factors and better penetration of light, consequently increased number of leaves produced and the size of individual leaves in plants at wider row spacing. Also (Sangoi *et al.* 2001) reported that higher leaf area of maize was attained from wider row spacing (75 cm) than at (50 cm) row spacing.

3.5. Number of rows Ear^{-1}:

Analysis of variance showed highly significant (P<0.01) effects of intra-row spacing, significant (P<0.05) effects of sowing methods and non significant effects of the interactions of sowing method with intra-row spacings on number of rows per ears (table 3). The highest number (24.0) of rows ear^{-1} was scoured from the interactions of the terrace sowing method with 25 cm intra-row spacing.

Table 3: Effects of Sowing Methods and Intra-row Spacing on Yield Components of Maize

Treatments	Rows.ear^{-1}	Kernels.row^{-1}	Kernels. Ear^{-1}
IRSP1(10cm)	22.69b	28.13a	636.86c
IRSP2(15cm)	22.59b	31.00b	700.39b
IRSP3(20cm)	22.67b	32.62ab	739.48ab
IRSP4(25cm)	23.60a	33.31a	786.30a
IRSP5(30cm)	23.33ab	33.47a	780.62a
L. S.	**	***	***
LSD (0.05)	***0.44***	***1.03***	***26.24***
SM1(drilling)	22.91a	32.08a	735.66a
SM2(ridging)	22.99a	32.01a	712.00a
SM3 (terrace)	23.03a	31.03a	737.53a
L.S.	*	**	***ns***
LSD (05)	***0.23***	***1.26***	***31.91***
SM1 IRSP1	22.20	30.13	670.00
SM1 IRSP2	22.60	31.27	706.50
SM1 IRSP3	22.80	34.00	775.37
SM1 IRSP4	23.53	32.80	773.23
SM1 IRSP5	23.40	32.20	753.20
SM2 IRSP1	22.93	26.87	613.97
SM2 IRSP2	22.90	30.80	704.73
SM2 IRSP3	22.87	29.53	675.20
SM2 IRSP4	23.27	34.07	792.50
SM2 IRSP5	23.00	33.87	778.60
SM3 IRSP1	22.93	47.40	626.60
SM3 IRSP2	22.27	30.93	689.93
SM3 IRSP3	22.33	34.33	767.87
SM3 IRSP4	24.00	33.07	793.17
SM3 IRSP5	23.60	34.33	810.07
L. S	***ns***	***ns***	***ns***
LSD (0.05)	*0.54*	*1.27*	*32.14*

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.

These results showed that terrace sowing method performed better at 25 cm intra-row spacing in bearing rows ear^{-1} than at other sowing methods and intra-row spacings. The lowest (22.20) rows ear^{-1} was recorded at interaction of drilling sowing method with 10 cm intra-row spacing. In general, number of rows ear^{-1} was fluctuated increased in all sowing methods as intra-row increasing and decreased, however, the ridging sowing method is the best among all followed by drilling and terrace (Table 3). These results were agreed with (Temesgen 2019), he found that the number of ear plant^{-1} increased in all varieties under his study as intra-row increased. And since the size of the ear was increases, that means an increase in the number of rows per ear

Table 4: Effects of Sowing Methods and Intra-row Spacings on 1000-kernels Weight and Grain Yield of Maize

Treatments	1000-Kernels. wt (g)	Yield. T. ha^{-1}
IRSP1(10cm)	268.56a	2.89c
IRSP2(15cm)	276.00b	2.622b
IRSP3(20cm)	354.67a	3.20a
IRSP4(25cm)	270.44b	2.37bc
IRSP5(30cm)	270.33b	2.13c
L. S.	*********	*********
LSD (0.05)	***9.08***	***0.16***
SM1(drilling)	283.40a	2.51a
SM2(ridging)	298.47a	2.72a
SM3 (terrace)	282.13a	2.34a
L.S.	***ns***	***ns***
LSD (05)	***12.08***	***0.25***
SM1 IRSP1	267.33	2.33
SM1 IRSP2	277.67	2.80
SM1 IRSP3	359.67	3.20
SM1 IRSP4	251.33	2.13
SM1 IRSP5	261.00	2.07
SM2 IRSP1	276.67	2.47
SM2 IRSP2	280.00	2.73
SM2 IRSP3	374.00	3.53
SM2 IRSP4	284.00	2.53
SM2 IRSP5	277.00	2.33
SM3 IRSP1	261.67	2.07
SM3 IRSP2	270.33	2.33
SM3 IRSP3	330.33	2.87
SM3 IRSP4	276.00	2.43
SM3 IRSP5	272.33	2.00
L. S	***ns***	***ns***
LSD (0.05)	***11.12***	***0.19***

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.

3.6. Number of kernels row^{-1}:

Analysis of variance showed highly significant ($P<0.01$) effects of intra-row spacing, significant ($P<0.05$) effects of sowing methods and non significant effects on the interactions of sowing methods with intra-row spacing on number of kernels row^{-1} (table 3). The highest number (47.40) of kernels row^{-1} was scoured from the interactions of terrace sowing method with 10 cm intra-row spacing, while the lowest (26.87) was obtained from riding sowing method combined with 10 cm intra-row spacing.

These results were in contrast with (Azam *et al.* 2007; Roy and Biswas 1992), they found that response of number of grains per cob to spacing was significant and number of grains increased with increasing in row spacing.

3.7. Number of kernels Ear^{-1}:

Analysis of variance showed a highly significant (P<0.01) effects of intra-row spacing, and no significant effects of sowing methods and their interactions on the number of kernels per ears among all treatment means (table 3). The heighest number (810.07) of kernels cob^{-1} was recorded at terrace sowing method interacted with 30 cm and the lowest number (613.97) of kernels cob^{-1} was recorded at ridging sowing method interacted with 10 cm (table 3). İncreasing intra-row spacing from 10 cm to 30 cm showed linear and consistent kernels increment though there was no significant difference between 20, 25, and 30 cm intra- row spacing. 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 ofkernels per ear. These results were in line with (Roy and Biswas 1992), they found that grain number per cob was highest at 33300 plants/ha^{-1}. Also (Azam *et al*. 2007), reported that the response of number of grains per cob to spacing was significant and found the maximum number of grains per cob was recorded at the wide space and minimum number of grains per cob was recorded at the narrow space.

3.8. Thousand kernels weight (g):

Thousand kernels weight is a major yield component that has an essential role in determining the potential yield of variety (Dalley and Kells 2006). 1000-kernels weight was shown in (table 4).

Analysis of variance revealed that intra-row spacing was highly significant (p< 01). Two-ways of sowing methods and interaction of sowing method× intera-row spacings showed non significant effects.

Mean values of sowing methods indicated that maximum thousand grain weights (298.47 g) was observed at ridging sowing method and the minimum grain weights (282.13 g) was observed at the terrace sowing method. The maximum grain (354.67 g) weight in the intra-row spacing was obtained at the 20 cm and the minimum (268.56 g) was obtained at 10 cm, the best weight (374.00 g) was recorded under interactions of ridging sowing method× 20 cm intra-row spacing (table 4). These results were completely agreemeed with (Okan Sener and Kilinc 2004), they found that grain weight per ear increased with increasing spacing and the weightiest ears obtained from 20.0 cm intra-row spacing and the lightest ears obtained from 10.0 cm intra-row spacing.

3.9. Grain yield t. ha^{-1}:

Grain yield is the end result of many complex morphological and physiological processes occurring during the growth and development of the crop.

Grain yield was significantly (p< 0.01) affected by the intra-row spacing but not significant effects by sowing methods and interactions of sowing methods with intra-row spacing (table 4).

The highest grain yield (3.20 t.ha^{-1}) was obtained in combination of 20 cm intra-row spacing and interaction of ridging sowing method with 20 cm intra-row spacing, while the lowest grain yield (2.0 t.ha^{-1}) was obtained from terrace sowing method× wider intra-row spacing 30 cm (table 4). The lowest grain yield at the widest spacing might be due to the presence of less plants number per unit area, also increase in grain yield per plant at wider spacing is not surprising because lower plant density exerts lesser interplant competition for space as well as growth factors. These results were agreed with (Kebede 2019), he found that the low plant density per unit area could get better available growth factors like moisture, nutrients, light, and space could not offset the grain yield obtained from high plant density per unit area. Also (Borrás *et al.* 2003) reported 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 or low plant stand.

4. Conclusion and Recommendations:

From the findings, it’s recommended to adopt ridging sowing method combined with 20 cm intra-row spacing in the area and to use Hudeiba II cultivar of maize.

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