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EFFECTS OF SPACING ON GROWTH OF SORGHUM (*SORGHUM BICOLOR* L) AT ASSOSA DISTRICT, BENISHANGUL GUMUZ, ETHIOPIA

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ABSTRACT

A field experiment was conducted at Assosa District during the main cropping season of 2016 to evaluate the effect of spacing (inter- and intra-row spacing) on yield and yield components of sorghum (Sorghum bicolor L.). Four inter-row spacing (50cm,60cm,70cm and 80cm) and four intra-row spacing (10, 15, 20, and 25cm) were evaluated as treatments using a randomized complete block design with three replications. Yield and yield related parameters such as plant height, tillers per plant, grains per panicle, thousand grain weight and grain yield were collected and analyzed using SAS software. Results of the experiment showed that out of the parameters measured, plant height, tillers per plant, grains per panicle, 1000-seed weight and grain yield were affected by inter-row spacing significantly (P<0.01).Similar to the effect of inter-row spacing, intra-row spacing also affected plant height, tillers per plant, grains per panicle and grain yield significantly (P<0.01) but thousand grain weight affected non-significantly (P<0.01).The economic analysis showed that inter-row spacing, intra-row spacing and their interaction effect had maximum net income, benefit cost ratio and marginal rate of return at 70cm inter-row spacing, 15 cm intra-row spacing and interaction effect of 70cm x15cm while had minimum net income, benefit cost ratio and marginal rate of return at 50cm inter-row spacing, 25 cm intra-row spacing and interaction effect of 80cm x25cm. Finally, 70cm inter-row spacing with 15cm intra-row spacing is recommended for higher yield in the district.

KEYWORDS: Spacing, Inter-row spacing, Intra-row spacing.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is a monocotyledon crop belonging to the family Gramineae. It is naturally self-pollinated and short day plant with the degree of spontaneous crosspollination, in some cases, reaching up to 30% depending on panicle types. [1] It is originated in Ethiopia. As [2] reported, 5000 years ago the Caucasoid Agau people in the region of North Africa, which is now Ethiopia, were cultivating wheat and a weed of this crop was a grass, wild sorghum.

Sorghum is a staple food in the drier parts of the tropical Africa, India and China. It is the second most important crop for injera (staple food of Ethiopians'-thin pan cake) next to teff. The grain is also used for the preparation of traditional beverages.[3]

Ethiopia is the largest sorghum producing country in Eastern and Southern Africa next to Sudan.[4] This is due to very rich genetic diversity of sorghum in Ethiopia besides; there is a wealth of sorghum farming knowledge and systems that have been developed over thousands of years. [3] Its production shows an increasing trend in the past 15 years. In Ethiopia, sorghum is the third most important crop after teff and maize in terms of area coverage and total production. Recently, sorghum production in Ethiopia is estimated to be 3.6 million metric tons from 1.7 million hectares of land, giving the average grain yield of two tons per hectare. It accounts for 13.93% of the total area allocated to grain crops such as cereals, pulses and oil crops and it also accounts for 18.78% of the area covered by cereals. Oromiya, Amhara and Tigray regions are the three major producers of sorghum covering 86.4% of the total area and 89% of the total production in the last nine years.[5]

Sorghum is a major cereal crop in arid and semi-arid areas of the world.[6] Attributed to its drought resistance, sorghum is a crop of choice for regions and agro ecological zones with unreliable rainfall. [7] It is cultivated in all regions of Ethiopia in altitude ranges of 400m to 2500m.[4]

Plant spacing plays an important role on growth, development and yield of cereal crops. Optimum plant spacing ensures that plants grow properly with their aerial and underground parts by utilizing more sunlight, water, soil nutrients and pest control. [8] These relationships are also important for optimal physiological function of the crop. In sorghum, yield is a function of the number of grains per panicle, 1000 grains weigh and harvest index.

Optimizing plant density is very important for improving seed yield in a particular environment. Though optimal plant densities for grain sorghum differ from one region to another, as many studies have undertaken by different researchers it shown that grain yield is greatly increased through plant density increase and after it, the yield is fixed in a range of density and through more increase in plant density due to intense competition between plants decreases the yield.[9]

In crop management it is important to realize that plant population should be seen not only in terms plant per unit area (i.e. plant density) but also in terms of arrangements of these plants on the ground (plant rectangularity). Plant rectangularity can be most easily visualized in a row crop where it can be defined as the ratio of the distance between plants within the row to the distance between rows. The extent to which rectangularity may affect the yield of a crop is clearly dependent on the plasticity of the individual plant, which in turn must be dependent on the plant species.

Currently, at national level 15-20 cm x 50-75 cm inter and intra row spacing is used as a blanket recommendation for all sorghum growing areas of Ethiopia, which does not consider the potential of the respective area.[10] The grain yield is always influenced by inter-specific and intra-specific plant competition for access to production factors. Optimum inter- and intra-row spacing varies with soil fertility status, soil moisture, the nature of the crop and degree of weed infestation.[11]

In Benishangul Gumuz region, especially Assosa *Zone* where this research will be conducted, the yield of sorghum is very low (16.96 quintals/ha) as compare to other regions Tigray (24.24 quintals/ha), Oromiya (22.05 quintals/ha) and Ahmara (19.42 quintals/ha) and national yield average (21.06 quintals/ha). In this zone, though more than 23,698 ha of the area are covered with sorghum, there is no recommended plant spacing i.e. farmers have been sown higher plant populations per specific unit of area through broadcasting methods.[5]

From different agronomic practices that limit the production of sorghum, lack of optimum plant population (in appropriate spacing) is the main factors that reduces yield of sorghum. Closer spacing hampers intercultural operations and in a densely populated crop, the inter-plant competition for nutrients, air and light is very high, which usually results in mutual shading, lodging and thus favours more straw yield than grain yield.[12] Farmers in the semi-arid areas usually use high population for all crops grown for various reasons.[13] This practice mostly resulted in poor seedling growth and developments because of severe competition at the seedling stage that leads to lower yield. [14] According to [15] as plant density increases, competition between plants becomes more intense, affecting the growth, development and production of each plant. Hence, this study was conducted to have appropriate plant spacing. Therefore the objectives of these studies are to evaluate the effects of spacing on growth of sorghum.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted from May to November 2016 in Assosa woreda at specific place of Tsentsalo kebele. Assosa woreda is located in Benishangul-Gumuz National Regional State, Assosa Zone. The woreda's administrative town is known as Assosa, it is also the Zonal and Regional administrative town. The town is 661 km away from Addis Ababa through the Nekemte road in the western direction. Assosa woreda is bordered in the North-western direction by Kurmuk and Komosha woreda; in the North-eastern direction bordered by Mange woreda and in the southern Direction by Mao-Komo Special woreda of Benishangul-Gumuz Region. The woreda is bordered in the Western direction by Sudan and in the Eastern direction bordered by Bambasi woreda's of Benishangul-Gumuz Region. The woreda has wider land forms, plains, plateaus valleys and mountains. The altitude range of the woreda is between 900m and 1560m.a.s.l. It has 74 rural kebeles those depends on agricultural production.[15]

Most of the agro-ecological zone of Assosa woreda is kola, but it consists least of ecological zone of "Weyna Dega". The average temperature of the woreda is 27^0C. The rainfall pattern is mono-modal rainfall distribution. The rainy season starts in May and extends to October; and the dry season starts in November and extends to end of April. The dry seasons have a wider temperature differences mainly on the onset it is too cold in the morning and at the night; and too hot in the midday. The dry season in the woreda has also a windy and cloudy nature. The annual rainfall of the woreda ranges between 900mm to 1400mm by using the moisture available from rainwater most of the crops are cultivated in the woreda. [15]

Assosa woreda has a total of 231,700 hectare of land. Out of the total land 60,983 hectares of land are used for annual crop production and 13,300 hectares of land are used for perennial crops mainly fruits such as Mango, Lemon and Orange. The commonly produced field crops are Maize, Sorghum, soybean, finger millet and sesame.[15]

Description of Experimental Material

From different sorghum varieties, Assosa 01 variety was used as planting material to implement this research experiment. Assosa 01 variety was released by Assosa Agricultural research Center for commercial production.

Treatments and Experimental Design

The experiment was consisted of four intra-spacing (10 cm, 15 cm, 20 cm and 25 cm) and four inter-spacing (50 cm, 60 cm, 70 cm and 80 cm). The experiment was laid out as randomized complete block design (RCBD) in factorial arrangement with three replications. There were 16 treatment combinations. Spacing between plots and between blocks were 0.8 m and 1.2 m, respectively. Treatments were assigned to each plot randomly by using lottery method randomization. Each plot treatment was 3.6 m length and 5m width ($18m^2$). Six, seven, eight and ten rows were accommodated per plot for 80 cm, 70 cm, 60 cm and 50 cm row spacing, respectively. Fourteen, eighteen, twenty four and thirty six plants were grown per row for 25 cm, 20 cm, 15 cm and 10 cm intra-row spacing, respectively. The two outer most rows (one from each side) were considered as the border rows. To eliminate the border effect from each of the rows, two plants from each end of the rows were considered as the border.

Experimental Procedures

The land was prepared manually by local plowing system to a depth of 25-30 cm. After laying out as per the specification, each plot were leveled and ridged manually. In June 2016, the seeds were drilled at a depth of about 3 cm to ensure adequate emergence. From emergence days, after two week when seedlings attained 15 cm height, it was thinned to require spacing to maintain required spacing between plants. All other crop management practices (fertilizer, weeding, and cultivation, harvesting, drying and threshing) were carried out uniformly for each plot as per the recommendation at the appropriate time. [10]

Data to be collected

Growth parameters

Plant height (cm): The heights of 5 randomly taken plants were measured at the time of maturity from the ground level to the base where the panicle starts branching and the mean value were recorded.

Tillers per plant; The tillers of 5 randomly taken plants were measured at the time of maturity from the ground level to the base where the panicle starts branching and the mean value were recorded.

Data Analysis

All collected data was subjected to ANOVA following the procedure described by [16] using the SAS software of version 9.1.3. Treatments that show significant differences were subjected to the Duncan's Multiple Range Test for mean separation at 1% probability level.

RESULT AND DISCUSION

Growth parameters

Plant height

Analysis of variance showed that inter-row spacing had highly significant ($p<0.01$) variations on plant height. The main effect of inter-row spacing on plant height showed that the tallest plants (230.05cm) were recorded at 60 cm inter-spacing while the shortest plants (216.10 cm) were recorded at 80 cm inter-row spacing (Table 1). In other way, 60 cm inter-row spacing gave significantly higher mean values in plant height than 50, 70 and 80. However, the mean difference in plant height between 50, 60, 70 and 80 cm were not statistically significant (Table 1). Also the result showed that, as row spacing increased, plant height tended to increase to a certain level from 50 cm to 60 cm while, further increasing in row spacing resulted in decreased plant height. Similar to this, [17] were reported, increase in sorghum height with increase in inter-row spacing up to a certain level.

Similar to the effect of inter- row spacing, analysis of variance also showed that intra-row spacing had highly significant ($p<0.01$) variations on plant height. The main effect of intra-row spacing on plant height showed that the tallest plants (229.483 cm) were observed at 15 cm intra-row spacing while shortest plants (217.108cm) were recorded at 25 cm intra-row spacing (Table 2). As [18] reported sorghum plant height was significantly affected by intra-row spacing. A par with these summarized that plant height was gradually increase with increased plant population and denser plant cultivars produced longer stems due to competition for available resources especially of light that penetrates the plant canopy.

Further, the mean values for intra-row spacing showed that plant height increased with each increment of intra-row spacing from 10 cm to 15 cm while further increasing in intra-row spacing resulted in decreasing plant height. However, the four intra-row spacing were statistically similar with each other for their mean plant height. With respect to interaction effect, analysis of variance showed that the interaction between inter-row spacing and intra-row spacing had highly significant ($P <0.01$) variations on plant height. The interaction effect showed that the tallest plants (244.40cm) were observed at 60x10cm spacing, while shortest plants (203.60cm) were observed at 70x25cm spacing (Table 5).

Tillers per plant

Analysis of variance showed that inter-row spacing had highly significant ($p<0.01$) variations on tillers per plant. The main effect of inter-row spacing on tillers per plant showed that higher numbers of tillers (3.45) were recorded at 80 cm inter-spacing while the shortest plants (1.9) were recorded at 60 and 70 cm inter-spacing (Table 1). 80 cm inter-row spacing gave significantly higher number of tillers than 50, 60 and 70. The increase in number of tillers per plant with increase in inter-row spacing might be due to the plant nutrients present in the soil were enough for the vegetative growth and tiller formation when there were less number of plants per unit area. They were less competitive for all essential elements as compared to the greater number of plants per unit area.

This result is confirmed with [19] who reported that increase in number of tillers per plant is due to increased inter-row spacing. This result also confirmed with those reported by [20] who reported that increasing inter-row spacing may result in more tillers per plant. However, the mean difference in number of tillers between 50, 60, 70 and 80 cm inter-row spacing were not statistically significant or statistically similar with each other (Table1).

Similar to the effect of inter- row spacing, analysis of variance also showed that intra-row spacing had highly significant ($p<0.01$) variations on tillers per plant. The main effect of intra-row spacing on tillers per plant showed that the higher numbers of tillers (3.35) were observed at 25 cm intra-row spacing while shortest plants (1.95) were recorded at 20 cm intra-row spacing (Table 2). This could be because of the intra-plant competition for nutrient, moisture and sun light increases as the intra-row spacing decrease and then results lower tillers per plant. The four intra-row spacing were statistically similar with each other for their mean number of tillers per plant.

With respect to interaction effect, analysis of variance showed that the interaction between inter-row spacing and intra-row spacing had a non-significant ($P <0.01$) variations on number of tillers per plant. Comparatively, the interaction effect showed that the higher numbers of tillers (5.16) were observed at 80x25cm spacing, while shortest plants (1.8) were observed at 70x10cm spacing (Table 3).

Table 1: Effect of inter-row spacing on growth parameters of sorghum.

Inter-Row Spacing	Plant Height	Number of Tillers Per Plant
50	228.575a	2.03a
60	230.05a	1.9a
70	221.45a	1.95a
80	216.10a	3.45a

Means followed by the same letter are not significantly different at 1% level of significance.

Table 2: Effect of intra-row spacing on growth parameters of sorghum.

Intra-row spacing	Plant height	Number of Tillers per Plant
10	224.55a	1.9667a
15	229.483a	2.0667a
20	225.033a	1.95a
25	217.108a	3.35a

Means followed by the same letter are not significantly different at 1% level of significance.

Table 3: Interaction effect of intra-row spacing and Inter-row spacing on growth parameters of sorghum.

Inter-row spacing per plant	Intra-row spacing	Plant height	No. of tillers
50	10	232. 33a	1.933a
	15	233. 33a	2.067a
	20	224. 60a	1.933a
	25	224. 03a	2.20a
60	10	244.40a	1.867a
	15	223.87a	1.933a
	20	233.13a	1.867a
	25	218.80a	1.933a
70	10	225.80a	1.80a
	15	230.20a	2.00a
	20	233.60a	2.00a
	25	203.60a	2.00a
80	10	207.72a	2.08a
	15	230.40a	2.16a
	20	218.72a	2.00a
	25	214.64a	5.16a

Means followed by the same letter are not significantly different at 1% level of significance.

CONCLUSION

A study was conducted to investigate the effect of intra row and intra spacing on growth of one sorghum varieties. It was conducted during 2016 production season at the experiment site of Assosa Wereda Tsetsehalo kebele, Benishangule Gumuz. The experiment was done using randomized complete block design (RCBD) in factorial arrangement with three replications, four intra-spacing (10 cm, 15 cm, 20 cm and 25 cm) and four inter row spacing (50 cm, 60 cm, 70 cm and 80 cm). Phonological factor of the plant, plant height and tillers per plant were examined.

As a conclusion, from this study it was noted that inter and intra row spacing were found highly significant ($P<0.01$) for plant height and tillers per plant. The interaction effect of inter-row *spacing and intra-row spacing were found highly significant ($P<0.01$) for plant height and while anon-significant difference were noted for tillers per plant. In appropriate use of inter and intra row spacing have influence on the growth parameters of the plant. Money researches observed that the reduction in plant height and number of tiller have effect on the total yield of the plant. Therefore, it is recommended that using 70cm inter-row spacing with 15cm intra-row spacing is recommended for higher yield in the district where grain yield were maximum, and sorghum producing farmers in the district should adopt appropriately recommended inter-row spacing and intra-row spacing for enhanced productivity in the area. However, this tentative generalization should be validated by testing more spacing and more varieties for more than one season to give a valid recommendation.

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