

Effect of Inter and Intra Row Spacing on Growth, Yield and Yield Components of Sorghum (*Sorghum bicolor* (L.) Moench) at Assosa District, Western Ethiopia

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Abstract: Studies on plant populations are scarce and poorly recorded in western Ethiopia, which is a necessary condition for successfully cultivating the sorghum crop. To identify the ideal planting spacing for sorghum productivity in the main cropping season, this experiment was carried out at the Assosa Agricultural Research Center, Benishangul-Gumuz Region, in the 2020 and 2021 cropping seasons. The experiment was set up in a randomized complete block design (RCBD) with three replications. It had a factorial configuration with three levels of inter-row spacing (70 cm, 75 cm, and 80 cm) and four levels of intra-row spacing (15 cm, 20 cm, 25 cm, and 30 cm). The current finding indicates that plant height decreased as intra-row space increased. Inter n and intra-row spacing had a substantial interaction effect on grain yield ($P < 0.01$). As a consequence, a planting spacing of 75 cm by 20 cm produced the highest grain production ($4784.6 \text{ kg ha}^{-1}$). Similar to this, the main effect of 20 cm intra-row spacing produced a significant maximum head weight (12.7 kg/plot). At low population levels, yield reductions were observed (75 cm inter and 30cm intra row). The findings indicate that the decrease in final grain output was a result of an increase in intra-plant separation from 20 cm to 30 cm between plants. In general, plants placed properly provided a great output, whereas plants spaced widely produced a poor yield. Therefore, to maintain sorghum productivity with the necessary spacing, improved sorghum varieties in Assosa and other regions with comparable agro-ecologies can be encouraged to use 75 cm inter-row spacing and 20 cm intra-row spacing.

Keywords: Inter and Intra Row Spacing, Growth, Yield and Adukara

1. Introduction

One of the most important staple grains in the majority of the world, particularly in dry and semiarid regions, is sorghum (*Sorghum bicolor* (L.) Moench). After maize, wheat, rice, and barley, it is the fifth largest cereal crop in the world by weight [9]. It is utilized as both animal feed and human nourishment. Sorghum is produced more widely than any other crop in places with moisture stress. It is one of the most important food crops in Ethiopia [17], second only to teff for manufacturing "injera" and also used to make "Kitta," "Nifro," baby food, syrup, and regional beverages like "Tella." In addition to being utilized as animal feed, the stalk is also used to build homes, fences, and firewood [12].

With 70–80% carbohydrate, 11–13% protein, 2–5% fat, 1–3% fiber, and 1% ash, sorghum grain has a high nutritive value. Sorghum's protein is gluten-free, making it a particular food for those with celiac disease, including diabetics, and an excellent alternative to cereal grains like wheat, barley, and rye [8].

In the Benishangul-Gumuz region in general and the Assosa district in particular, sorghum is the primary food crop. Both permanent and temporary agricultural practices, which are widely used in the villages, are used to produce sorghum in the district. Sorghum crop productivity was far lower than the projected yields, which were $4\text{--}6 \text{ t ha}^{-1}$ in farm verification trials and research stations, respectively [3]. Even while the number of farmers and the area they cover is occasionally growing, agricultural yields are typically on the decline [7].

Sorghum's reaction to plant population density has been studied in numerous regions of the nation, although few researches have yet been conducted in western Ethiopia's Assosa district. Similar to this, the primary food crop in the Assosa district as well as the Benishangul-Gumuz region as a whole is sorghum. However, in the area, its productivity was less than 2 t ha^{-1} , which is far less than the potential yields discovered on research stations and in farm verification experiments. Ineffective sowing techniques using intra- and inter-row spacing are one factor in the low yield. As a result, the current sorghum production system is unable to meet customer demand since the majority of Ethiopian farmers use traditional farming methods.

Due to a lack of research in selecting the most practical current technology, the production system is not effectively supported by it. Maintaining intra and inter row planting techniques is thus one of the major difficulties in the cultivation of sorghum.

Sorghum yield increases with good control of the main plant population. The best plant densities for growing grain sorghum vary from region to region, and grain yields typically rise as plant population's rise at densities lower than those recommended. They also raise as the number of grain sorghum heads per plant or seeds per head rise relative to the recommended plant density [6]. Row width and intra-row spacing are both key factors in regulating plant density, particularly under dry soil conditions; row width is crucial [15]. The potential yield of a crop can also be impacted by the row spacing, and grain sorghum production benefits from narrow row planting over wider spacing [11]. Open canopy structures make it harder for weeds to compete with sorghum, while growing it in short rows provides it a competitive edge over weeds and reduces light transfer to the soil [11]. Sorghum water use can also be impacted by plant population by changing canopy development. The likelihood of plant water stress, which could be brought on by high water demand, is reduced by optimizing plant population based on the probable supply of water [4].

For sorghum the most crucial agronomic factor that requires attention is plant population. In Ethiopia, sorghum seeds are generally recommended to be sown under conditions ranging from dry to wet, with a row spacing of 75 cm between rows and 15 cm between plants. Plants compete fiercely for sunlight above ground and nutrients below ground when plant density surpasses an ideal threshold. As a result, plant development slows and the production of grain falls. Sorghum yield components significantly increased when seed rates decreased from greatest to lowest. Therefore, in order to achieve the highest yields, the ideal plant population density per unit area must be established.

One of the main problems restricting sorghum productivity is sorghum planting techniques including broadcasting and row planting. The traditional sowing method, which most farmers use, involves scattering little seeds at a rate of 25 kg per hectare, which results in an excessive crop density and increases competition among plants for nutrients, water, sunlight, and carbon dioxide (CO_2). Additionally, compared

to row sowing, disseminating systems require more seed per unit of area, which raises the cost of production. Due to the high plant density, this seeding strategy also results in expensive thinning and weeding operations, which is the primary reason for the low yield of sorghum. Sorghum row planting is said to produce higher yields than spread planting. Low seed rates, row planting, early sowing, and the use of plant growth regulators were employed to reduce the issue of excessive plant population density on sorghum. Consideration should be given to planting techniques (such as row planting rather than broadcasting) in order to increase sorghum production and productivity.

In spite of the fact that sorghum is a frequently grown commodity in the area, there is a significant lack of agronomic guidance for its development. Therefore, the goal of this study was to identify the best intra and inter row spacing planting technique for sorghum production in the study area's Nitisols under rain-fed conditions.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Assosa Agricultural Research Center (AsARC) of Assosa district western Ethiopia in the main rainy season of 2020 and 2021. It is located 660 km from Addis Ababa, the capital city of Ethiopia and about 8 km north of Assosa, the capital city of Benshangul-Gumuz Regional state. Geographically, the experimental site is located at $10^{\circ}2' 35.58''$ North latitude and $34^{\circ}34' 2.15''$ East longitude with an altitude of 1560 m.a.s.l. The site received a mean annual rainfall of 1358 mm were received between May and October during the cropping season and with an average minimum and maximum temperature of 14.5 and 28.8°C, respectively. The soil textural class of the experimental site was clay with pH of 5.5 - 5.7.

2.2. Treatments and Experimental Procedures

Three replications of the randomized complete block design (RCBD) were used to set up the trial. The trial used a better, more mature sorghum variety called *Adukara*. Three inter-row spacing levels (70, 75, and 80 cm) and a factorial combination of four intra-row spacing levels (15, 20, 25 and 30 cm) were used as treatments. Each treatment was given its own 5.1 m x 4.5 m plot with blocks spaced out by 1 m and 1.5 m, respectively. Di Ammonium Phosphate (DAP) was applied during planting, whereas 50% of the urea was applied at planting and the remaining 50% was applied at knee height. Nitrogen was applied to each treatment at a rate of 23 kg N ha^{-1} and phosphorus at a rate of 46 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$. The area was expertly prepped with a tractor before sowing. According to the proposed inter and intra-row spacing, sorghum seeds were sown. Seeds are initially drilled in a row and afterwards thinned to the desired plant spacing when they have three to four leaves. Hoeing, weeding, and other acceptable agronomic procedures were uniformly applied to the experimental field.

2.3. Agronomic Data Collection and Statistical Analysis

Data were gathered and examined on growth-indicating characteristics such as plant height, stand count at harvest, number of heads per plot, head weight, and grain yield. The two outermost rows of each treatment were left as border effects, and the data were taken from the middle rows of a net plot area. To gather information on plant height, five plants from the net plot area were pre-tagged. Utilizing an electronic sensitive balance from the harvested plants of the net plot area, the grain yield from the center rows was recorded, and grain yield per hectare was determined. The SAS computer software version (9.1) was used to do an analysis of variance (ANOVA) on the gathered agronomic data, and the least significant difference (LSD) at the 5% level of probability was used to calculate the significance difference between the treatments means [13].

3. Results and Discussion

Analysis of Grain Yield and Yield Components of Sorghum

3.1. Plant Height

Plant height varied greatly depending on the crop year and intra-row spacing, while inter-row spacing had no discernible impact on the plant height of the sorghum crop. Accordingly, the plant height was measured at 20 cm for the maximum value (167.9 cm), and at 30 cm for the lowest value, despite large intra-row separation (Table 1). The current finding was consistent with the findings of, who claimed that taller plants suffered from the highest density due to greater competition for light [5]. Similar result revealed that plants with narrower spacing tend to grow shorter as a consequence of competition for nutrients and other growth-promoting stimuli [14]. Additionally, pointed out that sorghum's increased height as a result of closer intra-row spacing may be caused by competition for light [16].

3.2. Stand Count at Harvest

Inter-row spacing and crop year had no discernible impact on the number of stands in sorghum at harvest. However, intra-row spacing had a substantial impact on stand count at harvest ($P < 0.01$). Consequently, the maximum numbers of plants (160.4) were grown at a 15 cm intra-row spacing (Table 1).

Table 1. Effect of sorghum plant height and stand count on intra and inter-row spacing.

Intra spacing (cm)	Plant Height (cm)	Stand count at H
15	165.8 a	160.4 a
20	167.9 a	141.7 b
25	161.4 ab	125.7 c
30	158.1 b	107.2 d
Level of significance	**	**
LSD (0.05)	0.027	<.0001
Inter spacing (cm)		
70	162.5	133.2
75	164.6	137.7
80	162.9	130.5

Intra spacing (cm)	Plant Height (cm)	Stand count at H
Level of significance	NS	NS
LSD (0.05)	0.752	0.327
Year		
Y-1	158.96 b	132.6
Y-2	167.69 a	134.9
Mean	163.33	133.79
LSD (0.05)	0.0007	NS
CV	6.26	12.39

LSD (0.05) stands for the least significant difference, and it indicates that means with the same letter (s) in the same column are not substantially different. Coefficient of variation (CV), non-significant (NS), and Y-1= 2020; Y-2=2021

3.3. Number of Head Per Plot

Cropping year and intra-row spacing both had a considerable impact on the number of heads per plot, but inter-row spacing had no discernible impact. The highest number recorded per plot originated from an intra-spacing of 15 cm (153.1), and the lowest number arose from an intra-spacing of 30 cm (104.3 (Table 2).

3.4. Head Weight Per Plot (kg)

Head weight is a significant yield-contributing element that is vital in demonstrating a variety's potential. Head weight per plot was strongly impacted by intra-row spacing ($P < 0.05$), although inter-row spacing and crop year had no significant impact on the number of heads per plot (Table 2). According to data in (Table 2), head weight was significantly highest at a plant population density of 15 cm intra spacing (12.7 kg), followed by a plant population density of 25 cm spacing (12.1 kg) for head weight. Results showed that the lowest plant population density led to the lowest head weight, which was achieved by the lowest intra spacing of (30 cm) at a weight of (9.5 kg).

Table 2. Number of heads and head weight per plot in sorghum are affected by the intra and inter-row spacing.

Intra spacing (cm)	Number of head/plot	Head weight/plot
15	153.1 a	11.8 a
20	132.4 b	12.7 a
25	121.1 b	12.1 a
30	104.3 c	9.5 b
Level of significance	**	*
LSD (0.05)	<.0001	0.036
Inter spacing (cm)		
70	126.5	11.9
75	128.9	11.4
80	127.9	11.5
Level of significance	NS	NS
LSD (0.05)	0.903	0.903
Year		
Y-1	132.6 a	11.15
Y-2	122.8 b	12.03
Mean	127.75	11.59
LSD (0.05)	0.028	0.283
CV	14.33	19.79

Y-1 = 2020; Y-2 = 2021; LSD (0.05) = least significant difference; CV = coefficient of variance; NS = non-significant.

3.5. Grain Yield (kg ha^{-1})

Grain yield is a product of the combined effects of cultivar genetics and environmental factors on the crop's yield components. The end outcome of the intricate physiological and morphological processes that take place throughout a crop's growth and development is its grain yield. Different plant spacing's alter the growing environment [18].

The sorghum crop's grain output was significantly impacted by planting spacing. According to Table 3, shows that inter and intra-row spacing interaction considerably ($P < 0.05$) affects the grain yield of *Adukara* sorghum variety. As a result, the interaction of 75 cm by 20 cm of inter and intra spacing provided the highest yield ($4784.6 \text{ kg ha}^{-1}$), followed by (75x15 cm), which produced ($4451.3 \text{ kg ha}^{-1}$), while the lowest yields were obtained at a wider inter-row and intra-row spacing interaction. This may be because plants that are close together may capture the majority of the photosynthetic dynamic radiation, and because plants with more leaves have more surfaces available for photosynthesis and assimilate production. This investigation supported the findings of that the yield of maize grains decreased significantly with each increase in intra-row spacing [10] and [5]. According to similar findings, the interplay of inter and intra row spacing had a major impact on sorghum grain yield [2] and [1]. Increasing plant densities resulted in higher biomass production and seed yield per unit area, but they were unable to make up for the low quantity and weight of grains per head.

Table 3. Effect of year, intra and inter-row spacing on *Adukara* sorghum variety grain yield.

Year		Grain yield (kg ha^{-1})			
Y-1		3802.2 b			
Y-2		4165.9 a			
Level of significance		*			
LSD (0.05)		0.022			
Inter row spacing (cm)	Intra-row spacing (cm)				
	15 20 25 30				
70	4452.2 ^{ab}	3694.3 ^{bcd}	3546.3 ^{de}	4193.7 ^{a-c}	
75	4451.3 ^{ab}	4784.6 ^a	3607 ^{c-c}	2846.9 ^c	
80	4092.4 ^{a-d}	4075.3 ^{a-d}	4338.8 ^{a-c}	3725.6 ^{b-d}	
Mean	3984.02				
Level of significance		**			
LSD (0.05)		782.36			
CV		16.38			

Y-1 = 2020; Y-2 = 2021; LSD (0.05) = least significant difference; CV = coefficient of variance; NS = non-significant.

4. Conclusion

On the growth, development, and yield of cereal crops, plant spacing is crucial. In order to correctly cultivate plants with their aerial and underground crop sections by utilizing more sunshine and soil nutrients, optimal plant density is crucial. Increased yield production is achieved by increasing the canopy's ability to block solar radiation. The current result indicates that inter and intra-row spacing's of 75 cm

and 20 cm produced the best grain yield for *Adukara* sorghum variety in tested areas. Therefore, the ideal planting distance for sorghum production in a rain-fed environment is 75 cm between rows and 20 cm inside rows.

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