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Research Article

Effect of Productive Tillers on Seed Yield and Seed Quality of Sorghum (*Sorghum bicolor L.*) Varieties in Assosa District, Western Ethiopia

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Abstract

Poor management of sorghum tillers is a significant problem in the Benishangul-Gumuz region of Ethiopia, affecting seed yield and quality. An experiment was conducted to determine the impact of sorghum productive tillers on seed yield and quality. The study involved two Sorghum varieties (Assosa-1 and Adukara) and three plant types per spot. The treatments were aligned as RCBD and CRD in factorial combination, replicated three and four times for field and laboratory experiments respectively. Varieties influenced TSW ($P < 0.0001$), Number of tiller influenced by number plants head matured for seed production ($P \leq 0.0001$), plants height ($P \leq 0.0004$), The interaction effects of varieties and number of tillers per plant influenced yields, Panicle length ($P < 0.0001$). For laboratory experiments varieties influenced Speed of germination ($P < 0.0001$), number of Dead seeds ($P < 0.0001$). Number of tiller influenced Speed of germination ($P < 0.0001$), number of Dead seeds, shoot length ($P < 0.004$), Vigor index one and Vigor index two ($P \leq 0.05$). The interaction effects of varieties and number of tillers per plant influenced Standard germination ($P < 0.001$). The main shoot plants had the highest number of fertile sorghum heads (86.5), followed by primary tillers (27.08). Secondary tillers had the highest plant height (96.52 cm). The main shoot plant yielded more seeds than primary and secondary tillers, with the shoot exceeding these yields by 302.96% and 1333%, respectively. Primary and secondary tillers had higher percentages of dead seeds than the main shoot plant, 53.5% and 45.2%, respectively. The primary and secondary tillers experienced a decline in seedling vigour index one over different periods, while the main sorghum plant varieties, Adukara and Assosa-1, showed an upward trend. The germination percentages of the primary and secondary tillers were less than the 85% Ethiopian seed standard requirement. Because sorghum tillers lower seed quality, they should be eliminated for seed production. If sorghum is grown for grain production, secondary tillers have the benefit of raising overall yield production.

Keywords

Sorghum, Seed, Quality, Main Shoot, Primary Tiller, Secondary Tiller, Yield

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1. Introduction

Grain sorghum (*Sorghum bicolor* (L.) Moench) is important crop in arid and semi-arid regions of the world. Ethiopia accounts for 9% of the area producing grain sorghum in the Africa, producing on 23010 metric tons [19].

It is adapted to hot and dry climates and is more tolerant of heat and moisture stress than other crops [3]. It is relatively slow growing in early vegetative stages compared to other crops [18]. It has been reported to grow more slowly when planted early in the growing season [1, 18]. The slow growth of grain sorghum in early vegetative stages decreases its competitive ability and allows weeds to establish more easily than other crops [16].

Sorghum is used as a source of food for rural populations. In comparison to other food crops, sorghum preferred crop for dry land farming agriculture because of its enormous flexibility and tolerance to unfavorable environments [7, 10]. Sorghum is one of Ethiopia's most stable and varied food crops [15].

Modern sorghum hybrids produce from zero to four fertile tillers in field conditions so that at plant densities below 4 m^{-2}, around 70–80 % of total plant leaf area and grain yield can be attributed to tillers [12, 13].

Assosa Agricultural Research Center released two varieties of sorghum which is highly productive for low land humid area of BG region. The verities of sorghum contain a lot of potential which is no addressed yet. These are productivity under poor soil fertility, tolerance of acidic soil and diseases, and large tillering ability. Tillering is an important agronomic trait in many high-tillering cereals such as wheat (Triticum aestivum), rice (Oryza sativa) and barley (Hordeum vulgare), and contributed significantly to improved yield associated with the 'green revolution' [6]. Crop stand and optimum number of crop plant per hectare determine seed yield and seed quality in sorghum seed production. Optimum numbers of crop per hectare based space between plant and raw. As space between plant and raw increase number of plant per hectare decrease and vies versa. High or low numbers of crop plant population per acre affect not only the yield but also the quality of the seed to be produced. Tillering has a significant effect on canopy development and, hence, on resource capture, crop growth and grain yield in sorghum. Tillering has a major influence on plant leaf area development [12] and, hence, on crop water-use patterns and adaptation to water-limited environments [11].

Sorghum varieties released by Assosa Agricultural Research Center is very poor on the field at early germination period. They require proper land preparation, keeping appropriate planning depth, crop protection against insect pest (grasshopper, shoot fly) and weeds. The slow growth of grain sorghum in early vegetative stages decreases its competitive ability and allows weeds to establish more easily than other crops [16].

But the farm of sorghum seed producer patch in terms of plant population due to lack of proper land preparation, keeping appropriate planning depth and crop protection against insect pest (grasshopper, shoot fly) and weeds. Sometime farmers transplant seedlings to solve the problem. Due to erratic rain fall and technical transplanting error transplanted seedling may die. Sparsely planted sorghum farm produce a lot of tillers at each seedlings and cause competition of nutrients, moisture, and light during photosynthesis which influence on seed yield and seed quality. Sorghum produce tillers at different time and matured one after the other. The alternate maturity affects the quality of the seed production. On the other hand removal of tillers cause continues production of tillers which increase cost of production.

High seed rate during seed planting production result in stunted seedling on the farm due to competition among seedlings. These affect the yield and quality of seed production. The alternate tiller emergency and seed maturity affects the quality of the seed during seed production. The removal of densely populated seedling incurs cost of seed production which reduces profitability in seed production business.

Therefore, the current work proposed to identify effect of productive tiller on seed yield and seed quality and to identify the effect of tiller on seed production business.

2. Materials and Methods

2.1. Description of the Experimental Site

The research was conducted in Benishangul Gumuze National Regional State, at air port seed production farm sit and Bambasi District on farm, in 2017-2019 during the main cropping season. The experiment was conducted under both fields as well as in a laboratory. Benishangul Gumuze National Regional State is positioned on Geographical location of 10004'N latitude, and 34031'E longitude and at altitude 1570 meter above sea level at distance of 667 km to the west of Addis Ababa-Ethiopia.

2.2. Description of the Material Used

Planting Materials

The planting material used for the research was Assosa-1 and Adukara sorghum variety, which originated from Assosa Agricultural Research Centre. They are adaptable to low land humid area. Both released in the year 2015.

The number of days to flowering is 138 -144 and 148-154, on farm average yield is 27.6-41.3qt and 30-30.6 qt per hectare for Assosa-1 and Adukara respectively. The seed of Assosa-1 is white and Adukara is red in colour [20].

2.3. Treatments and Experimental Design

The treatment aligned as RCBD in factorial combination replicated three times and the treatments was consist of Number of plant per hole /Main plant (one seedling), two plants (one tiller and main seedling), three plants (two tiller and main seedling), Planting space 20cm by 75cm.

2.4. Experimental Procedure

2.4.1. Sampling

The land was ploughed, harrowed and well prepared for planting by a tractor. The seed was sown in rows at the depth of 3 - 4 cm. Hand Weeding, hoeing and/ or hand pulling operation starts two weeks after planting. Only plants in the middle rows were harvested for estimation of yield and quality leaving aside those in the border rows as well as those at the ends of each row. The crop was harvested manually and dried until the moisture content reaches between 10 and 12%. The evaluation of the effect of productive tillers on seed yield and seed quality of sorghum was done in the laboratory for only seeds harvested at maturity. Yields of replicated treatments of physiologically mature were bulked and thoroughly mixed to take sample of 0.9 kilogram sorghum seeds tested for seed quality as prescribed by ISTA rules.

2.4.2. Procedure

Parameters which are indicator for seed quality such as analytical purity, thousand seed weight, standard germination, vigour, vigour index I, vigour index II, germination rate index and speed of germination test determination was tested in the laboratory according to ISTA rules for all the treatments harvested. Then obtained data were analyzed.

2.4.3. Data Collected on Field

Crop Growth Characters such as Plant height (cm), Days to flowering, Yield and Yield Components, Panicle length (cm), Weight of 1000-grains (g), Seed yield (t ha-1), Seed yield (t ha-1) were collected.

2.4.4. Data Analysis

All data were subjected to analysis of variance (ANOVA) using the Generalized Linear Model (GLM) method of SAS (SAS, 2002). Differences between treatment means were separated using the Least Significant Difference (LSD) test at 5% level of significance.

3. Result and Discussion

3.1. Thousand Seed Weight (TSW)

TSW was significantly (P < 0.0001) impacted by the major influence of verities, sorghum plant heights and head count were not. There was statistical parity across varieties based on the quantity of heads and plants per net plot. There was a noticeable greater TSW in comparison to the sorghum variety of Assos-1 to Adukara sorghum variety (23.89 g). The variety's better yield was partly attributed to more TSW. This is a consequence of the genetic variations in crop composition across cultivars. The result is consistent with [2, 17], the Dibaba variety performed better on average in thousand seed weight (42g), which was directly correlated with yield and also had a significant impact on germination and vigouresity.

Table 1. *The main effect of varieties on thousand seed weight of sorghum during the main cropping season of 2017-2019.*

Variety	TSW
AD	23.8906^{a}
AS	20.0472^{b}
Lsd (0.05)	0.78
CV	5.22
P=	< 0.0001

Means followed by the same letter within a column are not significantly different at 5% level of significance. LSD = Least significant difference; CV = Coefficient of variation; AD= Adukara; AS = Assosa-1; P= probability; TSW= thousand seed weight

3.2. Numbers of Head and Plant Heights of Sorghum

Analysis of variance showed that the main effects of main shoots and tillers significantly (P ≤ 0.0001) and (P ≤ 0.0004) affected the mean numbers of head and plant heights respectively and TSW did not (Table 2).

The main shoot plants had the largest mean number of fertile sorghum heads (86.5), with primary tillers coming in second with 27.08 fertile plant heads. Secondary tillers exceeded both primary tillers and the main sorghum plant to attain the greatest plant height of 96.52 cm. The lowest mean number of plant heads was reported by the secondary tiller. Since a moisture shortage was caused by the rain ceasing before the late-emerging tillers attained maturity, they produced unproductive tillers. Fertility appears to have been significantly influenced by the plants assimilate supply, and yield responses to density may be connected with resource acquisition and interplant competition. The finding is in line with the assimilate supply in the main shoot at the time of tiller emergence appears the most likely determinant of subsequent tiller fertility [2].

Table 2. *Main effect of Tiller number of heads and plant height of sorghum during the main cropping season of 2017-2019.*

Tiller	Numbers of head	Plant height (cm)
0	86.5[a]	28.02[b]
1	27.083[b]	14.72[b]
2	10.833[c]	96.52[a]
Lsd(0.05)	11.45	34.14
CV	22.90	105.5
P	≤ 0.0001	≤ 0.0004

Means followed by the same letter within a column are not significantly different at 5% level of significance. LSD = Least significant difference; CV = Coefficient of variation; T= sorghum tiller; NH = number of head; PH= plant height;

3.3. Yield and Panicle Lengths of Sorghum

The average yield and panicle lengths of sorghum were significantly ($P < 0.0001$) impacted by the interaction effects of varieties and number of tillers per plant (Table 3).

A higher average yield of 2685.5 kg was produced by the sorghum variety Adukara. It increased 14% over Assosa-1. This could be because the genetically promising sorghum variety Adukara yields more than Assosa-1. The result is consistent with [20].

On the other hand the seed recorded from the main shoot plant greater than the seed harvested from the primary shoot tillers and secondary tillers. The shoot of main plant exceeded by yield primary and secondary shoot tillers by 302.96% and 1333% respectively, while the primary tillers exceeded secondary by 255.8%. It showed that main plant shoot is high yielder than primary and secondary tillers and primary tiller also gave high yield than secondary tillers.

Table 3. *Interaction effect of Varieties and Tiller on seed yield and panicle length of sorghum during the main cropping season of 2017-2019.*

Variety	Yield (kg)	Panicle Length (cm)
AD	2685.5[a]	20.922[a]
AS	2355.5[b]	22.45[a]
Tiller		
0	4240.7[a]	28.658[a]
1	1052.4[b]	12.978[c]
2	295.9[c]	18.185[b]
Lsd(0.05)	372.33	3.36
CV	16	16.8
P	≤ 0.0001	≤ 0.0001

Means followed by the same letter within a column are not significantly different at 5% level of significance. LSD = Least significant difference; CV = Coefficient of variation; AD= Adukara; AS = Assosa-1

Despite producing a lesser yield than the parent plant, plant tillers have the potential to increase the total yield per hectare in the production of sorghum seeds. The report in line with that Tillering is an important agronomic trait in many high-tillering cereals such as wheat (Triticum aestivum), rice (Oryza sativa) and barley (Hordeum vulgare), and contributed significantly to improved yield associated with the ‘green revolution [6].

While statistically indicating parity, the panicle length of the Assosa-1 sorghum variety measured at a higher 22.45 cm than Adukara's 20.992 cm. The main plant shoot produced the longest panicles, measuring 28.658 cm, while the secondary tillers shoot ranked second.

Table 4. *Interaction effect of varieties and tiller on speed of germination, standard germination and percentage of dead seed of sorghum during the main cropping season of 2017-2019.*

Variety	Parameter		
	Sp	SG (%)	DD (%)
AD	18.5275[a]	81.25[a]	16.25[d]
AS	17.935[a]	81[a]	18.25[d]
1AD	17.6125[a]	76.5[a]	22.25[b]
1AS	15.695[b]	70.875[c]	26.5[b]
2AD	17.3883[a]	75.5[c]	22[b]
2AS	12.7533[c]	64.667[d]	32.417[a]
Tiller			
0	17.8088[a]	78.458[a]	19.625[b]
1	14.755[b]	67.5[b]	30.125[a]

Variety	Parameter		
	Sp	SG (%)	DD (%)
2	13.815[c]	68.375[b]	28.5[a]
Lsd	1.18	5.27	3.55
CV	6.53	6.41	18.15
P	≤ 0.0001	≤ 0.001	≤ 0.0001

Means followed by the same letter within a column are not significantly different at 5% level of significance. LSD = Least significant difference; CV = Coefficient of variation; AD= Adukara; AS = Assosa-1; 1AD= primary tiller of Adukara; 2AD= secondary tiller of Adukara; 1AS= primary tiller of Assosa-1; 2AS=secondary tiller of Assosa-1; Sp= speed of germination; SG= standard germination; DD= percentage of dead seed

3.4. Speed of Germination

The speed of germination as measured in the laboratory was substantially (P ≤ 0.0001) impacted by varieties and the number of tillers per plant, according to the analysis of variance (Table 4).

The seed from a plot that contained only the main shoot plants of the Adukara variety had the highest (18.53) mean number of speed of germination, while the seed from secondary shoot plant of Assosa-1 had the lowest (12.75) mean number of speed of germination.

The speed of germination showed that seed plots of main shoot plants with primary and secondary shoot tillers of Adukara (2AD) and Adukara and Assosa-1 main shoot varieties (AD and AS) showed statistical parity, as did the plot area of main plants with each of these varieties. This means that, compared to the Assosa-1 variety, Adukara sorghum variety has an elevated genetic capacity for storing food to sustain future seedling growth and development.

When compared to plots with one and two shoot tillers, the speed at which seeds from the plot with the main plant shoot germinated was often far faster and the main plant shoot produced well-developed, robust seeds, whereas the other plant was unable to do so due to competition for nutrients, water and sunlight among the main plants and tillers. The finding indicated that *a* prolonged mean germination time may be an indication of deteriorated seed quality as a result of exposure of the seeds to harsh or unfavourable conditions in the field and after harvesting [4]. Such conditions slows the rate of emergence and growth of the seedlings [2].

The study found that seeds from a plot with only the main shoot plants of the Adukara variety had the highest mean number of germination speed (18.53), while seeds from a secondary shoot plant of Assosa-1 had the lowest speed (12.75). This indicates that the Adukara sorghum variety has an elevated genetic capacity for storing food to sustain future seedling growth and development.

The main plant shoot plots germinated seeds faster and produced robust, well-developed seeds compared to plots with one tiller and two shoot tillers, due to competition for nutrients, water, and sunlight among the main plants and tillers.

3.5. Standard Germination

Analysis of variance revealed that number normal seedling significantly (P ≤ 0.001) affected by the interaction effects of varieties and number of tillers per plants (Table 4).

The laboratory seed testing showed that the seed harvested from the main plant was superior to the seed from primary and secondary tillers interims of germination percentage. The highest (81.25%) normal germination percentage recorded from the seed harvested from the main shoot plant of Adukara closely followed by Assoasa-1 sorghum varieties. The germination percentage of Adukara from primary shoot tiller showed statically parity with the seed of main plant shoot of Adukara and Assoasa-1varieties. The seed harvested from the secondary tiller recorded the lowest (64.67%) germination percentage. The seed harvested from the primary and secondary tillers showed statistically parity in germination percentage which is below the standard of Ethiopian seed standards. This due to sufficient plant nutrient available for seed plots of main plant for fully development of the seeds while the others seed plots with primary and secondary tillers were in competition for resources. It is reported that Seeds produced under conditions of nutrient stress have their chemical compounds such as carbohydrates and proteins stored and not utilized in the provision of energy and biochemical building blocks of the seed to enhance germination [9]. High grain yield and high seed quality can be achieved by the availability of phosphorus and nitrogen at the desired time and in optimal amounts [7]. Seeds treated with fertilizer contained larger food reserves, which enable them to nourish the embryo longer during germination.

3.6. Dead Seeds

Analysis of variance reviled that percentage number of dead seeds significantly (P ≤ 0.0001) influenced by varieties and the number of tiller per plants (Table 4).

Between 16.25 and 32.42 percent of the seeds harvested from main shoot and tiller under examination were dead seed. The Assosa-1 sorghum variety's secondary tiller had the greatest proportion of dead seeds (32.42) found. In contrast, the main shoot of Adukara plants yielded the lowest proportion (16.25%), closely followed by the primary shoot of Assoasa-1 plants (18.25). Primary and secondary tillers had higher percentages of dead seeds than the main sorghum plant, 53.5%, and 45.2%, respectively. The premature seed development as a result of lack of nutrients owing to plant competition and late tiller emergence led to an increase in the number of dead seeds from the primary and secondary tillers.

The germination rate of seeds from the primary and secondary tillers decreased as a result of the larger number of dead seeds.

Table 5. Main effect of verities effects on seedling shoots length and vigor index of sorghum during the main cropping season of 2017-2019.

Variety	Parameter		
	SH (cm)	VI	VII
AD	17.265[a]	2253.41[a]	54.793[a]
AS	16.86[a]	2129.59[a]	41.843[a]
1AD	16.865[a]	2081.22[b]	51.694[a]
1AS	16.0438[b]	1834.42[a]	45.136[a]
2AD	16.7175[a]	2013.15[b]	46.769[a]
2AS	16.0058[b]	1701.28[c]	32.62[b]
Lsd(0.05)	0.75	164.76	13.68
CV	4.035	7.53	27.17
P	≤ 0.004	≤ 0.0001	≤ 0.02

Means followed by the same letter within a column are not significantly different at 5% level of significance. LSD = Least significant difference; CV = Coefficient of variation; AD= Adukara; AS = Assosa-1; 1AD= primary tiller of Adukara; 2AD= secondary tiller of Adukara; 1AS= primary tiller of Assosa-1; 2AS=secondary tiller of Assosa-1; SH = shoot length; VI= vigor index one; VII= vigor index two

3.7. Seedling Shoot Length

The average mean value of seedling shoot length was significantly ($P \leq 0.004$) affected by the main effects of the number of tillers of the verities (Table 5).

The seedling shoot length observed from the experiment revealed that the highest 17.265 cm length of shoot recorded from the seed harvested from the main plants of Adukara sorghum variety followed by seeds from main plants of Assosa-1, primary and secondary tiller of Adukara. While the primary and secondary tiller of Assosa-1 recorded the lower length of seedling length. Quality seed produce vigor seedlings with well-established seedling. Since the seeds from the main plants fully matured than tillers they gave the longest seedling lengths.

The maximum 17.265 cm length of shoot recorded from the seeds extracted from the main plants of the Adukara sorghum variety was found in the experiment's seedling shoot observations. The seeds from the main plants of the Assosa-1, primary and secondary tillers of Adukara, were next in line. However, Assosa-1's primary and secondary tillers measured the shorter seedling length. Vigorous seedlings with well-established seedlings are produced by quality seeds. The main plants' seeds produced the longest seedling lengths because they were far better grown compared to the seeds of the tillers.

3.8. Vigour Index One

The data in the bar chart illustrates how the number of tillers of the sorghum cultivars Adukara and Assosa-1 affected seedling vigour index one in the Benishangul Gumuz area during the 2019 and 2020 crop seasons.

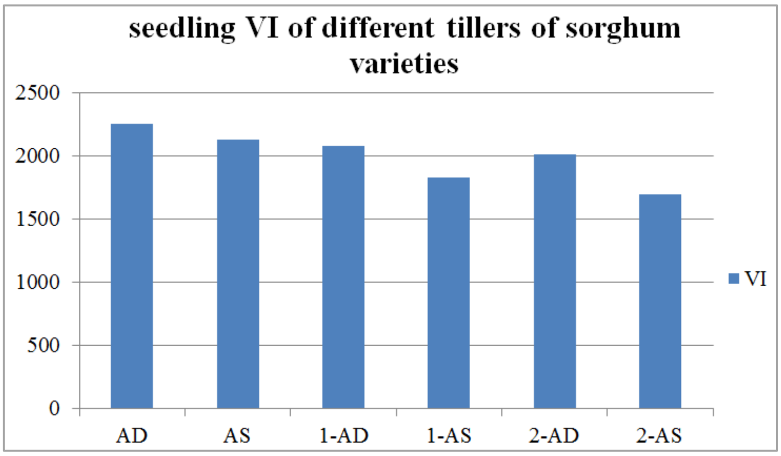

Figure 1. The number of tillers of the sorghum cultivars Adukara and Assosa-1 affected seedling vigour index one.

The primary and secondary tillers had a decline in overall seedling vigour index one across the periods, whereas the main sorghum plant varieties, Adukara and Assosa-1, exhibited an upward trend. Vigour index one figures for the two varieties of sorghum fluctuated significantly. At the conclusion of the periods, secondary tillers outran the lowest, despite the vigour index-one observing a lower rate in primary and secondary tillers for the variety Assosa-1.

In comparison to the main plants of the Assoa-1 variety, the main plant of the Adukara sorghum variety had mean vigour index one values of almost 2250, which was greater. Nonetheless, the figure demonstrated that the Adukara prime tiller's vigour index-one was somewhat higher than the mean values of 2000 and steadily declined compared to the secondary tillers, which produced mean values of about 2000.

Higher vigour index one is the outcome of seedlings with greater biomass in their roots and shoots, which is encouraged by superior seed quality. More leaves emerge from a shoot that is developing quickly, and more leaves are crucial for the interception of photosynthetic activity and well-established agricultural field performance. According to [14], the finding consistent with a high shoot biomass is a sign of higher seed vigour and following crop development cycles. [5] claim that high-quality seeds promote the growth of seedlings with larger biomass roots, which is a sign of their capacity to endure stress, as well as make it easier for the next generation to produce high-quality grains.

While the primary tiller's mean vigour index one value was marginally below the 2000 mean, the main plant's vigour index one of the Assosa-1 sorghum variety was marginally higher than 2000. The same variety's secondary tillers reported mean VI values of around 1600, which touched lower traces.

3.9. Vigour Index Two

The analysis of variance revealed that the number of tillers in the verities had a significant ($P \leq 0.05$) impact on the seedling vigor index (VI and VII) (Table 5).

While Adukara gave the highest 2253.41 following by Assosa-1 2129.59 mean value of vigor one. The lowest was recorded by seed harvested from secondary tillers of Assosa -1.

On the other hand the seed harvested from Adukara sorghum varieties gave the highest 54.793. Seedling vigor two and the lowest 32.62 value were observed from seed harvested from secondary tiller of Assosa-1 variety. Except the lowest value of recorded in the experiments all the mean values of Vigor index two recorded were statistically parity.

The highest seedling vigor index two was the results of genetic variation among the varieties and fully maturity of the seed on the fields. Seed vigor and yield are ultimately influenced by seed quality, which is heavily influenced by the environment during embryogenesis and seed maturity. The number of tiller per plants cause competition for plant nutrient also affected the seedling vigor. The study in line with the finding of stated that Seed vigour is usually influenced by genetic constitution during seed development and Seed vigor is usually influenced by environmental factors during seed development. These environmental factors include soil moisture, soil fertility and post maturation/ pre-harvest environment [8].

4. Summary and Conclusion

The study analyzed the seed quality and yield of sorghum seeds in Ethiopia, focusing on the main shoot plants and tillers. The Adukara sorghum variety showed higher yields than the Assosa-1 variety due to its genetic potential. The main shoot plant yielded more seeds than primary and secondary tillers, with the shoot exceeding these yields by 302.96% and 1333%, respectively. Primary tillers also yielded more seeds than secondary tillers by 255.8%. Seeds from the plot with the main plant shoot germinated faster and produced robust seeds, while other plants struggled due to competition for nutrients, water, and sunlight. Laboratory seed testing revealed that seeds from the main plant were more successful in germination percentage than those from primary and secondary tillers. Primary and secondary tillers recorded germination percentages below blew recommended seed standards. Quality seeds produce vigor seedlings with well-established seedlings, as the seeds from the main plants fully matured than the seeds of the tillers. The main plants' seeds produced the longest seedling lengths because they were far better grown compared to the seeds of the tillers. The study also found that seed vigor two and yield are influenced by genetic variation among varieties and seed maturity on the fields.

In conclusion, the poor quality of the seed obtained from sorghum tiller affects the planting values. In order to prevent competition for nutrients among seedlings for seed production and to ensure seed quality, the tillers should be regularly removed. Conversely, secondary tillers have the potential to boost overall yield production but only if sorghum is grown for grain production. To reach a definitive conclusion, a comparable research comprising the cost of production for grain and seed production using various planting spaces should be conducted again at different locations.

Abbreviations

AD: Adukara
ANOVA: Analysis of Variance
AS: Assosa-1
CRD: A completely Randomized Design
GLM: Generalized Linear Model
LSD: Least Significant Difference
RCBD: Randomized compLete Block Design
SAS: Statistical Analysis System
TSW: Thousand Seed Weight
VI: Vigour Index One
VII: Vigour Index Two

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Author Contributions

Fekede Tena Ayana: Conceptualization, Software, Formal Analysis, Methodology, Writing – original draft, Writing – review & editing

Mosisa Tolosa: Conceptualization, edition

Conflicts of Interest

The authors declare no conflicts of interest.

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