Austin Journal of Plant Biology

Open Access

Austin Publishing Group

Research Article

Evaluation of Released Sorghum [*Sorghumbicolor* (*L.*) Moench] Variety for Lepidopteran Stem Borer Tolerance at West Oromia, Ethiopia

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Received: April 30, 2025
Accepted: May 15, 2025
Published: May 19, 2025

Abstract

The field experiment was conducted on nine improved sorghum varieties and one local check at Haro Sabu Agricultural Research Center during the main cropping season of 2021/22. The main objective of the study was to evaluate stem bore tolerance under field condition. The field experiment was executed in Randomized Complete Block Design with three replications. Stem borer infestation data such as number of larvae/plant, number of hole/plant, number of dead hearted plant, tunnel length, and crop data like days to 50% flowering, days to 90% maturity, stand count at harvesting, plant height, number of productive tiller/plant, number of non-productive tiller/plant, number of internodes/plant, internodes length, panicle length, panicle weight and grain yield-1ha were collected, and analyzed by SAS-software. The analysis of variance showed significant difference between varieties for all observations, indicating the existence of exploitable genetic variability for stem borer tolerance. Significantly higher larvae/plant, hole/plant, tunnel length and dead heart plant, and significantly lower grain yield and most of yield related traits were recorded from Melkam, Teshale, Gembela 1107, Bonsa, Tilahun and Geremew varieties. These varieties had also shorter days to flowering, days to maturity and plant height compared with the rest. In addition to longer days to flowering, days to maturing and taller plant height; Gemedi, Sedi and local check had significantly lower number of larvae/plant, number of hole/plant, tunnel length, and number of dead heart. However, merera variety which showed medium performance for plant height and maturity had also highest stem borer tolerance. The finding of present study identified merera followed by Sadi variety for higher grain yielding-1ha and better stems borer tolerance. Therefore, merera and Sadi were suggested for demonstration and popularization in the study area and similar agro-ecologies where sorghum stem borer infestation is important.

Keyword: *Sorghum bicolor (L.)*; Stem Borer; Tolerance; Yield

Introduction

Sorghum [Sorghum bicolor (L.) Moench] is the fifth most important cereal crop in the world, following wheat, maize, rice and barley. It is the second main crop next to maize in Africa and ranking third in area coverage following tef and maize in Ethiopia [1]. Sorghum is drought tolerant and nutrient-efficient crop that can be cultivated in over 80% of the world's ecologies. Though it has lion share in providing human consumption in majority of rural areas, the crop has great potential to supplement fodder resources because of its wider adaptation, rapid growth, high green and dry fodder yielding due to higher ratooning and drought tolerance [2]. Sorghum production is adversely expanding in intermediate, wet lowland, highland and dry lowland agro ecological zones of Ethiopia.

Despite its huge economic benefits, sorghum productivity in unit area of land remained low compared to the yielding potential of the crop and suitability of agro-ecological zone probably due to a variety of biological and environmental reasons [1]. Lepidopteran stem borers are by far the most injurious on cultivated maize and sorghum [3]. Stem borers can cause severe damage at different growth stages. When infestation is severe, there is a physiological disruption of plant growth, panicle emergence and grain formation, resulting into kernel number and weight reduction. On the other hands, feeding and stem tunneling by larvae of Chilopartellus resulted in crop losses up to 80% yield in eastern Ethiopia [4].

Numerous findings reported sorghum stem borer managements; insecticide [5], intercropping [6], push pull and tolerant variety [7]. Deploying resistant cultivar is an essential component of integrated pest management which offers an economic, stable and ecologically sound to minimize the damage. Inspire of progress in area coverage of sorghum in Qellem Wollega, Western part of Ethiopia, stem borer infestation is becoming major challenge associated with low productivity (Zonal Agricultural Office, 2022). This is probably attributed due to climate change and/or farmers' introduction of stem borer susceptible variety. No comprehensive studies conducted on stem borer distribution, prevalence, severity and total yield loss and tolerance level of different varieties in the area. However, present study is specifically conducted to evaluate and recommend stem borer

Citation: Dereje Abera. Evaluation of Released Sorghum [*Sorghumbicolor* (*L.*) Moench] Variety for Lepidopteran Stem Borer Tolerance at West Oromia, Ethiopia. Austin J Plant Biol. 2025; 11(2): 1062.

Table1: Description of sorghum varieties evaluated at HSARC in 2022 main cropping season.

#	Sorghum variety	Year of release	Altitude	Releasing center	Flowering date	Height (cm)	Research yield (ton/ha)	Farm yield (ton/ha)	Seed color
1	Gambell 1107	1976	Drylowland	MARC/EIAR	80-90	150-200)	5-Mar	2.5	White
2	Teshale	2002	Drylowland	MARC/EIAR	65-76	170-210	2.6-5.2	3.6	White
3	Melkam	2009	Drylowland	MARC/EIAR	76-82	126-163	3.7-5.8	3.5-4.3	White
4	Geremew	2007	Drylowland	MARC/EIAR	1003	170	4.9	4	Red
5	Bonsa	2017	Intermidiate	MARC/EIAR	111.7	168.1	5	4.3	Brown
6	Gemedi	2013	Intermidiate	BARC/OARI	115	287	3.3	2.8	Yellow
7	Tilahun	2002	Drylowland	MARC/EIAR	94-102	138	3.2-4.5	4	white
8	Merera	2020	Intermediate	BARC/OARI	86-95	210	4.8-5.9	4.7	Red
9	Sadi	2021	Intermediate	HSARC/OARI	110-120	250	5.018	4.8	Brown
10	Local	Local cultivar			115	254	2.9-5	2.6	Red

tolerant/resistant and high yielding sorghum variety/ies in the study area.

Materials and Methods

Description of Study Area

The field experiment was conducted at Haro Sabu Agricultural Research center field condition during 2022 main cropping season. Soil condition of the study area is characterized by sandy loam soil textural classes. The area is located at 652 kilometers from Addis Ababa, the capital city of Ethiopia. It lies between latitude of 08⁰52'40.904"and longitude of 035⁰13'56.039"with altitude of 1558 meter above sea level (m.a.s.l). The study area is also noted with unimodal rain fall distribution pattern from April to November. During the field experimentation, the area received 1481 mm annual rain fall with 12.65 °C and 28.93 °C monthly minimum and maximum temperature, respectively.

Experimental Materials

Field trial was carried out on nine (9) improved sorghum varieties released in Ethiopia and one local cultivar. These varieties were released from Bako, Malkasa and Haro Sabu Agricultural research Centers so far (Table 1).

Experimental Design

The field experiment was done in randomized complete block design (RCBD) with three replications. The spacing of 1.5m, 1m, 0.75m and 0.15m were used between replication, plot, row and plant, respectively. Plot size of 4.5mx3m with six rows in which four harvestable rows used was deployed in the study.

Experimental Procedures

Experimental field was thoroughly ploughed by tractor in order to prepare good seed bed that can provide good contact of soil-water-seed for better seed germination and seedling establishment on the field. Three to five seeds planted per each hill were thinned to one stand at the spacing of 15 cm on 30days after planting when good seedlings were established in the field. Hence, a single row of each plot was adjusted to 20 stands at establishment. The inorganic fertilizer (NPS) was applied at the rate of 100 kg-1ha at sowing, where UREA was used at the rate of 200 kg-1ha in split form. The split application comprises of each 50% at sowing and knee height growth stage. All crop management practices were uniformly applied as per requirement for the field.

Data Collection

Plant and plot-based data were collected in present study. Plot based observation were made on days to 50% flowering, days to 90% maturity, stand count at harvest, grain yield and number of dead hearted plant from the plot. Whereas plant height, number of productive tiller/plant, non-productive tiller/plant, number of internodes/plant, internodes length, panicle length and panicle weight, number of larvae/plant, number of hole/plant due to stem borer and tunnel length were computed from randomly tagged plants in each plot.

Phonological Data:

Days to 50% flowering: number of days counted from sowing to when 50% plants started flowering.

Days to 90% maturity: number of days from sowing to when 90% of plants in each plot reached physiological maturity.

Grain Yield and Yield Component Data:

Stand count at harvest: number of productive stands counted at harvesting.

Plant Height (cm): heights of 10 different representative plants measured from the soil surface to the apex of the central leaf number of productive tiller/plant in each plot and divided by ten.

Number of productive tiller/plant: number of productive tiller/10 plants divided by ten.

Non-productive tiller/plant: number of non-productive tiller/10plants divided by ten.

Number of internodes/plant: number of internodes/10plants divided by ten.

Internodes length: length of one upper node plus one middle node plus one lower node/plant was measured from ten plants and divided by ten.

Panicle length: mean length of the panicle measured on a sample of five panicles measured from the base to the tip of the head.

Panicle weight (gm): ten randomly selected heads from plot were weighed and divided by 10.

Grain Yield (ton-1ha-): weight of harvested grain per plot, expressed in ton per hectare.

Table 2: Analysis of variance for stem borer tolerance in sorghum variety.

SV	Df	DF	DM	SCH	PH	NI	IL	NPT
Rep	2	9.63	0.7	142.43*	108.7	2.87	13.2	0.23
Entry	9	674.58**	266214.73**	196.87**	12520.52**	19.18**	32.87**	0.12*
Error	18	102.97	2.29	32.06	113.11	1.41	7.69	0.07
SV	Df	NNT	NL	TL	DH	HL	PW	GY
Rep	2	0.22	0.04	11.48	0.96	6.96	22.53	0.05
Entry	9	3.27**	0.18*	322.37**	4.35**	83.63**	1041.17**	0.29**
Error	18	0.37	0.05	14.85	0.14	3.48	177.97	0.03

*Whereas; Df=degree of freedom, DF=days to 50% flowering, DH=dead heart, DM=days to 90% maturity, GY=grain yield per hectare in ton/ha, HL=head length, TSW=thousand seed weight in gram, IL= internodes length, NH= number of hole per plant, NI=number of internodes per plant, NL=number of larvae per plant, NP=number of productive tiller per plant, NNP=number of non-productive tiller per plant, PH= plant height, PW=panicle weight, SCH=stand count at harvesting, Tunnel length, SV=source of variation, **=highly significant at 1% probability level, *=significant at 5% probability level.*

Stem Borer Infestation Data:

Larvae/plant: number of larvae counted from 10 representative stands by destructing the stem of sorghum and dividing by 10.

Hole/plant: number of hole made due to stem borer was counted from10 representative stands and divided by ten.

Number of dead heart plant: number of plants with dead hearted was counted from the plot following the stand count at establishment to harvesting.

Tunnel length (cm): The distance between consecutive hole/ plant was measured and added for each plant. After collecting from 10 independent representative plants, the value was added together and divided by ten. The main stem of plants infested with stem borer larvae was split open from the base to the apex to measure the cumulative tunnel length.

Data Analysis

Data were analyzed by SAS software, in which varietal mean performance were compared using a protected Fishers' least significant difference test at P = 0.05.

Results and Discussions

Analysis of Variance (ANOVA)

Analysis of variance showed highly significant difference between sorghum varieties for all observed parameters (Table 2). This indicates the existence of different response among sorghum varieties probably due to their genetic make-up or phenotypic variability. The finding of this study was in agreement with Fisseha et al. [8]; Petel et al. [9], who report existence of exploitable genetic variability among sorghum genotype for grain yield and yield related traits. In the same way, Muturi, et al., [10] reported genetic variability among sorghum varieties for resistance to sorghum stalk borer, which was in accordance with the finding of this study.

Mean Performance of Grain Yield and Yield Components

Phonological Parameters: Days to 50% flowering (DF) varied from 77 (Melkam to 118 (Gemedi) with grand mean of 96.93. Significantly shorter DF was recorded from Melkam (77), Teshale (84), Gambela1107 (84), Merera (86.33) and Geremew (91) compared with Gemedi (118), Local (115) and Sadi (116) as shown in table 3. Days to 90% maturity (DM) ranged from 151 (Gambela1107) to 179.67 (Sadi) with the grand mean of 165.7 days. Gambela 1107 (151), Tilahun (152.67), Teshale (156.67) and Melkam (157.33) had significantly shorter DM, while Sadi (179.67) and Gemadi (178) had significantly longer DM. However, Merera variety explained medium DM in present study (Table 3). The finding of this study was in agreement with Fisseha et al. [8]; Biru et al. [11], who reported existence of genetic variability for phonological traits among sorghum genotypes.

Gran Yield and Yield Components: For stand count at harvest (SCH), the lower (30) and higher (52) mean with grand mean of 39.93 were recorded from Gambela 1107 and Sadi, respectively. Gambela 1107, Tashale, Melkam and Tilahun showed significantly lower SCH, while significantly higher SCH was recorded from Sadi, Merera and Gemedi varieties which increased SCH by 30.23%, 26.05% and 24.39% over grand mean (39.93) as observed in table 3. The significant difference of SCH was likely attributed due to stalk borer infestation at different plant parts and growth stage. Plant height (PH) ranged from 113.33cm (Bonsa) to 293cm (Gemedi) with grand mean of 183.00cm. Significantly shorter PH was recorded from Bonsa (113.33cm), Melkam (126cm), Tilahun (142cm) and Teshale (155cm). Inversely, Gemedi (293cm), Sadi and Local cultivar had significantly taller PH. More specifically, Merera variety had medium PH accounted to 211cm, and increased PH only by 15.30% over grand mean of 183cm (Table 3). This probably implies that sorghum variety with tall and medium plant height had photosynthetic advantage and were efficient in channeling assimilates to the sink organs to enhance grain yields. The result obtained from this study was in line Muturi et al. [10]. The result of present study was also in accordance with Fisseha et al. [8], who reported exploitable genetic variability among sorghum genotypes in plant statue. Regarding number of inter

Table 3: Mean performance of phonological and yield component traits for sorghum variety.

Variety	Days to flowering	Days to maturity	Stand count at harvest	Plant height (cm)	Internodes number/plant	Internodes length(cm)
Bonsa	98cd	168.33c	39.67cd	113.33f	6.00c	13.33c
Gambela1107	84de	151e	30d	151.33d	6.00c	21.73ab
Gemedi	118a	178a	49.67ab	293a	10.67ab	21.9ab
Geremew	91de	166.67c	40bc	129.33ef	6.33c	14.13c
Local	115a-c	173bc	38cd	253.33b	10.67ab	19.43ab
Melkam	77e	157.33d	33.33cd	126ef	5.53c	17.28bc
Merera	86.333de	171.67b	50.33a	211c	9.00b	22.07a
Sadi	116ab	179.67a	52.00a	255.67b	11.67a	19.5ab
Teshale	84de	156.67d	31.67cd	155d	6.00c	22.7a
Tilahun	100b-d	152.67e	34.67cd	142de	5.00c	19.92ab
Mean	96.93	165.7	39.93	183	7.69	19.2
CV	10.47	0.95	18.92	5.81	15.47	14.45
Lsd	17.41	2.68	9.71	18.24	2.04	4.76

Whereas; CV=coefficient of variation, Lsd=Least significant difference at 5% probability level.

Table 4: Mean performance of sorghum variety for grain yield and yield component traits.

Variety	Number of productive tiller/plant	Number of non-Productive tiller/plant	Panicle length(cm)	Panicle weight (gram)	Grain yield (ton/ha)
Bonsa	0.00c	0.13c	29.067a	82.43a	1.747ab
Gambela	0.27a-c	2.00b	19.333c	54.7b-d	1.593bc
Gemedi	0.27a-c	0.13c	29a	62.08a-c	1.19d
Geremew	0.13bc	0.13c	30.6a	82.85a	1.663a-c
Local	0.00c	0.67c	22.667b	51.13b-e	1.433cd
Melkam	0.4a-c	0.4c	22.867b	39.16de	1.153d
Merera	0.13bc	0.13c	15.8d	73.9ab	1.943a
Sadi	0.33a-c	0.00c	25.467b	73.01ab	1.941a
Teshale	0.6a	3.2a	19.4c	46.27c-e	1.29d
Tilahun	0.47ab	0.93c	17cd	28.28e	1.173d
Mean	0.26	0.77	23.12	59.38	1.51
CV	100.3	78.81	8.07	22.47	11.38
Lsd	0.45	1.05	3.2	22.88	0.3

Whereas; CV=coefficient of variation, Lsd=least significant difference, mean with the same letter are not significantly different.

nodes per plant (NI), the lower value of 5 (Tilahun), 5.33 (Melkam), 6 (Teshale, Gambela 1107 and Bonsa) and 6.33 (Geremew) were recorded. However, the higher NI was computed from Sadi (11.67), Gemedi and Local cultivar (10.67). Merera had nine (9) NI which was slightly higher than grand mean (Table 4).

The shortest internodes length (IL) was recorded from Bonsa (13.33 cm), whereas the longest IL recorded Teshele (22.7cm) with grand mean of 19.20cm. Significantly shorter IL was recorded from Bonsa, Geremew and Melkam, while significantly longer IL from Teshale, Merera, Gemedi and Gembela 1107 (Table 3).

Productive tiller per plant (NPT) varied from 0 (zero) for Bonsa and Local cultivar to 0.6 for Teshale with grand mean of 0.26. Significantly lower NPT was expressed by Bonsa, Local cultivar, Merera and Geremew, while significantly higher NPT was explained by Teshale (0.6), Tilahun and Melkam (Table 4). This finding support Patel, et al. (2021), who reported the maximum tillers per plant from stem borer susceptible variety in the screening of different sorghum varieties for resistance to stem borer infesting forage sorghum.

Grain yield (GY) varied from 1.153 ton-1ha for Tilahun to 1.943 ton-1ha for Merera variety with grand mean of 1.51 ton-ha. Significantly lower GY was recorded from Melkam (1.153 ton-1ha), Tilahun (1.173 ton-1ha), Gemedi (1.19 ton-1ha) and Teshale (1.29 ton-1ha).

Conversely, Merera (1.943 ton-1ha) and Sadi (1.941 ton-1ha) attained significant and superior yield compared with the rest varieties (Table 4). Merera and Sadi varieties improved grain yield mean by 28.68% and 28.48% over the grand mean, respectively. The result of this study was in correspondence with the report of earlier researchers, Muturi, et al. ; Tadeos and Fano; Patel et al. [9,10,12], who stated different performance of sorghum variety for grain yield and yield components.

Stem Borer Infestation: Number of larvae per plant (NL) ranged from 0.2 (Merera) to 0.8 (Tilahun) with grand mean of 0.52. The desirable lower NL was recorded from Merera (0.2), Sadi (0.23) and Gemedi (0.27), while the undesirable higher NL was estimated for Tilahun (0.8), Gembela 1107 (0.77), Teshale (0.70), Bonsa and Local cultivar (0.67), and Geremew (0.6) as shown in Table 5. So far, Tadeos and Fano (2019) reported significant difference among sorghum varieties for number of larvae/plant, which was in complement with the finding of present study. The averaged number of holes per plant (NH) due to stem borer ranged from 0.43 for Merera to 5.07 for Gembela with grandmean of 2.06. The desirable lower and significant NH was counted from Merera (0.43), Gemedi (0.57) and Sadi (0.6) variety. However, the undesirable and significantly higher NH was estimated for Gembela (5.07), Bonsa (3.5) and Local check (3.33). Merera, Gemedi and Sedi varieties reduced number of hole per plant due to stem borer by 79.13%, 72.33% and 70.87% over grand mean (2.06), respectively (Table 5). Number of non-productive tiller per plant (NPT) ranged from 0 (Zero) for sadi to 3.2 for Teshale with grand mean 0.77.

All varieties showed significantly lower NPT than Teshale and Gembela 1107. Never the less, Tilahun, Local cultivar and Melkam had higher NPT after Teshale and Gembela 1107 (Table 4). Sorghum varieties which were severely affected by stem borer revealed significant effect for most of stem borer related data.

This pattern probably indicates a close relationship between stem borer related traits, grain yield and yield components, which were further studied in this study. Hence, in order to predict the status of stem borer severity in sorghum field, one of stem borer related data could be used. The finding of present study was in agreement with Muturi et al. [10], who studied inheritance of resistance traits to African stem borer in grain sorghum.

Averaged dead heart (DH) ranged from1.25 (Merera) to 4.13 (Bonsa) with grand mean of 2.92. The desirable significant and lower DH was recorded from Merera, Sedi and local cultivar. The undesirable and significantly higher DH was depicted by Bonsa,Tilahun, Teshale, Melkam and Geremew (Table 5). The result of this study supported Tadeos and Fano [12] and Patel et al. [9], who found significant difference of sorghum varieties for number of dead heart plant.

The minimum and maximum tunnel length per plant (TL) was estimated for Gemedi (1.43) and Bonsa (23.63cm) with grand mean of 10.69. Significantly lower TL was recorded for Gemedi, Merera and Sadi, while significantly higher TL was expressed by Teshale, Bonsa, Local cultivar, Tilahun, Melkam, Geremew and Gambela 1107 (Table 5). These results were in correspondence with Patel et al. [9] report which explained exploitable genetic variability among sorghum varieties for stem borer infestation associated traits.

Despite using stalks for fencing, wood and animal feeding, a sorghum variety which has good tolerance to lodging, disease, gray mold, stalk borer and bird attack [13]. In line with stem borer

Table 5: Stem borer infestation on sorghum variety.

Variety	Number of larvae/plant	Number of hole/plant	Dead heart	Tunnel length(cm)
Bonsa	0.67ab	3.5b	4.13a	23.63b
Gambela 1107	0.77a	5.07a	2.58b	4.13cd
Gemedi	0.27cd	0.57e	2.5b	1.43d
Geremew	0.6a-c	1.53de	3.85a	5.17cd
Local	0.67ab	3.33bc	1.58c	18b
Melkam	0.3b-d	1.63de	3.88a	9.45c
Merera	0.2d	0.43e	1.25c	1.53d
Sadi	0.23cd	0.6e	1.33c	2.1d
Teshale	0.7a	2.17b-d	3.95a	31.37a
Tilahun	0.8a	1.8c-e	4.08a	10.17c
Mean	0.52	2.06	2.92	10.69
CV	42.41	43.32	12.93	36.03
Lsd	0.38	1.53	0.65	6.61

***Whereas**, CV=coefficient of variation, Lsd=least significant difference, mean with the same letter are not significantly different.*

tolerance level, the finding of present study was in agreement with MoANR [13] for Merera variety.

Conclusions and Recommendations

Analysis of variance revealed significant difference among sorghum varieties for grain yield, yield components, and stem borer infestation related data. The result further illustrated existence of exploitable genetic potential that enable plant breeder to develop stem borer tolerant/resistant sorghum variety coupled with higher grain yield. Sorghum varieties identified for earlier plant phenology such as Melkam, Teshale, Gembela 1107, Bonsa, Tilahun and Geremew had significantly shorter plant height, higher hole/plant, larvae/plant, dead hearted plant and tunnel length, indicating higher susceptibility to stalk borer. Though data were not included, these varieties also showed higher bird attack at dough stage. However, Sadi, Gemedi and Local cultivar were noted with longer plant phenology, taller plant height, lower hole/plant, lower tunnel length and dead hearted plants. From these, Gemedi was severely attacked by bird as earlier maturing varieties. Merera variety had medium days to flowering and maturity, medium plant height, and best stalk borer infestation tolerance as indicated from lower mean larvae per plant, dead hearted plants and tunnel length. In addition to better stem borer tolerance, Merera and Sadi varieties showed significantly higher panicle weight and grain yield than all varieties in present study [14,15].

Therefore, demonstration and popularization of Merera and Sadi varieties was recommended in the study area and areas with similar agro-ecologies where sorghum stem borer infestation is important.

Data Availability

The data used to support the findings of this research are available from the corresponding author upon request.

Funding Statement

This research was funding by Oromia Agricultural Research Institute for the implementation at Haro Sabu Agricultural Research Center.

Authors' Contributions

The author collected, analyzed, interpreted, and prepared the manuscript of the study

Acknowledgements

The author is grateful to the financial support provided by Oromia Agricultural Research Institute for the research.

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