Peertechz

LIFE SCIENCES GROUP

Open Journal of Plant Science
OPEN ACCESS JOURNAL

ISSN: 2640-7906 DOI: https://dx.doi.org/10.17352/ojps

Research Article

# Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum [*Sorghum bicolor (L.)* Moench] hybrids in Ethiopia

**Fantaye Belay[1]*, Firew Mekbib[2] and Taye Tadesse[3]**

[1]Abergelle Agricultural Research Center, P.O. Box 44, Abi-Adi, Ethiopia

[2]School of Plant Sciences, Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia

[3]Ethiopian Institute of Agricultural Research, P.O. Box 2003, Addis Ababa, Ethiopia

**Received:** 24 June, 2021
**Accepted:** 09 July, 2021
**Published:** 10 July, 2021

***Corresponding author:** Fantaye Belay, Abergelle Agricultural Research Center, P.O. Box 44, Abi-Adi, Ethiopia, Tel: +251- 912725888; Fax: +251 344 461 035; E-mail: fantaye933@gmail.com

**Keywords:** GEI; *Sorghum bicolor L*; Hybrid; Stability parameters; Yield stability

https://www.peertechzpublications.com

Check for updates

## Abstract

*Sorghum* (*Sorghum bicolor*) known as a Camel crop of cereals, is among the dominant staple food grains for the majority of Ethiopians. Forty nine sorghum genotypes (hybrids + open pollinated varieties) were tested at five locations in a simple lattice design with two replications during the 2016 main cropping season. The objectives of this study were to determine yield stability using univariate methods and to assess the association among stability parameters of striga resistant sorghum genotypes in the dry lowland areas of Ethiopia. The result of the combined analysis of variance for grain yield revealed highly significant ($P \leq 0.001$) difference among Environment (E), Genotype (G) and Genotype × Environment Interaction (GEI). Based on the combined ANOVA over locations, the mean grain yield of environments ranged from 588 kg $ha^{-1}$ in Humera to 4508 kg $ha^{-1}$ in Sheraro. The highest yield was obtained from ESH-1 (3278 kg $ha^{-1}$), while the lowest was from K5136 (735 kg $ha^{-1}$) and the average grain yield of genotypes was 2184 kg $ha^{-1}$. Different stability models were used in measuring of genotype stability such as AMMI Stability Value (ASV), Yield Stability Index (YSI), coefficient of regression (bi) and deviation from regression ($S^2di$). Yield was significantly correlated with bi (0.91), r2 (0.55) and ASV (-0.56), while it was not correlated with $S^2di$ (-0.26). The non-significant correlation among yield and stability statistics indicated that, stability statistics provide information that can not be collected from average yield. The high positive correlation among mean grain yield and stability parameters is expected as the values of these parameters were higher for high yielding genotypes and the vice versa. Highly correlated stability parameters indicate that they can measure stability similarly. However, there were inconsistencies with the univariate stability parameters used, which created uncertainty to select or recommend the stable genotypes. Therefore, as the data is from one year, it is necessary to repeat the experiment at least for one more year across diverse dry lowland areas of Ethiopia.

## Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is naturally self-pollinated monocotyledon crop plant with the degree of spontaneous cross pollination, in some cases, reaching up to 30%, depending on panicle type [1]. It is a staple crop for more than 500 million people in 30 sub-Saharan Africa and Asian countries [2]. In Ethiopia, sorghum is produced by five million small holder farmers and its production is estimated to be four million metric tons from nearly two million hectares of land, giving the potential average grain yield of around two tons per hectare. It is ranked third in area coverage and fourth in total production [3]. However, low yields of sorghum have been recorded due to a number of biotic and abiotic constraints. Sorghum production constraints vary from region to region within Ethiopia; but, drought and striga are reported to be important sorghum production constraints in the north and northeastern parts of the country [4].

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

Striga hermonthica, the dominant striga species, is the most severe in the highly degraded north, northwestern and eastern parts of the country, viz. Tigray, Wollo, Gonder, Gojam, North Shewa and Hararghe [5]. Where soil fertility (nutrient deficiency) and moisture stress are limiting factors, *i.e. striga* is rapidly expanding in areas where the soil has low fertility and drought is frequent. Nationally, *striga* causes annual yield loss as high as 65-70% and, at times, leaves plot uncultivated [6].

Many researchers [7,8] have reported variability in sorghum responses to *striga* infestation. The presence of a wide range of variability in *striga* resistant and/or drought tolerance traits among sorghum genotypes suggests an opportunity to develop high yielding and resistant/tolerant genotypes through hybridization [9]. In order to address the constraints affecting sorghum, and increase its production, the National Agricultural Research Systems (NARS) in collaboration with international research centers like, ICRISAT and Purdue University are developing hybrid sorghums.

The numerous importances attached to sorghum hybrids stems from the fact that there has been a yield advantage of sorghum hybrids whenever they are compared to the improved and landrace cultivars, commonly in order of 20 to 60% [10]. Sorghum hybrids have been shown to yield 15 to 41% higher than open pollinated varieties under small holder conditions in India and West Africa [11,12]. Reports from research has shown that sorghum hybrids holds a lot of importance and appear to be more reliable than inbred varieties in erratic environments, typically of sorghum growing regions in the semi-arid tropics [13].

One of the importance attached to sorghum hybrids whenever they are compared to the open pollinated and landrace cultivars, increase the yield in order of 20 to 60% [10]. Beside yield superiority over open-pollinated varieties, hybrids are more stable across different environments [14] and more tolerant to moisture stress. In Ethiopia, hybrids give 27-30% more grain yield advantage as compared to check varieties and proved to be early maturing than their parental lines [6,15,16].

The yield advantage in sorghum hybrid is due to the complementarity effect of the two inbred lines on the F1 hybrid [17]. It is thus presumed that inbred lines that have *striga* resistant genes complement each other and the F1 hybrids express superiority in reaction to *striga* and could give better yield. Abebe, et al. [18] also reported that most resistant sorghum hybrids produced consistently higher grain yields under *S.hermonthica* infestation, supported fewer emerged parasites, and less sustained minimal parasite damage symptoms across locations. However, there is no information on yield stability of *striga* resistant sorghum hybrids in Ethiopia. Therefore, the specific objectives of the study were to determine yield stability using univariate methods and to assess the association among commonly used stability parameters for striga resistant sorghum hybrids in dry lowland areas of Ethiopia.

# Materials and methods

## Description of the study sites

The field experiment was conducted during the 2016 main cropping season at five locations (Sheraro, Kobo, Mehoni, Fedis and Humera), representing the dry lowland areas of Ethiopia located in the altitude range of 609 - 1600 meter above sea level (m.a.s.l), where sorghum is widely grown. The detailed agro-ecological features of the locations are presented in Table 1, Figure 1.

## Experimental materials

Breeding materials comprised of 49 sorghum genotypes that include three *striga* resistant check varieties, Gobye (P9401), Abshir (P9403) and Birhan; two *striga* susceptible hybrids, ESH-1 and ESH-4 released by the national program and 44 striga resistant sorghum hybrids introduced from Purdue University. The majority of the introduced hybrids were derived from the locally adapted striga resistant sorghum inbred lines with best performing seed parent developed at Purdue. The detailed information of the tested genotypes is presented on Table 2.

## Experimental design and crop management

The trial was laid out using a 7x7 lattice design with two replications in each location. Each plot consisted of two rows of 5 m length with 0.75 m and 0.20 m, between rows and plants, respectively. All plots were fertilized uniformly with 100 kg ha$^{-1}$ Di-ammonium Phosphate (DAP) and 50kg ha$^{-1}$ Urea. Full dose of DAP and half of urea were applied at the time of planting and the remaining half was side dressed at knee height stage of the crop. All of the other agronomic management practices were applied as required at all locations as per the recommendations for sorghum in dry lowland areas of Ethiopia.

## Data collection

Data were collected both on plot and plant basis, based on the descriptors list for sorghum (IBPGR/ICRISAT, 1993). Phenological data (days to emergence, flowering, grain filling period and maturity date), morphological data (plant height and panicle length), and yield and yield related traits (grain yield and thousand grain weight) were collected.

## Data collected on plant basis

From the two rows five plants were selected randomly and tagged to collect the morphological data such as, plant height and panicle length. The detail of the data collection for each trait was carried out as follows:

Plant height (PH): was determined from the average height of five plants in cm from ground level to the tip of the panicle (at physiological maturity).

Panicle length: was measured (cm) from the base of the panicle to the tip from five randomly selected plants per plot at maturity.

## Data collected on plot basis

Days to 50% seedling emergence: The number of days from the date of sowing to the date at which 50% of the seedlings in a plot were emerged.

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

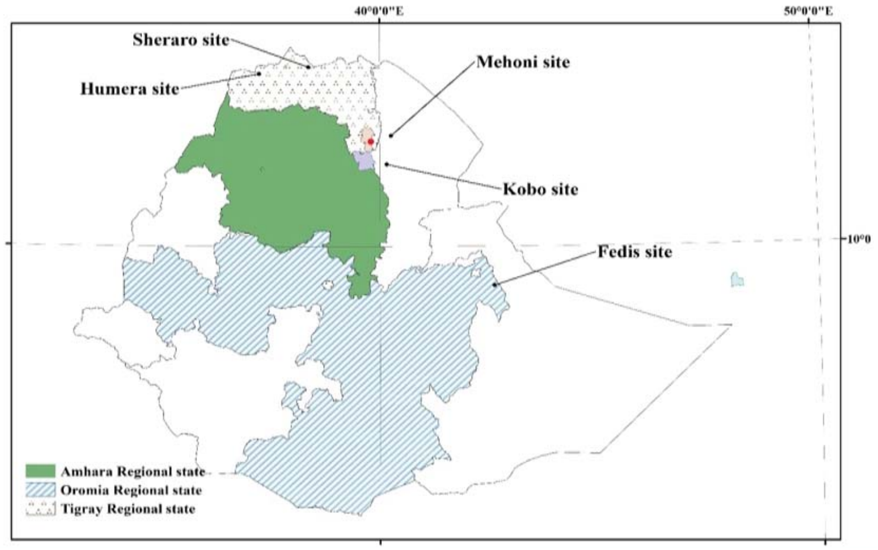

**Figure 1:** Map of the study sites.

**Table 1:** Agro-ecological features of the experimental locations.

| Location | Geographic position | | | Annual Rain fall (mm) | Temperature (°C) | | Soil type | Location code |
|---|---|---|---|---|---|---|---|---|
| | Altitude | Latitude | Longitude | | Min | Max | | |
| Humera | 609 | 14° 06'N | 39° 38'E | 576.4 | 27.0 | 42.0 | *Vertisol* | E1 |
| Kobo | 1468 | 12° 09'N | 39° 38'E | 673.4 | 15.4 | 30.2 | *Vertisol* | E2 |
| Fedis | 1600 | 9° 07'N | 42° 04'E | 724.5 | 10.5 | 28.1 | *Alfisols* | E3 |
| Mehoni | 1578 | 12° 41'N | 39°42'E | 539.3 | 18.0 | 32.0 | *Vertisol* | E4 |
| Sheraro | 1028 | 14° 24' N | 37° 45' E | 700.0 | 19.3 | 34.8 | *Vertisol* | E5 |

Source: respective research centers, 2016

Days to 50% flowering: The number of days from 50% seedling emergence to the date at which 50 % of the plants in a plot started flowering.

Days to 90% maturity: The number of days from emergence to the stage when 90% of the plants in a plot have reached physiological maturity.

Grain filling period: The numbers of days from flowering to maturity, *i.e.* the number of days to maturity minus the number of days to flowering and it includes watery ripe stage, milk stage, soft dough stage, hard dough stage and ripening stage.

Grain yield (kg $ha^{-1}$): The panicles from the two rows of each plot were threshed, cleaned and adjusted to standard moisture level at 12.5% and weighted to get the grain yield per plot in grams and converted to kg $ha^{-1}$ for analysis.

Thousand grain weight: The weight of 1000 randomly sampled grains from each plot was measured in grams using sensitive balance and adjusted at 12.5% moisture content.

## Data analyses

Homogeneity of residual variances was tested prior to analysis over locations using Bartlett's tests [19]. Analysis of variance for each environment, combined analysis of variance over environments, correlation coefficient among stability parameters and agronomic traits were computed using GenStat 18th edition (2016. Coefficient of regression (bi) and deviation from regression ($S^2di$) stability parameters were also analyzed using SPAR 2.0 software.

## Individaul and combined ANOVA

As the error variance was homogenous for all traits continued to combined analysis of variance from the mean data of all environments to detect the presence of GEI. Genotypes were assumed to be fixed and environment effects were treated as random. Genotype by environment interaction was quantified using pooled analysis of variance, which partitions the total variance into its component parts (genotype, environment, genotype x environment interaction and pooled error). Mean separations for the treatment means having significant differences at 5% probability levels was done using Duncan's Multiple Range Test (DMRT) comparison procedure. GenStat 16th edition (2016) statistical software was used for statistical analyses. The relative efficiency of the simple lattice design over Randomized Complete Block Design (RCBD) was checked. For most of the yield and yield related traits RCBD was found to be more efficient than that of the lattice design. The analysis of variance for each location and combined analysis of variance over locations was used as suggested by Gomez and Gomez (1984). The model employed in the analysis was;

$Yijk = \mu + Gi + Ej + Bk + GEij + \varepsilon ijk$ where:

Yijk is the observed mean of the ith genotype (Gi) in the jth environment (Ej), in the kth block (Bk); μ is the overall mean; Gi is effect of the ith genotype; Ej is effect of the jth

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

**Table 2:** Description of the experimental materials.

| SN | Genotypes | Pedigree | Code | Source |
|---|---|---|---|---|
| 1 | K7416 | P140895A x P9401 | G1 | Purdue University |
| 2 | K7417 | P140895A x P9405 | G2 | " |
| 3 | K7418 | P140895A x BRHAN | G3 | " |
| 4 | K7437 | P140919A x P9401 | G4 | " |
| 5 | K7438 | P140919A x P9405 | G5 | " |
| 6 | K7439 | P140919A x BRHAN | G6 | " |
| 7 | K7445 | P140927A x BRHAN | G7 | " |
| 8 | 5136 | P111535A x PSL985066 | G8 | " |
| 9 | 5151 | P111539A x P9401 | G9 | " |
| 10 | 5152 | P111539A x P9405 | G10 | " |
| 11 | 5153 | P111539A x P9406 | G11 | " |
| 12 | 5155 | P111539A x PSL985062 | G12 | " |
| 13 | 5156 | P111539A x PSL985066 | G13 | " |
| 14 | 5160 | P111539A x PSL985369 | G14 | " |
| 15 | K7229 | P111043A x P9401 | G15 | " |
| 16 | K7230 | P111045A x P9401 | G16 | " |
| 17 | K7231 | P111047A x P9401 | G17 | " |
| 18 | K7232 | P111051A x P9401 | G18 | " |
| 19 | K7233 | P111055A x P9401 | G19 | " |
| 20 | K7234 | P111073A x P9401 | G20 | " |
| 21 | K7235 | P111107A x P9401 | G21 | " |
| 22 | K7236 | P111125A x P9401 | G22 | " |
| 23 | K7237 | P111131A x P9401 | G23 | " |
| 24 | K7242 | P111163A x P9401 | G24 | " |
| 25 | K7244 | P111173A x P9401 | G25 | " |
| 26 | K7245 | P111183A x P9401 | G26 | " |
| 27 | K7249 | P111209A x P9401 | G27 | " |
| 28 | K7251 | P111225A x P9401 | G28 | " |
| 29 | K7252 | P111269A x P9401 | G29 | " |
| 30 | K7255 | P111339A x P9401 | G30 | " |
| 31 | K7256 | P111371A x P9401 | G31 | " |
| 32 | K7259 | P111021A x BRHAN | G32 | " |
| 33 | K7260 | P111043A x BRHAN | G33 | " |
| 34 | K7263 | P111051A x BRHAN | G34 | " |
| 35 | K7265 | P111073A x BRHAN | G35 | " |
| 36 | K7266 | P111107A x BRHAN | G36 | " |
| 37 | K7267 | P111125A x BRHAN | G37 | " |
| 38 | K7268 | P111131A x BRHAN | G38 | " |
| 39 | K7270 | P111143A x BRHAN | G39 | " |
| 40 | K7273 | P111163A x BRHAN | G40 | " |
| 41 | K7274 | P111169A x BRHAN | G41 | " |
| 42 | K7276 | P111183A x BRHAN | G42 | " |
| 43 | K7277 | P111187A x BRHAN | G43 | " |
| 44 | K7280 | P111209A x BRHAN | G44 | " |
| 45 | BRHAN | Check variety | G45 | Melkassa Agricultural Research Center (MARC) |
| 46 | GOBYE | Check variety | G46 | |
| 47 | ABSHIR | Check variety | G47 | |
| 48 | ESH-4 | PU207 x PU304 | G48 | |
| 49 | ESH-1 | P9401A x ICSR14 | G49 | |

environment; Bk is block effect of the ith genotype in the jth environment; GEij is the interaction effects of the ith genotype and the jth environment; and εijk is the error term.

## Eberhart and Russell's stability analysis

Eberhart and Russell [20] procedure involves the use of joint linear regression where the yield of each genotype is regressed on the environmental mean yield. Then, the behavior of the genotype was assessed by the model: $Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$ using Spar 2.0 statistical software.

Where: $Y_{ij}$ = the mean performance of the ith genotype in the jth environment, $\mu_i$ = the grand mean of the ith genotype over all the environments, $\beta_i$= the regression coefficient which measures the response of the ith genotype on environmental index, $I_j$ = the environmental index obtained by the difference between the mean of each environment and the grand mean and $\delta_{ij}$ = the deviation from regression of ith variety in the jth environment

The pooled deviations mean square was tested against the pooled error mean square by the F-test to evaluate the significance of the differences among the deviations of genotypes being evaluated from their expected performances. As a result, in order to test the validity of the hypothesis that whether there is significant difference among the 49 genotypes with respect to their mean grain yields or not and whether there is significant difference among the regression coefficient or not, genotypes mean square and regression mean square were tested against the pooled deviation using the F-test.

## Correlation and coefficient of determination

Spearman's correlation coefficient between different stability parameters and among agronomic traits and coefficient of determination ($r^2$) for grain yield of each genotype was estimated by using GenStat 18th edition (2016) statistical software and Microsoft excel, respectively.

## AMMI Stability Value (ASV)

In order to compute and rank genotypes according to their yield stability, the additive main effect and multiplicative interaction effect stability value (ASV) was proposed by Purchase [21]. It was calculated using Microsoft excel (2007) by employing the following formula:

$$ASV=\sqrt{\left[\frac{SS_{IPCA1}}{SS_{IPCA2}}(IPCA1_{score})\right]^{2}+(IPCA2_{score})^{2}}$$

Where: ASV = AMMI'sstability value, IPCA1= interaction principal component analysis one, and IPCA 2= interaction principal component analysis II.

Similarly yield stability index (YSI) was also computed by summing up the ranks from ASV and mean grain yield [22]:

YSI= RASV+RGY;

Where: RASV is rank of AMMI stability value and RGY is rank of mean grain yield to statistically compare the stability analysis procedures used in the study.

# Results and discussion

## Mean performance of genotypes

The overall performance of 49 sorghum genotypes tested based on mean grain yield and other agronomic traits across locations is presented in Tables 3. In this study days to flowering, maturity, plant height, panicle length, grain yield and thousand grain weight were highly significantly (P≤ 0.001)

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

**Table 3:** Mean performances for yield and yield related traits of 49 sorghum genotypes evaluated at five environments in Ethiopia.

| Genotype | DTE | DTF | DTM | GFP | PHT | PL | GY | TGW |
|---|---|---|---|---|---|---|---|---|
| G1 | 6.00$^{ns}$ | 60.60$^{h-m}$ | 97.90$^{c-i}$ | 39.30$^{ns}$ | 133.50$^{l-o}$ | 29.56$^{a-h}$ | 2692$^{b-f}$ | 26.60$^{a-e}$ |
| G10 | 7.10$^{ns}$ | 67.80$^{ab}$ | 106.00$^{a}$ | 40.20$^{ns}$ | 151.80$^{a-i}$ | 28.72$^{b-h}$ | 1000$^{pq}$ | 26.40$^{a-e}$ |
| G11 | 7.10$^{ns}$ | 67.40$^{abc}$ | 104.10$^{ab}$ | 38.70$^{ns}$ | 142.30$^{g-m}$ | 28.26$^{c-h}$ | 932$^{pq}$ | 25.00$^{a-e}$ |
| G12 | 6.60$^{ns}$ | 62.90$^{d-k}$ | 101.30$^{b-f}$ | 40.40$^{ns}$ | 152.50$^{a-i}$ | 29.72$^{a-h}$ | 1561$^{m-o}$ | 25.50$^{a-e}$ |
| G13 | 7.10$^{ns}$ | 66.40$^{a-d}$ | 100.90$^{b-f}$ | 36.50$^{ns}$ | 148.20$^{c-j}$ | 27.60$^{f-h}$ | 1159$^{o-q}$ | 27.50$^{abc}$ |
| G14 | 6.40$^{ns}$ | 68.90$^{a}$ | 101.70$^{a-e}$ | 34.80$^{ns}$ | 144.40$^{f-l}$ | 28.68$^{b-h}$ | 838$^{q}$ | 25.90$^{a-e}$ |
| G15 | 6.70$^{ns}$ | 61.40$^{f-m}$ | 99.80$^{b-h}$ | 40.40$^{ns}$ | 153.50$^{a-h}$ | 30.30$^{a-h}$ | 2249$^{e-j}$ | 26.50$^{a-e}$ |
| G16 | 6.20$^{ns}$ | 62.20$^{e-m}$ | 98.50$^{c-i}$ | 38.30$^{ns}$ | 156.00$^{a-f}$ | 29.92$^{a-h}$ | 2658$^{b-f}$ | 25.80$^{a-e}$ |
| G17 | 6.10$^{ns}$ | 63.00$^{d-k}$ | 98.30$^{c-i}$ | 37.30$^{ns}$ | 156.30$^{a-f}$ | 29.46$^{a-h}$ | 2251$^{e-i}$ | 27.80$^{abc}$ |
| G18 | 6.30$^{ns}$ | 63.20$^{d-j}$ | 99.20$^{c-i}$ | 38.00$^{ns}$ | 156.10$^{a-f}$ | 30.40$^{a-h}$ | 2623$^{b-f}$ | 28.10$^{ab}$ |
| G19 | 6.20$^{ns}$ | 62.70$^{d-l}$ | 98.90$^{c-i}$ | 38.20$^{ns}$ | 158.50$^{a-e}$ | 29.63$^{a-h}$ | 2456$^{c-g}$ | 28.30$^{a}$ |
| G2 | 6.10$^{ns}$ | 63.60$^{d-h}$ | 99.50$^{b-i}$ | 37.90$^{ns}$ | 132.60$^{l-o}$ | 28.70$^{b-h}$ | 1898$^{h-m}$ | 24.50$^{c-e}$ |
| G20 | 6.00$^{ns}$ | 63.00$^{d-k}$ | 99.30$^{b-i}$ | 38.30$^{ns}$ | 160.70$^{abc}$ | 29.04$^{b-h}$ | 2894$^{abc}$ | 24.70$^{b-e}$ |
| G21 | 6.20$^{ns}$ | 61.70$^{e-m}$ | 98.50$^{c-i}$ | 38.80$^{ns}$ | 162.30$^{ab}$ | 30.52$^{a-f}$ | 2828$^{abcd}$ | 27.00$^{a-e}$ |
| G22 | 6.00$^{ns}$ | 61.50$^{f-m}$ | 99.80$^{b-h}$ | 40.30$^{ns}$ | 142.00$^{g-m}$ | 28.94$^{b-h}$ | 2652$^{b-f}$ | 26.40$^{a-e}$ |
| G23 | 5.80$^{ns}$ | 62.10$^{e-m}$ | 100.20$^{b-h}$ | 40.10$^{ns}$ | 147.00$^{e-k}$ | 29.04$^{b-h}$ | 2175$^{e-l}$ | 25.70$^{a-e}$ |
| G24 | 6.10$^{ns}$ | 64.20$^{c-h}$ | 101.00$^{b-f}$ | 38.80$^{ns}$ | 143.00$^{g-m}$ | 29.10$^{b-h}$ | 2679$^{b-f}$ | 25.30$^{a-e}$ |
| G25 | 5.70$^{ns}$ | 63.70$^{d-h}$ | 100.00$^{b-h}$ | 38.30$^{ns}$ | 154.70$^{a-g}$ | 28.02$^{d-h}$ | 2410$^{c-h}$ | 26.10$^{a-e}$ |
| G26 | 6.50$^{ns}$ | 59.40$^{j-m}$ | 98.30$^{c-i}$ | 40.90$^{ns}$ | 151.50$^{a-i}$ | 29.94$^{a-h}$ | 2274$^{efgh}$ | 26.30$^{a-e}$ |
| G27 | 6.30$^{ns}$ | 60.70$^{g-m}$ | 97.90$^{c-i}$ | 39.20$^{ns}$ | 151.30$^{a-i}$ | 30.22$^{a-h}$ | 2303$^{d-h}$ | 27.90$^{abc}$ |
| G28 | 6.10$^{ns}$ | 59.60$^{i-m}$ | 98.50$^{c-i}$ | 40.90$^{ns}$ | 156.20$^{a-f}$ | 30.56$^{a-f}$ | 2567$^{b-g}$ | 26.90$^{a-e}$ |
| G29 | 6.20$^{ns}$ | 61.10$^{f-m}$ | 98.50$^{c-i}$ | 39.40$^{ns}$ | 159.80$^{a-d}$ | 31.42$^{a-d}$ | 3051$^{ab}$ | 24.70$^{b-e}$ |
| G3 | 6.20$^{ns}$ | 61.80$^{e-m}$ | 96.90$^{e-i}$ | 37.10$^{ns}$ | 134.80$^{k-o}$ | 29.31$^{a-h}$ | 2244$^{e-k}$ | 27.70$^{abc}$ |
| G30 | 6.50$^{ns}$ | 62.00$^{e-m}$ | 98.50$^{c-i}$ | 38.50$^{ns}$ | 152.80$^{a-h}$ | 29.96$^{a-h}$ | 2200$^{e-k}$ | 26.80$^{a-e}$ |
| G31 | 5.90$^{ns}$ | 60.60$^{h-m}$ | 100.30$^{b-h}$ | 41.70$^{ns}$ | 150.60$^{b-j}$ | 30.48$^{a-g}$ | 2197$^{e-k}$ | 26.30$^{a-e}$ |
| G32 | 6.00$^{ns}$ | 59.10$^{lm}$ | 95.70$^{hi}$ | 38.60$^{ns}$ | 160.60$^{abc}$ | 30.22$^{a-h}$ | 2377$^{c-h}$ | 26.00$^{a-e}$ |
| G33 | 6.40$^{ns}$ | 64.50$^{b-g}$ | 102.00$^{a-d}$ | 39.50$^{ns}$ | 139.70$^{i-n}$ | 30.58$^{a-f}$ | 2172$^{e-l}$ | 25.30$^{a-e}$ |
| G34 | 6.40$^{ns}$ | 64.50$^{b-g}$ | 98.70$^{c-i}$ | 36.20$^{ns}$ | 141.30$^{h-m}$ | 31.68$^{abc}$ | 2510$^{c-g}$ | 26.40$^{a-e}$ |
| G35 | 6.50$^{ns}$ | 63.60$^{d-h}$ | 100.60$^{b-g}$ | 39.00$^{ns}$ | 152.30$^{a-i}$ | 29.56$^{a-h}$ | 2040$^{g-m}$ | 28.30$^{a}$ |
| G36 | 6.20$^{ns}$ | 63.30$^{d-i}$ | 99.60$^{b-i}$ | 38.30$^{ns}$ | 144.80$^{f-l}$ | 31.42$^{a-d}$ | 2458$^{c-g}$ | 26.10$^{a-e}$ |
| G37 | 6.20$^{ns}$ | 64.10$^{c-h}$ | 100.60$^{b-g}$ | 38.50$^{ns}$ | 133.30$^{l-o}$ | 31.04$^{a-f}$ | 2179$^{e-l}$ | 25.60$^{a-e}$ |
| G38 | 6.00$^{ns}$ | 61.50$^{f-m}$ | 95.80$^{g-i}$ | 36.30$^{ns}$ | 149.50$^{c-j}$ | 31.08$^{a-f}$ | 2305$^{d-h}$ | 27.10$^{a-e}$ |
| G39 | 6.40$^{ns}$ | 58.70$^{m}$ | 97.90$^{c-i}$ | 41.20$^{ns}$ | 140.80$^{h-m}$ | 31.32$^{a-e}$ | 2374$^{c-h}$ | 25.10$^{a-e}$ |
| G4 | 6.40$^{ns}$ | 62.30$^{e-m}$ | 99.70$^{b-h}$ | 39.40$^{ns}$ | 156.50$^{a-f}$ | 26.86$^{gh}$ | 2713$^{b-f}$ | 23.70$^{e}$ |
| G40 | 6.20$^{ns}$ | 62.00$^{e-m}$ | 97.40$^{d-i}$ | 37.40$^{ns}$ | 138.00$^{j-n}$ | 29.96$^{a-h}$ | 2726$^{b-f}$ | 27.20$^{a-d}$ |
| G41 | 5.70$^{ns}$ | 61.50$^{f-m}$ | 97.80$^{c-i}$ | 38.30$^{ns}$ | 142.20$^{g-m}$ | 30.38$^{a-h}$ | 2354$^{c-h}$ | 25.60$^{a-e}$ |
| G42 | 6.00$^{ns}$ | 63.50$^{d-h}$ | 99.40$^{b-i}$ | 37.90$^{ns}$ | 156.00$^{a-f}$ | 32.81$^{a}$ | 2258$^{e-h}$ | 27.40$^{a-d}$ |
| G43 | 5.90$^{ns}$ | 60.70$^{g-m}$ | 97.60$^{c-i}$ | 38.90$^{ns}$ | 146.10$^{e-k}$ | 31.95$^{ab}$ | 2321$^{d-h}$ | 26.40$^{a-e}$ |
| G44 | 6.20$^{ns}$ | 59.30$^{k-m}$ | 96.50$^{f-i}$ | 39.20$^{ns}$ | 147.50$^{d-j}$ | 31.84$^{abc}$ | 2352$^{c-h}$ | 25.90$^{a-e}$ |
| G45 | 6.60$^{ns}$ | 62.00$^{e-m}$ | 99.60$^{b-i}$ | 39.60$^{ns}$ | 123.70$^{op}$ | 27.99$^{d-h}$ | 1673$^{l-n}$ | 25.50$^{a-e}$ |
| G46 | 6.90$^{ns}$ | 64.70$^{b-f}$ | 100.70$^{b-f}$ | 38.00$^{ns}$ | 131.00$^{m-o}$ | 27.72$^{e-h}$ | 1718$^{i-n}$ | 27.30$^{a-d}$ |
| G47 | 6.70$^{ns}$ | 61.40$^{f-m}$ | 97.60$^{c-i}$ | 38.20$^{ns}$ | 127.90$^{no}$ | 29.62$^{a-h}$ | 1899$^{h-m}$ | 26.90$^{a-e}$ |
| G48 | 6.90$^{ns}$ | 63.00$^{d-k}$ | 100.80$^{b-f}$ | 39.80$^{ns}$ | 117.20$^{p}$ | 30.82$^{a-f}$ | 1353$^{n-p}$ | 24.00$^{de}$ |
| G49 | 6.60$^{ns}$ | 66.20$^{a-d}$ | 101.90$^{a-d}$ | 37.70$^{ns}$ | 142.10$^{g-m}$ | 29.04$^{b-h}$ | 3278$^{a}$ | 26.30$^{a-e}$ |
| G5 | 6.50$^{ns}$ | 64.30$^{b-h}$ | 101.50$^{b-e}$ | 39.20$^{ns}$ | 163.30$^{a}$ | 26.82$^{h}$ | 2170$^{f-l}$ | 26.60$^{a-e}$ |
| G6 | 6.40$^{ns}$ | 61.40$^{f-m}$ | 96.60$^{f-i}$ | 37.20$^{ns}$ | 152.90$^{a-h}$ | 27.92$^{d-h}$ | 2732$^{b-e}$ | 26.70$^{a-e}$ |
| G7 | 6.00$^{ns}$ | 59.10$^{lm}$ | 94.80$^{i}$ | 37.70$^{ns}$ | 149.90$^{b-j}$ | 30.76$^{a-f}$ | 2650$^{b-f}$ | 24.60$^{cde}$ |
| G8 | 6.80$^{ns}$ | 65.50$^{a-e}$ | 102.50$^{abc}$ | 39.00$^{ns}$ | 147.80$^{d-j}$ | 28.25$^{c-h}$ | 735$^{q}$ | 24.70$^{b-e}$ |
| G9 | 7.00$^{ns}$ | 64.90$^{b-f}$ | 102.30$^{a-d}$ | 39.40$^{ns}$ | 144.70$^{f-l}$ | 26.79$^{h}$ | 858$^{q}$ | 27.60$^{abc}$ |
| Mean | 6.34 | 62.71 | 100 | 37.29 | 147.00 | 29.70 | 2184.00 | 26.25 |
| CV (%) | 11.20 | 5.40 | 4.40 | 10.00 | 7.80 | 10.90 | 20.40 | 16.60 |

DTE = Days to Emergence (days), DTF = Days to Flowering (days), DTM = Days to Maturity (days), PTH = Plant Height (cm), PL=Panicle Length (cm), GY = Grain Yield (kg ha$^{-1}$), TGW= Thousand Grain Weight (g), LS= Level of Significance, CV (%) = Coefficient of variation in percent

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

affected by the combined effect of both genotype and growing conditions of locations, whereas days to emergence and grain filling period were non-significant (Table 4). The mean day to emergence at Humera was faster than the four locations.

This might be due to the amount and occurrence of rain fain and temperature at the time of plantation. The major environmental factors that affect germination of sorghum genotypes are temperature (including soil temperature), moisture and soil texture [23]. There was a variation among means of grain filling period of genotypes in the four locations. The grand mean grain filling period of locations was 39 days, Humera and Kobo were the two locations that had faster grain filling period than the rest three locations. At Humera, genotypes filled their grains at a faster period than the genotypes in the other locations.

## Grain yield

The mean grain yield obtained by the genotypes at the five locations was 2184 kg ha$^{-1}$ as shown in Table 4. The standard hybrid check ESH-1(G49) and K7252 (G29) produced higher mean grain yield with yield of 3278 and 3051 kg ha$^{-1}$ respectively, whereas, G8 (5136) had the lowest mean grain yield with 735 kg ha$^{-1}$. However, the newly evaluated hybrids had not shown yield advantage over the standard hybrid check. In disagreement with this study, many researchers [15,23-27] reported that tested varieties/ hybrids showed better performance than the best check for most of yield and other traits in sorghum.

## Days to flowering and maturity

Days to flowering of the genotypes ranged between 58 to 69 days and the mean days to flowering obtained was 63 days as shown in Table 4. The smallest days to flowering was recorded by genotype 7270 (G39) while G14 (5160) had recorded shorter days to flowering. The genotype K7445 (G7) had shorter days (95) to 90% maturity, whereas, the longest days to maturity (106) was recorded for genotype 5152 (G10).

## Plant height and panicle length

The genotype with the tallest plant height was K7438 (G5) followed by K7235 (G21) with 163.28 and 162.3 cm, whereas the hybrid check, ESH-4 (G48) recorded the shortest plant height (117.22 cm). The genotype with tallest panicle length was K7276 (G42) with 32.81 cm, whereas, the shortest was G9 (5151) with 26.79 cm and the difference with the other hybrids was significant at P≤ 0.05 (Table 4).

## Thousand grain weight

The average thousand grain weight (TGW) of the genotypes was 26.25g. The genotype with the maximum (28.3g) TGW was G19 (K7233) while genotype G4 (K7437) recoreded minimum (23.7g).

## Correlation coefficient among traits

Grain yield is the most complex trait and it is influenced by genetic and environmental factors that determine productivity of the genotypes. Therefore, understanding of interrelationships of grain yield and other traits are highly important for formulating selection.

The Pearson Correlation coefficient between grain yield and other agronomic traits revealed that grain yield had very highly significant (P≤ 0.001) positive correlation with plant height (r = 0.723), panicle length (r = 0.631) and thousand grain weight (r = 0.762) (Table 5). The result agreed with findings of Abdel, et al. [28] and Nada, et al. [29] who found highly significant and positive correlation of grain yield with panicle length and thousand grain weight.

Similarly, thousand grain weight had highly significant (P≤ 0.001) positive correlation with plant height (r = 0.634) and panicle length (r = 0.525). This confirmed the fact that better plant biomass can contribute for increased grain size due the advantage of having better assimilate to store in the sink. This result was in line with previous work reported by Yang, et al. (2010). Conversely, days to maturity had not correlated with grain yield; this could be related to the low variability of the test hybrids for the trait.

Earliness is a very important trait under low- rainfall conditions. The trait having the most dominant effect on fitting a plant to its environment for maximum productivity is the appropriate phenological development [30]. Conforming to the association among grain yield and other measured traits, the association between grain yield and days to flowering was strongly negative (r = -0.580) and highly significant (P≤ 0.001) while days to maturity was weakly negativly correlated with

**Table 4:** Mean squares of yield and other traits from combined analysis of variance of 49 sorghum genotypes grown at five locations in 2016 cropping season.

| Source | DF | DTE | DTF | DTM | GFP | PHT | PL | GY | TGW |
|---|---|---|---|---|---|---|---|---|---|
| Rep/en | 5 | 1.218 | 48.09 | 172.2 | 107.66 | 759 | 190.5 | 588556 | 89.1 |
| E | 4 | 33.814 | 106.17 | 978.3 | 491.14 | 34491 | 908.6 | 291949204 | 3648.9 |
| G | 48 | 1.314 | 52.79 | 46 | 18.57 | 1064 | 19.7 | 3581005 | 12.7 |
| GEI | 192 | 0.385$^{ns}$ | 17.12** | 21.6** | 19.20$^{ns}$ | 268*** | 8.9* | 1011598*** | 11.5* |
| Error | 240 | 0.502 | 11.08 | 15.5 | 15.87 | 127 | 6.7 | 243164 | 7.8 |
| Mean | | 6.34 | 62.71 | 100 | 37.29 | 147 | 29.70 | 2184 | 26.25 |
| CV (%) | | 11.2 | 5.9 | 4.4 | 10 | 7.8 | 10.9 | 20.4 | 11.6 |

*, **,*** = significant at P≤ 0.05, P≤ 0.01 and P≤ 0.001, respectively, Rep/en= Replication within environment, E= Environment, G= Genotype, GEI= Genotype by Environment Interaction, DF = Degree of Freedom, DTE = Days to Emergence (days), DTF = Days to Flowering (days), DTM = Days to Maturity (days), PTH = Plant Height (cm), PL= Panicle Length (cm), GY = Grain Yield (kg ha-1), TGW= Thousand Grain Weight (g), CV (%) = Coefficient of variation in percent

grain yield; $r = -0.095$ and non-significant. But, the association between days to maturity and days to flowering was positive ($r = 0.773$) and highly significant ($P \leq 0.001$).

The negative association between grain yield with days to flowering and maturity indicated that moisture stress after flowering might have caused a yield reduction in the late maturing genotypes, whereas, the early flowering and early maturing genotypes had the advantage to filled grain early and escaped the moisture stress conditions. Similar results were reported by Kassahun, et al. [24], Taye, et al. [16] on sorghum; Assefa, et al. [31] in wheat and Yirga [32] in sesame.

## Yield stability analysis

The following univariate stability analysis were performed for grain yield (kg/ha).

## Eberhart and Russell's linear regression model

The analysis of variance by Eberhart and Russel's Model of *striga* resistant sorghum hybrids on mean grain yield (kg $ha^{-1}$) tested at five locations is presented in Table 6. Genotype x environment interaction ANOVA of joint linear regression model is used for estimation and partitioning of genotype by environment interaction in to components. Hence, it permitted the partitioning of the sources of variation in to environment (linear), G x L (linear) interaction effects (sum of squares due to regression, bi) and unexplained deviation from linear regression (pooled deviation mean squares ($S^2di$). The genotype regressions term was tested for significance using an F-ratio by taking the deviations from regressions mean square as the error term.

The deviations from regressions mean square were tested for significance using the error term for overall GEI in the ANOVA. The result of Eberhart and Russell's ANOVA revealed highly significant ($P \leq 0.01$) difference among the genotypes for grain yield indicating the yield performance of genotypes was significantly different. The GE (linear) interaction was significant. Thus, the GE interaction was linear type and shows the existence of genetic differences among genotypes for their response to various locations.

The stability parameters of Eberhart and Russell [20] model for grain yield of *striga* resistant sorghum genotypes tested at five locations is presented in Table 7. According to this model, the genotype's performance is expressed in terms of three parameters, mean yield, regression coefficient and the deviation from the regression. Therefore, a stable genotype is one with high mean yield, bi=1, and $S^2di$ not significantly different from zero. Based on these three preconditions, G6, G38, G27, G41 and G43 had relatively high yield, near to unity regression coefficient (bi) and deviation from regression ($S^2di$) not significantly different from zero and considered as stable genotypes, while G49, G29, G20, G21, G40, G4, G1, G24, G16, G22, G7, G18, G28, G34, G36, G19, G25 and G32 had greater than unity estimated value (bi >1); suitable for high potential environments and considered as unstable genotypes for grain yield.

The stability analysis of variance revealed highly significant ($P \leq 0.01$) difference between genotypes, suggesting that there was considerable differential performance of the genotypes; this result was in line with Mekonen, et al. (2015) on sesame and Lalise (2015) on maize. The GEI (linear) interaction of grain yield (kg $ha^{-1}$) was highly significant ($P \leq 0.01$), indicating that the stability parameter (bi) estimated by linear response to change in environment was different for all genotypes or genotypes had different slopes (Table 7). This confirms that GEI was in a linear function of environment indices as the mean of all the genotypes tested.

Coefficient of determination ($r^2$) represents the predictability of estimated response of the genotypes. The values of coefficient of determination ranged between 0.5662 for G14 and 0.9999 for G34, suggesting that linear regression accounted from 56.62% to 99.99%. This result showed that the variation in sorghum mean grain yield was explained by genotype response across the testing environments, which is in agreement with the previous findings of Showemimo [33] in sorghum. Except one genotype (G14), all genotypes showed high coefficient of determination. However, seventeen out of 49 genotypes had yielded below average. Hence the interest of plant breeder is to develop genotypes with highest mean yield and which can be overcome by both predictable and unpredictable environment fluctuations.

## AMMI stability value

The result for stability analysis of genotypes using AMMI stability value (ASV) is given in Table 8. This stability analysis was based on the value of the first two IPCA scores of genotypes. According to this stability measure, the highest rank is given to the genotype that is close to the biplot origin, *i.e*, genotype that

**Table 5:** Correlation coefficients among some agronomic traits of 49 sorghum genotypes evaluated at five locations in Ethiopia in 2016 growing season.

| | | DTF | DTM | GY | PHT | PL | TGW |
|---|---|---|---|---|---|---|---|
| | DTF | 1 | | | | | |
| | DTM | 0.773*** | 1 | | | | |
| | GY | -0.580*** | -0.095$^{ns}$ | 1 | | | |
| | PHT | -0.369$^{ns}$ | -0.068$^{ns}$ | 0.723*** | 1 | | |
| | PL | -0.049$^{ns}$ | 0.054$^{ns}$ | 0.631*** | 0.461*** | 1 | |
| | TGW | -0.061$^{ns}$ | 0.034$^{ns}$ | 0.762*** | 0.634*** | 0.525*** | 1 |

*, **,*** = significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively, ns = non-significant, DTF = Days to Flowering (days), DTM = Days to Maturity (days), PTH = Plant Height (cm), PL=Panicle Length (cm), GY = Grain Yield (kg ha-1), TGW= Thousand Grain Weight (g)

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

**Table 6:** Analysis of variance by Eberhart and Russel's Model of striga resistant sorghum hybrids on mean grain yield (kg $ha^{-1}$) tested at five locations.

| Source of Variation | Df | Sum squares | Mean squares |
|---|---|---|---|
| Total | 244 | 767110004.9 | |
| Genotype | 48 | 85921925.17 | 1790040.11** |
| Loc. + (Gen. x Loc.) | 196 | 681188079.7 | 4633932.52** |
| Location (Linear) | 1 | 584058035.5 | 3973183.92** |
| Genotype x Location (Linear) | 48 | 58690982.96 | 1222728.81* |
| Pooled Deviation | 147 | 38439061.23 | 261490.21** |
| Genotype 1 | 3 | 574234.85 | 3906.36$^{ns}$ |
| Genotype 2 | 3 | 745988.28 | 248662.76* |
| Genotype 3 | 3 | 82574.58 | 27524.86$^{ns}$ |
| Genotype 4 | 3 | 2039112.33 | 679704.11** |
| Genotype 5 | 3 | 280858.64 | 93619.55$^{ns}$ |
| Genotype 6 | 3 | 655330.16 | 218443.39$^{ns}$ |
| Genotype 7 | 3 | 2132838.04 | 710946.01** |
| Genotype 8 | 3 | 153588.24 | 51196.08$^{ns}$ |
| Genotype 9 | 3 | 298582.15 | 99527.38$^{ns}$ |
| Genotype 10 | 3 | 110057.4 | 36685.8$^{ns}$ |
| Genotype 11 | 3 | 192264.15 | 64088.05$^{ns}$ |
| Genotype 12 | 3 | 292077.43 | 97359.14$^{ns}$ |
| Genotype 13 | 3 | 338435.85 | 112811.95$^{ns}$ |
| Genotype 14 | 3 | 936612.6 | 312204.2* |
| Genotype 15 | 3 | 2484781.66 | 828260.55** |
| Genotype 16 | 3 | 1011722.76 | 337240.92* |
| Genotype 17 | 3 | 199982.32 | 66660.77$^{ns}$ |
| Genotype 18 | 3 | 485531.3 | 161843.77$^{ns}$ |
| Genotype 19 | 3 | 1904662.13 | 634887.38** |
| Genotype 20 | 3 | 1187239.31 | 395746.44* |
| Genotype 21 | 3 | 318954.6 | 106318.2$^{ns}$ |
| Genotype 22 | 3 | 122671.89 | 40890.63$^{ns}$ |
| Genotype 23 | 3 | 4589.43 | 1529.81$^{ns}$ |
| Genotype 24 | 3 | 500019.4 | 166673.13$^{ns}$ |
| Genotype 25 | 3 | 1805630.09 | 601876.7** |
| Genotype 26 | 3 | 426170.18 | 142056.73$^{ns}$ |
| Genotype 27 | 3 | 636304.8 | 212101.6$^{ns}$ |
| Genotype 28 | 3 | 1637767.97 | 545922.66** |
| Genotype 29 | 3 | 238823.6 | 79607.87$^{ns}$ |
| Genotype 30 | 3 | 894564.386 | 298188.13* |
| Genotype 31 | 3 | 262716.58 | 87572.19$^{ns}$ |
| Genotype 32 | 3 | 989206.13 | 329735.38* |
| Genotype 33 | 3 | 780329.85 | 260109.95* |
| Genotype 34 | 3 | 2598.09 | 866.03$^{ns}$ |
| Genotype 35 | 3 | 435852.6 | 145284.2$^{ns}$ |
| Genotype 36 | 3 | 253606.44 | 84535.48$^{ns}$ |
| Genotype 37 | 3 | 121610.96 | 40536.99$^{ns}$ |
| Genotype 38 | 3 | 568151.998 | 189383.999$^{ns}$ |
| Genotype 39 | 3 | 119152.27 | 39717.424$^{ns}$ |
| Genotype 40 | 3 | 3030245.77 | 1010081.925** |
| Genotype 41 | 3 | 172749.24 | 57583.08$^{ns}$ |
| Genotype 42 | 3 | 1303019.87 | 434339.96* |
| Genotype 43 | 3 | 304362.1 | 101454.034$^{ns}$ |
| Genotype 44 | 3 | 963541.65 | 321180.55* |
| Genotype 45 | 3 | 1078479.7 | 359493.23* |
| Genotype 46 | 3 | 927793.17 | 309264.39* |
| Genotype 47 | 3 | 745636.08 | 248545.36* |
| Genotype 48 | 3 | 1402267.99 | 467422.66** |
| Genotype 49 | 3 | 2285770.2 | 761923.42** |
| Pooled Error | 245 | 24270710.75 | 99064.13 |

*, ** = significant at $P \leq 0.05$ and $P \leq 0.01$, respectively, ns = non-significant

has the smallest ASV (ASV value closest to zero). Accordingly, G6 (K7439) was found to be the most stable genotype, followed by G28 (K7251), G39 (K7270), G41 (K7274), G26 (K7245), G38 (K7268), G32 (K7259), G27 (K7249), G2 (K7417), G42 (K7276), G47(P9403) and G15 (K7229) using this method. The procedure also identified G8 (5136), G11 (5153), G9 (5151), G13 (5156), G37 (K7267) and G10 (5152) as the most unstable genotypes (genotypes with inconsistent performance) across the test environments.

Stability studies have allowed researchers to identify broadly adapted cultivar for use in breeding programs and have assisted to advance suggestions to farmers [34]. The most stable and adapted genotypes can be identified using ASV as that of Lins and Binns method. Almeida, et al. [35], Vange, et al. [36], Abiy [23] and Zigale [37] also used this stability parameter to characterize the stability of sorghum.

### Yield stability index

Genotypes with lowest estimated values of yield stability index (YSI) are desirable and considered as the most stable. Based on YSI, G6, G38, G27, G41 and G43 were the most stable. Conversely, G8, G9, G10, G11 and G14 were the most unstable genotpes (Table 8). Harmoniously, Showemimo ) [33] in sorghum; Olayiwola and Ariyo [38] in okra, Mohammed [39] and Yirga [40] in sesame used this model to identify stable genotypes.

### Relationship of stability parameters

The result of spearman's rank correlation coefficient presented in Table 9 showed that mean grain yield was positively and highly significantly ($P \leq 0.01$) correlated with bi ($r= 0.91$), $r^2$ ($r= 0.55$) and negatively and highly significantly ($P \leq 0.01$) correlated with IPCA1 ($r= -0.91$) and ASV ($r= -0.56$). This result is in line with the findings of Solomon, et al. [41] and Lalise [42] on maize. However, there was no significant correlation between mean grain yield with Eberhart and Rusell's deviation from regression ($S^2di$) ($r=0.269$) stability parameter and IPCA2 ($r= -0.10$).

The non-significant correlation among yield and stability statistics indicated that, stability statistics provide information that cannot be collected from average yield alone. The high correlation among mean grain yield, bi, and $r^2$ is expected as the values of these statistics were higher for high yielding genotypes. The positive and significant correlations between mean grain yield and $r^2$, and bi and $r^2$ suggest that the parameter, $r^2$ should be considered only in measuring dimensions of grain yield, but could not adequately detect stability and, hence, its efficiency in selecting desirable genotypes is limited when used alone. The same suggestion was given by Setegn and Habtu [43], Nigussie [44-51]. The negative correlation between grain yield and $S^2di$ indicated that high yielding genotypes may be associated with low $S^2di$.

## Conclusion

Combined analysis of variance revealed significant ($P \leq 0.001$) variations of genotypes, environments and GEI, suggesting

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

**Table 7:** Estimates of stability parameters and their ranking order for mean yield (kg ha-1), regression coefficient (bi), deviation from regression (S$^2$di) and coefficient of determination of 49 sorghum genotypes evaluated at five locations.

| Genotypes | Bi | Rank | S$^2$di | Rank | r$^2$ | Gy | Rank |
|---|---|---|---|---|---|---|---|
| G1 | 1.278** | 41 | 69814.4$^{ns}$ | 18 | 0.9713 | 2692 | 8 |
| G10 | 0.3324** | 5 | -62378$^{ns}$ | 23 | 0.923 | 1000 | 45 |
| G11 | 0.4962** | 6 | -34976$^{ns}$ | 15 | 0.9386 | 932 | 46 |
| G12 | 0.5642** | 7 | -1705$^{ns}$ | 7 | 0.9285 | 1561 | 42 |
| G13 | 0.3205** | 3 | -8861.9$^{ns}$ | 1 | 0.7835 | 1159 | 44 |
| G14 | 0.3203* | 2 | 190574$^{*}$ | 34 | 0.5662 | 838 | 48 |
| G15 | 0.9493** | 17 | 706649$^{*}$ | 48 | 0.8121 | 2249 | 29 |
| G16 | 1.1127** | 30 | 215819$^{*}$ | 37 | 0.9358 | 2658 | 10 |
| G17 | 1.1526** | 32 | -32403$^{ns}$ | 14 | 0.9875 | 2251 | 28 |
| G18 | 1.0892** | 26 | 40121.2$^{ns}$ | 11 | 0.9668 | 2623 | 13 |
| G19 | 1.380** | 46 | 513064$^{**}$ | 44 | 0.9226 | 2456 | 17 |
| G2 | 0.8648** | 13 | 127012$^{ns}$ | 29 | 0.9228 | 1898 | 39 |
| G20 | 1.3008** | 42 | 274409$^{*}$ | 39 | 0.9444 | 2894 | 3 |
| G21 | 1.3243** | 44 | 7254.07$^{ns}$ | 2 | 0.9849 | 2828 | 4 |
| G22 | 1.3354** | 45 | -58174$^{ns}$ | 20 | 0.9942 | 2652 | 11 |
| G23 | 1.1026** | 27 | -97534$^{ns}$ | 27 | 0.9997 | 2175 | 34 |
| G24 | 1.2586** | 39 | 45370.8$^{ns}$ | 13 | 0.9742 | 2679 | 9 |
| G25 | 1.0882** | 25 | 479635$^{**}$ | 43 | 0.8867 | 2410 | 18 |
| G26 | 1.0285** | 22 | 20318.4$^{ns}$ | 4 | 0.9673 | 2274 | 26 |
| G27 | 0.9736** | 18 | 90294.4$^{ns}$ | 24 | 0.9467 | 2303 | 25 |
| G28 | 1.0458** | 24 | 424360$^{*}$ | 42 | 0.8884 | 2567 | 14 |
| G29 | 1.3915** | 48 | -19456$^{ns}$ | 12 | 0.9897 | 3051 | 2 |
| G3 | 1.1629** | 33 | -71539$^{ns}$ | 25 | 0.9949 | 2244 | 30 |
| G30 | 1.1801** | 35 | 176483$^{*}$ | 32 | 0.9489 | 2200 | 31 |
| G31 | 1.0404** | 23 | -11492$^{ns}$ | 9 | 0.98 | 2197 | 32 |
| G32 | 1.1108** | 29 | 208124$^{*}$ | 36 | 0.937 | 2377 | 19 |
| G33 | 1.2262** | 37 | 138334$^{ns}$ | 31 | 0.9583 | 2172 | 35 |
| G34 | 1.3838** | 47 | -98198$^{ns}$ | 28 | 0.9999 | 2510 | 15 |
| G35 | 0.7411** | 9 | 23898$^{ns}$ | 6 | 0.9375 | 2040 | 37 |
| G36 | 1.1271** | 31 | -14529$^{ns}$ | 10 | 0.9835 | 2458 | 16 |
| G37 | 1.2686** | 40 | -58527$^{ns}$ | 21 | 0.9937 | 2179 | 33 |
| G38 | 0.9393** | 16 | 67880.1$^{ns}$ | 17 | 0.9487 | 2305 | 24 |
| G39 | 1.0119** | 21 | -59347$^{ns}$ | 22 | 0.9903 | 2374 | 20 |
| G4 | 1.1101** | 28 | 558497$^{*}$ | 45 | 0.878 | 2713 | 7 |
| G40 | 1.3072** | 43 | 888764$^{**}$ | 49 | 0.8704 | 2726 | 6 |
| G41 | 0.990** | 19 | -41481$^{ns}$ | 16 | 0.9855 | 2354 | 21 |
| G42 | 1.1801** | 36 | 312688$^{*}$ | 40 | 0.9272 | 2258 | 27 |
| G43 | 0.8432** | 12 | -20131$^{ns}$ | 3 | 0.9653 | 2321 | 23 |
| G44 | 1.2326** | 38 | 199506$^{*}$ | 35 | 0.9495 | 2352 | 22 |
| G45 | 0.6110** | 8 | 237934$^{*}$ | 38 | 0.8049 | 1673 | 41 |
| G46 | 0.7782** | 10 | 187638$^{*}$ | 33 | 0.8861 | 1718 | 40 |
| G47 | 0.9327** | 15 | 127042$^{ns}$ | 30 | 0.9329 | 1899 | 38 |
| G48 | 0.8172** | 11 | 345709$^{*}$ | 41 | 0.8502 | 1353 | 43 |
| G49 | 1.6388** | 49 | 640592$^{**}$ | 47 | 0.9333 | 3278 | 1 |
| G5 | 0.8689** | 14 | -5444.6$^{ns}$ | 8 | 0.9698 | 2170 | 36 |
| G6 | 0.9927** | 20 | 96744.7$^{ns}$ | 26 | 0.9472 | 2732 | 5 |
| G7 | 1.1639** | 34 | 589528$^{*}$ | 46 | 0.8833 | 2650 | 12 |
| G8 | 0.3237** | 4 | -47868$^{ns}$ | 19 | 0.8905 | 735 | 49 |
| G9 | 0.3085** | 1 | 463.27$^{ns}$ | 5 | 0.7916 | 858 | 47 |

*, ** = significant at P≤ 0.05 and P≤ 0.01, respectively, ns = non-significant, bi= regression coefficient and S$^2$di= deviation from regression, r$^2$= coefficient of determination

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

**Table 8:** Mean yield (kg $ha^{-1}$), rank, IPCA1 and IPCA2 scores and AMMI stability values (ASV) of 49 sorghum genotypes tested at five environments of Ethiopia during 2016.

| Gen | Yield | $R^y$ | IPCA1 | IPCA2 | ASV | $R^a$ | YSI ($R^y$+ $R^a$) | R |
|---|---|---|---|---|---|---|---|---|
| G1 | 2692 | 8 | -0.43486 | -0.27657 | 0.545 | 30 | 38 | 17 |
| G10 | 1000 | 45 | 0.918905 | -0.27442 | 1.682 | 44 | 89 | 45 |
| G11 | 932 | 46 | 0.724628 | -0.0436 | 2.954 | 48 | 94 | 47 |
| G12 | 1561 | 42 | 0.571187 | -0.37671 | 0.703 | 35 | 77 | 41 |
| G13 | 1159 | 44 | 0.948248 | -0.27019 | 1.776 | 46 | 90 | 46 |
| G14 | 838 | 48 | 0.873606 | -0.6576 | 1.007 | 39 | 87 | 44 |
| G15 | 2249 | 29 | 0.192897 | 0.705534 | 0.1007 | 12 | 41 | 20 |
| G16 | 2658 | 10 | -0.18914 | -0.23394 | 0.17 | 19 | 29 | 7 |
| G17 | 2251 | 28 | -0.23203 | -0.00678 | 1.358 | 41 | 69 | 39 |
| G18 | 2623 | 13 | -0.15679 | -0.21299 | 0.135 | 16 | 29 | 8 |
| G19 | 2456 | 17 | -0.41929 | 0.757454 | 0.32 | 25 | 42 | 21 |
| G2 | 1898 | 39 | 0.127688 | -0.44776 | 0.068 | 9 | 48 | 30 |
| G20 | 2894 | 3 | -0.50753 | -0.40521 | 0.568 | 31 | 34 | 13 |
| G21 | 2828 | 4 | -0.45226 | 0.15598 | 0.77 | 36 | 40 | 18 |
| G22 | 2652 | 11 | -0.45319 | 0.194041 | 0.693 | 34 | 45 | 25 |
| G23 | 2175 | 34 | -0.13771 | 0.061383 | 0.206 | 21 | 55 | 33 |
| G24 | 2679 | 9 | -0.4133 | -0.20336 | 0.589 | 33 | 42 | 22 |
| G25 | 2410 | 18 | -0.22022 | -0.62553 | 0.131 | 15 | 33 | 11 |
| G26 | 2274 | 26 | -0.05949 | -0.24029 | 0.03 | 5 | 31 | 10 |
| G27 | 2303 | 25 | 0.105713 | 0.331416 | 0.06 | 8 | 33 | 12 |
| G28 | 2567 | 14 | 0.0326 | 0.632006 | 0.007 | 2 | 16 | 2 |
| G29 | 3051 | 2 | -0.56516 | 0.084624 | 1.461 | 43 | 45 | 26 |
| G3 | 2244 | 30 | -0.24005 | -0.05747 | 0.491 | 28 | 58 | 35 |
| G30 | 2200 | 31 | -0.1721 | 0.40828 | 0.112 | 14 | 45 | 27 |
| G31 | 2197 | 32 | -0.0736 | 0.032812 | 0.11 | 13 | 45 | 28 |
| G32 | 2377 | 19 | -0.10665 | 0.41107 | 0.054 | 7 | 26 | 5 |
| G33 | 2172 | 35 | -0.23138 | 0.482005 | 0.16 | 17 | 52 | 32 |
| G34 | 2510 | 15 | -0.52739 | 0.123366 | 1.09 | 40 | 55 | 34 |
| G35 | 2040 | 37 | 0.360673 | 0.064443 | 0.853 | 38 | 75 | 40 |
| G36 | 2458 | 16 | -0.20918 | -0.04593 | 0.446 | 27 | 43 | 23 |
| G37 | 2179 | 33 | -0.36537 | 0.015762 | 1.759 | 45 | 78 | 42 |
| G38 | 2305 | 24 | 0.046851 | -0.11245 | 0.03 | 6 | 30 | 9 |
| G39 | 2374 | 20 | -0.04575 | -0.11307 | 0.029 | 3 | 23 | 3 |
| G4 | 2713 | 7 | -0.1944 | -0.24062 | 0.175 | 20 | 27 | 6 |
| G40 | 2726 | 6 | -0.5678 | -0.66397 | 0.525 | 29 | 35 | 14 |
| G41 | 2354 | 21 | 0.02126 | -0.01097 | 0.029 | 4 | 25 | 4 |
| G42 | 2258 | 27 | -0.16702 | 0.596513 | 0.088 | 10 | 37 | 16 |
| G43 | 2321 | 23 | 0.189446 | -0.14471 | 0.217 | 22 | 45 | 29 |
| G44 | 2352 | 22 | -0.24585 | 0.544461 | 0.165 | 18 | 40 | 19 |
| G45 | 1673 | 41 | 0.605294 | 0.373869 | 0.77 | 37 | 78 | 43 |
| G46 | 1718 | 40 | 0.377955 | 0.396967 | 0.369 | 26 | 66 | 36 |
| G47 | 1899 | 38 | 0.149284 | 0.374734 | 0.094 | 11 | 49 | 31 |
| G48 | 1353 | 43 | 0.348024 | 0.508453 | 0.288 | 24 | 67 | 37 |
| G49 | 3278 | 1 | -1 | -0.5198 | 1.387 | 42 | 43 | 24 |
| G5 | 2170 | 36 | 0.214792 | 0.029762 | 0.577 | 32 | 68 | 38 |
| G6 | 2732 | 5 | -0.01311 | -0.28803 | 0.003 | 1 | 6 | 1 |
| G7 | 2650 | 12 | -0.33157 | -0.63343 | 0.24 | 23 | 35 | 15 |
| G8 | 735 | 49 | 0.95511 | -0.03313 | 5.128 | 49 | 98 | 49 |
| G9 | 858 | 47 | 0.968017 | -0.14643 | 2.489 | 47 | 94 | 48 |

$R^a$ = Rank by ASV, $R^y$ = Rank by Grain Yield, YSI = Yield Stability Index

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

**Table 9:** The Spearman's rank correlation for all estimates of stability parameter.

| | Gy | bi | $S^2di$ | $r^2$ | IPCA1 | IPCA2 | ASV |
|---|---|---|---|---|---|---|---|
| Gy | 1 | | | | | | |
| Bi | 0.91** | 1 | | | | | |
| $S^2di$ | $0.269^{ns}$ | $0.132^{ns}$ | 1 | | | | |
| $r^2$ | 0.55** | 0.495** | -0.40* | 1 | | | |
| IPCA1 | -0.92** | -0.99** | $-0.126^{ns}$ | -0.57** | 1 | | |
| IPCA2 | $-0.160^{ns}$ | $0.117^{ns}$ | $-0.011^{ns}$ | $0.138^{ns}$ | $-0.035^{ns}$ | 1 | |
| ASV | -0.56** | -0.46** | $-0.29^{ns}$ | $-0.05^{ns}$ | 0.44** | $-0.192^{ns}$ | 1 |

*, ** = significant at P≤ 0.05 and P≤ 0.01, respectively, ns= non-significant; bi = Eberhart and Russell's regression coefficient; $S^2di$ = Eberhart and Russell [45] deviation from regression coefficient, ASV=AMMI stability value, $r^2$ = Coefficient of determination.

the high environmental variations and differential response of genotypes to the variable environments thus leading to inconsistent in ranking of genotypes. The mean grain yield of environments ranged from 588 kg $ha^{-1}$ in E1 (Humera) to 4508 kg $ha^{-1}$ in E5 (Sheraro).The highest yield was obtained from G49 (3278 kg $ha^{-1}$), while the lowest was from G8 (735 kg $ha^{-1}$). The large sum of square and highly significant environment effect indicated that the environments were diverse and caused most of the variation in grain yield. Therefore the largest proportion of the total variation in grain yield was attributed to environments. This indicates the existence of a considerable amount of differential response among the genotypes to the changes of growing environments and the differential discriminating ability of the test environments.

Different stability models were used in measuring of genotype stability such as AMMI Stability Value (ASV), Yield Stability Index (YSI), coefficient of regression (bi) and deviation from regression ($S^2di$). Yield was significantly correlated with bi (0.91), $r^2$ (0.55) and ASV (-0.56), while it was not correlated with $S^2di$ (-0.26). The non-significant correlation among yield and stability statistics indicated that, stability statistics provide information that cannot be collected from average yield. The high positive correlation among mean grain yield and stability parameters is expected as the values of these parameters were higher for high yielding genotypes and the vice versa. Highly correlated stability parameters indicate that they can measure stability similarly.

There were inconsistencies with the univariate stability parameters used, which created uncertainty to select or recommend the stable genotypes. The main problem of selection of superior genotypes in Ethiopia is the unpredictable weather changes from year to year and the variations of agro-ecologies leading to high contributor to genotype x environment interactions. Since the current study was conducted only for one year, the work should be repeated at least for some more years to give sound conclusions and reliable recommendations.

## Acknowledgments

The authors acknowledge financial support by Tigray Agriculture Research Institute (TARI) in collaboration with Integrated Striga Control Project. We are grateful to the National Sorghum Breeding Program of Ethiopia in partnership with the US Principal Investigator (Prof. Gebisa Ejeta) for the research facilities and supplying germplasm (breeding materials) used in the study.

## References

1. Poehlman JM, Sleper DA (1995) Breeding Field Crops, 4th eds. Oxford and IBM pub.Co. New Delhi, India 494.**Link:** https://bit.ly/36mtoZN
2. Kumar AA, Reddy BVS, Sharma HC, Hash CT, Rao PS, et al. (2011) Recent advances in sorghum genetic enhancement research at ICRISAT. American Journal of Plant Sciences 2: 589-600. **Link:** https://bit.ly/3xwoCF0
3. CSA (Central Statistical Agency) (2016) Agricultural Sample Survey report on Area and Production of Major Crops (Private Peasant Holdings 'Meher' Season): Statistical Bulletin 584. Addis Ababa, Ethiopia.
4. Wortmann CS, Mamo M, Abebe G, Mburu C, Kayuki KC, et al. (2006) The Atlas of Sorghum Production in Five Countries of Eastern Africa University of Nebraska, Lincoln, USA.
5. AATF [African Agricultural Technology Foundation] (2011) Feasibility Study on Striga Control in Sorghum. Nirobi, African Agricultural Technology Foundation. **Link:** https://bit.ly/3wqvClz
6. Tadesse T, Tesso T, Ejeta G (2008) Combining ability of introduced sorghum parental lines for major morpho-agronomic traits. Journal of SAT Agricultural research 6: 7-9. **Link:** https://bit.ly/3hPOAwS
7. Omanya GO, Haussmann BIG, Hess DE, Reddy BVS, Kayentao M, et al. (2004) Utility of indirect and direct selection traits for improving Striga resistant in two sorghum recombinant inbred populations. Field Crops Research 89: 237-252. **Link:** https://bit.ly/3xz7Ipq
8. Rodenburg J, Bastiaanms L, Weltzien E, Hess DE (2005) How can field selection for Striga resistant and tolerance in sorghum be improved?. Field Crops Research 93: 34-50. **Link:** https://bit.ly/36wcs33
9. Abate M, Mekbib F, Hussien T, Bayu W, Reda F (2014) Assessment of genetic diversity in sorghum (Sorghum bicolor (L.) Moench) for reaction to Striga hermonthica (Del.) Benth. Australian Journal of Crop Sciences 8: 1248-1256. **Link:** https://bit.ly/3huJo2c
10. Atokple IDK (2003) Sorghum and millet breeding in West Africa in practice. CSIR, Savanna Agricultural Research Institute,Tamale, Ghana 137-148.
11. Bidinger FR, Raj B, Nugusse AM, Obilana AB, Jones RB (2005) Top cross hybrids as entry point into commercial seed production of pearl millet in Eastern Africa. Experimental Agriculture 41: 335-356. **Link:** https://bit.ly/3e2LNiD
12. Toure A, Rattunde F, VomBrocke K, Weltzien E, Sansan D, et al. (2007) Guinea-race sorghum hybrids: a new approach for increasing yield of staple crop of West Africa.
13. Axtell J, Kapran I, Ibrahim Y, Ejeta G, Andrews DJ (1999) Heterosis in sorghum

and pearl millet. In: Proceeding of the genetic and exploitation of heterosis in crops. Euphytica 375-386. **Link:** https://bit.ly/3AMl7fW

14. House LR (1995) Sorghum: one of the world great cereals. African Crop Science Journal 3: 135-142. **Link:** https://bit.ly/3wsVYUe
15. Tefera H, Dahlberg J, Smale M (2012) External Evaluation Report on the Sorghum, Millet and Other Grains (SMOG)/INTSORMIL Collaborative Research Support Program (CRSP). International Institute of Tropical Agriculture. **Link:** https://bit.ly/3qXSOGC
16. Tadesse T, Mace ES, Godwin ID, Jordan DR (2016) Heterosis in locally adapted sorghum genotypes and potential of hybrids for increased productivity in contrasting environments in Ethiopia. Crop Journal 4: 479–489. **Link:** https://bit.ly/3e0d7y3
17. Xin Z, Gitz D, Burow G, Hayes C, Burke JJ (2015) Registration of two allelic erect leaf mutants of sorghum. Journal of Plant Registration 9: 254–257. **Link:** https://bit.ly/3wu2p9i
18. Menkir A, Makumbi D, Franco J (2012) Assessment of Reaction Patterns of Hybrids to Striga hermonthica (Del.) Benth under Artificial Infestation in Kenya and Nigeria. Crop Science 52: 2528–2537. **Link:** https://bit.ly/3AHXZit
19. Steel RG, Torrie JH (1980) Principles and procedures of statistics. McGraw-Hill, New York.
20. Eberhart S, Russell W (1966) Stability parameters for comparing varieties. Crop Science 6: 36-40. **Link:** https://bit.ly/36odgqL
21. Purchase JL (1997) Parametric analysis to describe genotype by environment interaction and stability in winter wheat. PhD Thesis. Department of Agronomy, Faculty of Agriculture, University of the Orange Free State, Bloem fonten, South Africa.
22. Farshadfar E, Vaisi Z, Yaghotipoor A (2011) Non parametric estimation of phenotypic stability in Wheat-barley disomic addition lines. Annals of Biological Research 2: 586-598. **Link:** https://bit.ly/36oNSRP
23. Legese A (2015) Genotype x Environment Interaction and Stability of Early Maturing Sorghum [Sorghum bicolor (L.) Moench] Genotypes in Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
24. Amare K, Zeleke H, Bultosa G (2015) Variability for yield, yield related traits and association among traits of sorghum [Sorghum bicolor (L.) Moench] varieties in Wollo, Ethiopia. Journal of Plant Breeding and Crop Science 7: 125-133. **Link:** https://bit.ly/3xtUQ3H
25. Nida H, Seyoum A, Gebreyohannes A (2016) Evaluation of yield performance of intermediate altitude sorghum (Sorghum bicolor (L.) Moench) genotypes using genotype x environment interaction analysis and GGE biplot in Ethiopia. International Journal of Trend in Research and Development 3: 27-33. **Link:** https://bit.ly/3xtUN81
26. Lamessa K, Chala G, Tarbush A, Gudeta D, Haile S, et al. (2016) Evaluation of Sorghum [Sorghum bicolor (L.) Moench] Varieties and Environments for Yield Performance and Stability in Western Hararghe, Ethiopia. Journal of Biology, Agriculture and Healthcare 6: 11-17. **Link:** https://bit.ly/2TRxaYG
27. Belay F, Meresa H (2017) Performance evaluation of sorghum [Sorghum bicolor (L.) Moench] hybrids in the moisture stress conditions of Abergelle District, Northern Ethiopia. Journal of Cereals and Oilseeds 8: 26-32. **Link:** https://bit.ly/3r2n8jt
28. Abdel-Fatah BE, Ali EA, Tag El-Din AA, Hessein EM (2013) Genetic Diversity among Egyptian Sorghum (Sorghum bicolor [L.] Moench) Genotypes Using agro-morphological traits and Molecular markers. Asian Journal of Crop Science 5: 106-124. **Link:** https://bit.ly/3wqxA5r
29. Nada B, Atif H, Idris E, Ismael I, Ali E, et al. (2016) Drought tolerance assessment in grain sorghum [Sorghum bicolor (L.) Moench] genotypes using agro-morphological traits and DNA markers. International Journal of Plant Breeding and Genetics 10: 125-131. **Link:** https://bit.ly/3r2nxCv
30. Muchow RC, Hammer GL, Vanderlip RL (1994) Assessing climate risk to sorghum production in water limited subtropical environments. Effects of planting date, soil water at planting, and cultivar phenology. Field Crops Research 36: 246-253. **Link:** https://bit.ly/3wDqDON
31. Workineh A, Abate B, Kefalle D (2014) Participatory Evaluation and Selection of Bread Wheat (Triticum aestivum L.) Varieties: Implication for Sustainable Community Based Seed Production and Farmer Level Varietal Portfolio Managements at Southern Ethiopia. World Journal of Agricultural Research 2: 315-320. **Link:** https://bit.ly/2TM4ujU
32. Belay Y (2017) Correlation and cluster analysis of white seeded sesame (Sesamum indicum L.) genotypes oil yield in northern Ethiopia. African Journal of Agricultural Research 12: 970-978. **Link:** https://bit.ly/3ATXX7x
33. Showemimo FA (2007) Grain yield response and stability indices in sorghum [Sorghum bicolor (L.) Moench]. Communications in Biometry and Crop Science 2: 68–73. **Link:** https://bit.ly/3AMGPR1
34. Yayeh Z, Bosland PW (2000) Evaluation of genotype, environment and genotype by environment interaction for capsaicinoids in Capsicum annum L. Euphytica 111: 185-190. **Link:** https://bit.ly/3k1OcOy
35. Almeida FJE, Tardin FD, Daher RF, Barbe TC, Paula CM, et al. (2014) Stability and adaptability of grain sorghum hybrids in the off-season. Genetic and Molecular Research 13: 7626-7635. **Link:** https://bit.ly/3yGqBH0
36. Vange T, Ango I, Nache AV (2014) Stability analysis of six improved sorghum genotypes across four environments in the Southern Guinea Savanna of Nigeria. International Journal of Advances in Agricultural Science and Technology 2: 1-14. **Link:** https://bit.ly/3xt3Ia4
37. Semahegn Z (2018) Genotype X Environment Interaction and Yield Stability of Early Maturing Sorghum [Sorghum bicolor (L.) Moench] Genotypes in Dry Lowland Areas of Ethiopia MSc Thesis, Jimma University, Jimma, Ethiopia.
38. Olayiwola MO, Ariyo OJ (2013) Relative discriminatory ability of GGE biplot and SYi in the analysis of genotype x environment interaction in okra (Abelmoschus esculentus). International Journal of Plant Breeding and Genetics 7: 146-158. **Link:** https://bit.ly/3k0xfnq
39. Abate M (2015) Genotype x Environment analysis for seed yield and its components in sesame (Sesamum indicum L.) evaluated across diverse agro-ecologies of the Awash valleys in Ethiopia. Journal of Advanced Studies in Agricultural, Biological and Environmental Sciences 4: 1-14.
40. Belay Y (2016) Genotype x Environment Interaction and Yield Stability of White Seeded Sesame (Sesamum indicum L.) Genotypes in Northern Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
41. Admasu S, Nigussie M, Zeleke H (2008) Genotype-Environment Interaction and Stability Analysis for Grain Yield of Maize (Zea mays L.) in Ethiopia. Asian Journal of Plant Sciences 2: 163-169. **Link:** https://bit.ly/3dZ4VhF
42. Ararsa L (2015) Genotype by Environment Interaction and Yield Stability of Maize (Zea Mays L.) Hybrids in Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
43. Gebeyehu S, Assefa H (2003) Genotype x Environment Interaction and Stability Analysis of Seed yield in Navy Bean Genotypes. African Crop Science Journal 11: 1-7. **Link:** https://bit.ly/3xHff5P
44. Kefelegn N (2012) Genotype x environment interaction of released common bean (Phaseolus vulgaris L.) varieties, in Eastern Amhara Region, Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
45. Ast AV, Bastiaans L, Kropff MJ (2000) A comparative study on Striga hermonthica interaction with a sensitive and a tolerant sorghum cultivars. Weed Res 40: 479-493. **Link:** https://bit.ly/2TRm9Xi
46. EIAR (Ethiopian Institute of Agricultural Research) (2014) Ethiopian strategy document for sorghum. Addis Ababa, Ethiopia.

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036

47. FAO (Food and Agricultural Organization) (1995) Sorghum and millets in human nutrition. Rome: Food and Agricultural Organization, Rome, Italy. FAO Food and Nutrition Series No. 27.

48. ICRISAT (International Crop Research Institute for Semi-Arid Tropics) (2005) Sorghum report. **Link:** https://bit.ly/2VtRCPX

49. UNDP (United Nations Development Programme) (2015) Integrated Drylands Management in Ethiopia. Proceedings of the High Level Policy Forum, 6-7 March 2014, Semera, Afar National Regional State, Ethiopia.

50. Yang RC, Crossa J, Corlenius PL, Burgueno J (2010) Biplot analysis of genotype by environment interaction: proceed with caution. Crop Science 49: 1564-1676. **Link:** https://bit.ly/3qXO2sQ

51. GenStat Release 16th Edition (PC/Windows 7) (2014) International Ltd. germplasm. Inc. A. Fatokun, S. A. Tarawali, B. B. Singh,P. M. Kormawa, & M. Tamo (Eds.). **Link:** https://bit.ly/2TJ57ux

**Citation:** Belay F, Mekbib F, Tadesse T (2021) Univariate stability analysis and relationship among parameters for grain yield of striga resistant sorghum *[Sorghum bicolor (L.)* Moench] hybrids in Ethiopia. Open J Plant Sci 6(1): 069-081. DOI: https://dx.doi.org/10.17352/ojps.000036