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Adaptation Study of Improved Soya Bean (*Glycine max* (L.) Varieties in East Shewa Zone, Oramia, Ethiopia

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Abstract: The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC), Lume and Dugda Districts during 2019 and 2020 main cropping seasons with the objective to identify adaptable and high yielder soyabean variety/ies for East Shewa Zone and similar agro ecologies. Ten released soyabean varieties were used as a planting material. The experiment was laid down in Randomized Complete Block Design (RCBD) with three replications. The plot size was 3m × 3 m (9 m^2) having 5 rows and a spacing of 0.60 m between rows and 0.50 m between replications, 1 m between blocks. The genotype and environment main effects and genotype x environment interaction effect were significant on soyabean varieties. AMMI model shows that environment accounted 47.68%, GXE 20.56%, genotype 15.22% of the total variation. The high percentage of environment is an indication that the major factor that influence yield performance of soybean is the environment. The first two IPCAs are the most accurate model that could be predicted the stability of the genotype and explained by IPCA-I (30.34%) and IPCA-II (25.83%) of GEI. According, to stability parameters (ASV, and GGE- Biplot) and mean yield results revealed that Gozella and Davis varieties are the most stable varieties across test locations. Therefore, Gozella and Davis were recommended for the study area and similar agro-ecologies.

Keywords: Soyabean, Genotype by Environment Interaction, Stability, AMMI, GGE-Biplot

1. Introduction

Soya bean [*Glycine max* (L.) Merrill] is an important source of edible vegetable oil and protein for both humans and animals; and it improves soil fertility by fixing atmospheric nitrogen [13]. The introduction of soybean crop to Ethiopia dated back to 1950s with the objective of supplementing the diet of Ethiopians especially during long periods of partial fasting [2]. In the International trade market, soybean ranks number one among the major oil crops with an average protein contents of 40% on dry matter basis. It has the highest protein contents of all field crops and is second only to groundnut in terms of oil content (20%) among the food legumes. [4] reported that soybean is more protein rich than any of common vegetable or legume food sources in Africa.

It is an ideal crop for improved nutrition, food security, sustainable crop production and suitable in livestock integration systems. Production and the usage of improved seeds is one of the most efficient ways of raising crop production. Even though, soya bean is very important oil crop in our country, its distribution through the country was limited to a certain areas. And also many improved soyabean varieties were released from research institutions but not well reached to the farmers.

Genotypes exhibit fluctuating yields when grown in different environments or agro-climatic zones. This complication demonstrates the superiority of a particular genotype. Multi-environment yield trials are crucial to identify adaptable high yielding cultivars and discover sites that best represent the target environment [3, 16]. Poor response of genotypes to different environmental condition is the result of genotype and genotype by environment interaction (GGE). Evaluating released varieties on different environmental conditions which were released from different institution/ research centers/ is the good approach in selection the best variety/ies which solve the limitation of improved seed distribution. Therefore, the objective of this study was:

to evaluate improved soya bean varieties that gives best yield for the study area and similar agro ecology.

2. Materials & Methods

2.1. Experimental Material

Table 1. *Lists and descriptions of Soybean varieties were used in the experiment.*

No	Variety	Maturity	Areas of adaptation	Yield (tha^{-1})	Released center	Year of release
1	NYALA	90-108	Short season growing Agro ecology	18.1	PARC	2014
2	NOVA	90-108	Short season growing Agro ecology	22.5	HwARC	2012
3	WILLIAMS	90-108	Short season growing Agro ecology	19-32	PARC	2012
4	PAWE- 01	100-120	Mid altitude Agro ecology	24.4	PARC	2012
5	PAWE- 02	100-120	Mid altitude Agro ecology	25.5	PARC	2012
6	GOZELLA	90-108	Short season growing Agro ecology	20.2	PARC	2010
7	WELLO	100-120	Mid altitude Agro ecology	19-32	PARC	2012
8	DAVIS	100-120	Mid altitude Agro ecology	25-30	PARC	2010
9	BOSHE	100-110	Short season growing Agro ecology	-	BARC	2003
10	JALALE	100-100	Short season growing Agro ecology	-	BARC	2008

Key; PARC= Pawe Agricultural Research Centre, HwARC = Hawassa Agricultural Research Center, BARC = Bako Agricultural Research Centre.

2.2. Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications Adami Tulu, Lume and Dudga Districts. Experimental unit comprised five rows of 3 meters length with row-to-row distance of 60 cm and plant-to-plant distance of 5 cm. Weeding and all other recommended agronomic practice was followed for all locations.

Data collected: Plant height (cm), number of pods per plant, number of seeds per pod, days to flowering, days to maturity, grain yield (kg ha^{-1}), were collected.

2.3. Statistical Analysis

Analysis of variance was calculated using the model:

$$Yij = \mu + Gi + Ej + GEij$$

Where Yij is the corresponding variable of the i-th genotype in j-th environment, μ is the total mean, Gi is the main effect of i-th genotype, Ej is the main effect of j-th environment, GEij is the effect of genotype x environment interaction.

2.3.1. The AMMI Model

AMMI was used for analyzing GEI to identify patterns of interaction and reduce background noise. It combines conventional ANOVA with principal component analysis [8]. Provide more reliable estimates of genotype performance than the mean across sites. To identify target breeding environments and to choose representative testing sites in those environments.

$$Y_{ij} = \mu + g_i + e_j + \sum_1^N \Lambda_k \Upsilon_{ik} \delta_{jk} + \varepsilon_{ij}$$

Where Yij is the grain yield of the i-th genotype in the j-th environment, μ is the grand mean, gi and ej are the genotype and environment deviation from the grand mean, respectively, ʎk is the eigenvalue of the principal component analysis (PCA) axis k, Yik and δjk are the genotype and environment principal component scores for axis k, N is the number of principal components retained in the model, and Ɛij is the residual term.

2.3.2. GGE- Biplot

GGE-bi-plot methodology, which is composed of two concepts, the bi-plot concept [7]. The GGE concept was used to visually analyze the METs data. This methodology uses a biplot to show the factors (G and GE) that are important in genotype evaluation and that are also the source of variation in GEI analysis of METs data [14]. The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition [15].

AMMI Stability Value (ASV): ASV is the distance from the coordinate point to the origin in a two-dimensional plot of IPCA1 scores against IPCA2 scores in the AMMI model [11]. Because the IPCA1 score contributes more to the GxE interaction sum of squares, a weighted value is needed. This weighted value was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 to the interaction sum of squares as follows:

$$ASV=\sqrt{[(SS_{IPCA1} \div SS_{IPCA2})(IPCA1score)]^2 + (IPCA2score)^2}$$

Where, SS_{IPCA1}/SS_{IPCA2} is the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASV values indicate more stable Varieties across environments [11].

Genotype Selection Index (GSI): Stability is not the only parameter for selection as most stable Varieties would not necessarily give the best yield performance. Therefore, based on the rank of mean grain yield of Varieties (RYi) across environments and rank of AMMI stability value RASVi), genotype selection index (GSI) was calculated for each genotype as:

GSIi = RASVi + RYi

A genotype with the least GSI is considered as the most stable [5]. Analysis of variance was carried out using statistical analysis system (SAS) version 9.2. Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 18th edition.

3. Results and Discussions

The combined analysis of variance for all varieties at different environmental conditions for grain yield and yield related traits was presented in Table 2. The result revealed that locations and varieties showed highly significant (P≤0.01) for all studied parameters. While year had significant effect only on number of branch per plant, pod length, number of pod per plant and grain yield. Location by variety had significant effect on number of branch per plant, number of pod per plant and grain yield. Year by Varieties had non-significant effect on the studied and indicate that season was not affected the response of varieties on the studied parameters. Location by varieties by year had significant effect on plant height, pod length number of pod per plant and number of seed per pod.

Table 2. Combined analysis of Soya bean varieties at ATARC, Dugda and Lume districts tested for two years (2019 & 2020).

Source of Variation	Df	DF	DM	NBP	PH (cm)	PL	NPPP	NSP	Yield (Qu/ha)
Rep	2	35.08^ns	26.40^ns	1.10^ns	79.9^ns	0.53^ns	34.35^ns	0.28*	0.15^ns
L	2	392.73**	2581.87**	10.46**	1792.49**	17.35**	5587.88**	0.98**	473.53**
Yr	1	3.2ns	27.22^ns	127.6**	261.12^ns	89.35**	23042.9**	0.22^ns	410.99**
V	9	215.94**	425.28**	4.02**	1493.87**	0.67*	339.22*	0.28**	175.56**
Lc*Vr	18	5.36^ns	26.11^ns	3.59**	99.11^ns	0.48*	191.82*	0.064^ns	118.58**
Lc*Yr	2	1.25^ns	5.40^ns	32.44*	103.84^ns	23.6**	6584.37**	0.242*	86.129^ns
Vr*Yr	9	5.631^ns	9.77^ns	0.98^ns	284.98^ns	0.21^ns	156.84^ns	0.086^ns	32.71^ns
L*Vr*Yr	18	9.91^ns	10.66^ns	0.78^ns	134.61*	0.64*	219.1*	0.107*	52.29^ns
Error	118	12.8	15.97	0.92	85.41	0.322	106.57	0.059	33.01
R^2		0.628	0.839	0.756	0.707	0.84	0.825	0.57	0.62
CV		6.287	3.55	20.30	14.93	15.86	22.44	8.38	23.34
Root mse		3.49	3.99	0.96	9.24	0.56	10.32	0.244	5.74

Key: ns= non-significant, *= significant, **= highly significant, V= Varieties, L= Location, Yr = Year, L*V = Location by Varieties, V*Yr = Varieties by year, L* Yr = Location by year, L*V*Yr = Location by Varieties by year, GY= Grain Yield, DF= Days to flowering, DM= Days to maturity, NCP= Number of cluster per plant, NPC= Number of pod per cluster, NPP= Number of pod per plant, NSP= Number of seed per pod, PH=Plant height.

3.1. Yield Performance of Soybean Varieties Across Locations

Mean performance of the tested soybean varieties was presented in table 3. It revealed that some varieties continually performed best some group of environment and some were inconsistent across the environments. The average grain yield ranged from the lowest 5.78 qun/ha at ATARC on station in 2019 to the highest 31.26 qun/ha at Dugda in 2020 with grand mean of 16.25 qun/ha. The average grain yield across the environment ranged from the lowest of Pawe-01 varieties 12.35 qun/ha to the highest of 22.74 qun/ha for Gozella varieties. This large portion of variation might be due to the genetic potential of the varieties. Gozella and Davis varieties were the higher yielder than other varieties through the studied environments. However, Pawe -01 varieties had the lowest yield potential through the tested locations. Similarly [1, 12] were reported differential yield response to different environment of medium set soybean varieties. The difference in yield ranks of varieties across the locations showed the high cross over types of GxE interaction [14].

Table. 3. Over year and across location mean performance of grain yield (Qt/ha) of soybean varieties.

Varieties	2019			2020			Com. Mean
	ATARC	Dugda	Lume	ATARC	Dugda	Lume	
Gozella	18.86^ab	25.70^a	14.71	25.55^a	31.26^a	20.37	22.74
Davis	23.21^a	18.54^ab	10.93	18.74^ab	28.81^a	14.60	19.14
Williams	21.29^ab	19.11^ab	10.25	25.55^a	13.44^c	17.25	17.82
Wello	16.36^ab	14.82^bc	9.59	17.62^ab	30..81^c	12.25	16.91
Jalale	17.91^ab	20.91^ab	8.83	17.70^ab	19.03^bc	12.50	16.15
Nyala	19.21^ab	8.96^c	11.71	15.77^abc	28.00^ab	12.04	15.95
Boshe	20.06^ab	13.92^bc	11.37	15.44^abc	17.04^c	9.04	14.48
Nova	14.78^b	19.15^ab	8.68	17.77^ab	15.40^c	9.02	14.14
Pawe-02	5.78^c	11.84^bc	14.58	7.00^c	15.40^c	22.58	12.86
Pawe-01	6.29^c	8.06^c	16.84	8.96b^c	16.11^c	17.84	12.35
Mean	16.38	16.10	11.75	17.01	21.53	14.75	16.25
CV %	13.3	18.5	17.7	11.0	14.9	22.6	23.35
LSD	6.54	8.69	9.61	9.04	9.21	13.31	3.79
F test	**	**	Ns	**	**	Ns	**

3.2. Additive Main Effect and Multiple Interaction (AMMI) Model

The AMMI model ANOVA for grain yield is shown in Table 4. This analysis also revealed the presence of highly significant (P< 0.01) differences among soybean varieties for grain yield performance. The variation was largely due to environmental variation (47.68%). GEI and genotype also accounted 20.56% and 15.22% of the total variation, respectively. As discussed above, the high percentage of environmental variation is an indication that the major factor that influence yield performance of soybean is the environment. The result revealed that there was a differential yield performance among the varieties across testing environments and the presence of strong genotype by environment (G X E) interaction. Similar findings have been reported in previous studies [10, 6].

As G x E interaction was significant, further calculation of genotype stability is possible. In the AMMI ANOVA, the GEI was further partitioned using PCA. The result of ANOVA showed that the first two IPCA were highly significant at (P<0.01) implying the inclusion of the first two interactions PCA axes in the model. Considerable percentage of GEI was explained by IPCA1 (30.34%) followed by IPCA2 (25.83%). This result revealed that there were differential yield performances among soybean Varieties across testing environments due to the presence of GEI. The presence of GEI could complicate the selection process of superior Varieties and might reduce the selection efficiency in a breeding program According to [9].

Table 4. *Additive main effect and multiplicative interaction analysis of variance (AMMI) for grain yield of 10 soybean varieties.*

Source	D. F	S. S	M. S	Ex. SS %
Varieties	9	1580	175.6**	15.22
Environments	5	4947	2473.5**	47.68
Block	6	28	4.6^{ns}	0.26
Interactions	45	2134	118.6**	20.56
IPCA 1	10	1704	170.4**	30.34
IPCA 2	8	430	53.7^{ns}	25.83
Residual	150	5686	39.5	

Key: DF = Degree of freedom, S. S = Sum of square, M. S = Mean of square, IPCA = Interaction principal component axis, ** = highly significance difference, Ex. SS% = Explained sum of square.

3.3. Evaluation of Varieties Based on GGE-bi-plot Model

The estimation of yield and stability of genotype were done by using the average coordinates of the environment (AEC) methods [14]. The average environment is defined by the average values of PC1 and PC2 for the all environments, and it is presented with a circle. The average ordinate environment (AOE) defines by the line which is perpendicular to the AEA (average environment axis) line and pass through the origin. This line divides the Varieties in to those with higher yield than average and in to those lower yield than average. By projecting the Varieties on AEA axis, the Varieties are ranked by yield; where the yield increases in the direction of arrow. In this case the highest yield had varieties Gozella, Davis and Williams but the lowers had Pawe1 and Pawe2 figure 1. Stability of the Varieties depends on their distance from the AE abscissa. Varieties closer to or around the center of concentric circle indicated these varieties are more stable than others. Therefore, the greatest stability in the high yielding group had varieties Gozella, Davis and William. The genotype ranking is shown on the graph of genotype so-called "ideal" genotype (Figure 1). An ideal genotype is defined as one that is the highest yielding across test environments and it is completely stable in performance that ranks the highest in all test environments; such as variety in this case was Gozella.

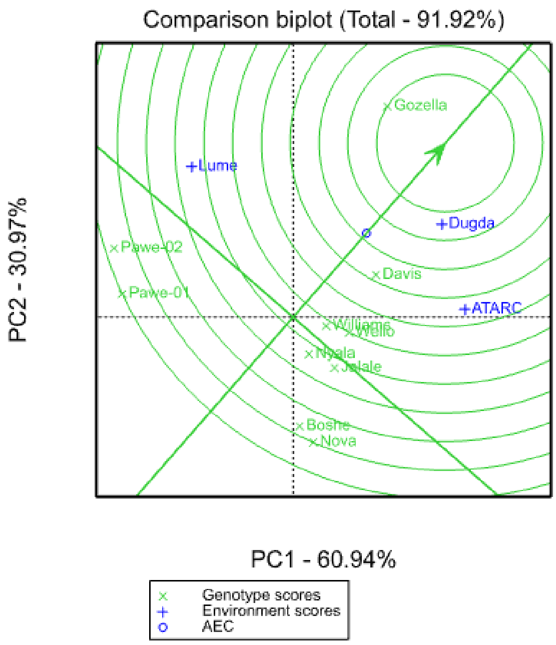

Figure 1. *GGE bi-plot based on Varieties focused scaling for comparison of varieties for their yield potential and stability.*

3.4. Genotypes by Environment Interaction (GGE) Bi-plot Analysis

GGE biplot is an essential tool for addressing the mega environment issues, by showing which cultivar won in which environments, and it was effective for visualizing in mega-environment identification [15]. Polygon views the GGE biplot showing the mega-environments and their respective highest yielding varieties (figure 2), and explicitly displays the "which-won-where pattern" as a concise summary of the GEI pattern derived from multi-environment yield trial data set for the three locations. The polygon dictated that Goxella, Davis, Nova, Pawe-01 and Pawe-02 were vertex Varieties, whereas the remaining Varieties lie inside the polygon. The winning Varieties for each sector are those placed at the vertex. Therefore, Davis is winner at both ATARC and Dugda locations similarly Gozella variety winning at Dugda environment. Pawe -01 and Pawe-02 better performed at Lume environment but below the grain mean grain yield (figure 2).

Table 5. *Mean grain yield of 10 Soybean varieties, AMMI stability values, Cultivar Superiority value and genotypic selection index.*

Varieties	Mean Yield	RYi	$IPCA_1$	$IPCA_2$	ASV	ASVi	GSIi
Boshe	14.48	7	1.558	0.898	6.239	8	15
Davis	19.14	2	4.947	-0.496	1.839	1	3
Gozella	22.74	1	0.353	-1.210	1.849	2	3
Jalale	16.15	5	0.713	-0.276	2.839	6	11
Nova	14.14	8	0.709	0.020	2.809	5	13
Nyala	15.95	6	0.559	0.153	2.222	4	10
Pawe-01	12.35	10	-2.410	0.304	9.553	9	19
Pawe-02	12.87	9	-2.739	-0.271	10.857	10	19
Wello	16.91	4	0.700	-1.189	3.017	7	11
Williams	17.82	3	0.110	2.016	2.062	3	6

Key: RYi =Rank of grain yield, IPCA = Interaction principal component axis, ASV = AMMI Stability value, ASVi = Rank of AMMI Stability value.

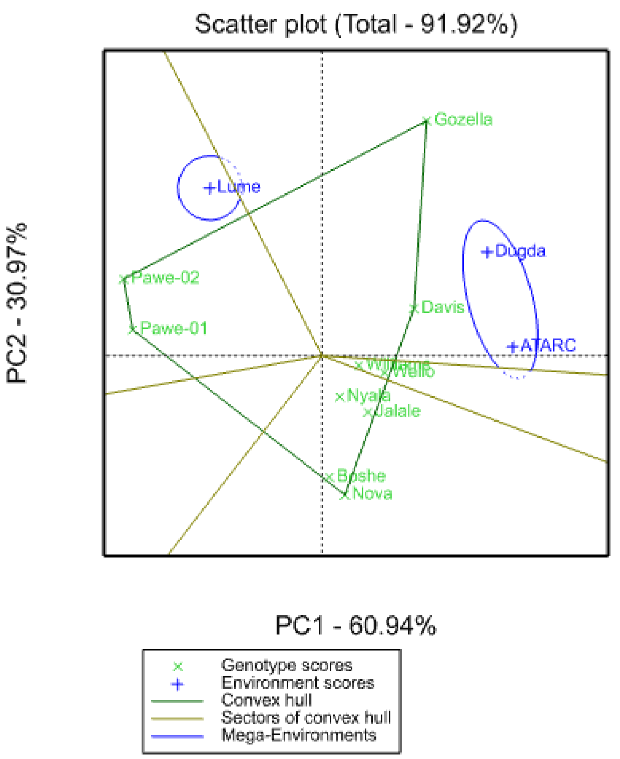

Figure 2. *The GGE biplot to show which Varieties performed best in which environment.*

AMMI Stability Value (ASV): The importance of AMMI model is in reduction of noises if the principal component did not cover much of the GE sum of squares. It is the distance from zero in two dimensional scatter of IPCA1 score against IPCA2 scores. Since the IPCA1 score more contributes more to the GEI sum of square, it has to be weighted by the proportional difference between IPCA1 and IPCA2 scores to compensate for the relative contribution of IPCA1 and IPCA2 to the total GEI sum of square. According to stability parameter, a genotype with least ASV score is the most stable. The varieties such as Davis, Gozella, Williams and Nyala varieties had least ASV value and were the most stable respectively (Table 5). Similar findings was reported by [3] on ground nut varieties in western Oromia. The high interaction of Varieties with environment was confirmed by high ASV value and difference in ranking order, suggesting unstable yield across environment. The most unstable varieties were Pawe-02, Pawe-02 and Boshe (Table 5).

4. Conclusion

The genotype and environment main effects (genotype and environment) and genotype x environment interaction effect were significant on soyabean varieties. Gozella and Davis varieties were the higher yielder than other varieties through the studied environments. However, Pawe- 02 and Pawe -01 varieties had the lowest yield potential through the tested locations. AMMI model shows the variation was largely due to environmental variation. The high percentage of environmental variation is an indication that the major factor that influence yield performance of soybean is the environment. Gozella and Davis were plotted to the ideal varieties considered as desirable varieties based on GGE bi-plot graph and stable varieties while Pawe1 and Pawe2 were far from the ideal varieties considered as most unstable varieties with poor performance across locations. Gozella and Davis varieties had least AMMI stability values and genotypic selection index value and were widely adaptable and stable high yielding varieties and thus were recommended for the study area.

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