Advances in Crop Science and Technology
ISSN: 2329-8863

Commentary | Open Access

Adaptation Studies of Durum Wheat Varieties for Yield and Yield Components in East Shewa Zones

Temesgen Dinsa* **and Urgaya Balcha**

Adami Tulu Agricultural Research Center, Batu, Ethiopia

Abstract

Durum wheat is a type of wheat with high protein content and is commonly used to make pasta couscous and some types of bread. The study was conducted at Adami Tulu Agricultural Research Center (ATARC), Lume, and Dugda Districts in the 2020 and 2021 main cropping seasons to identify stable, high-yielding durum wheat varieties for East Shewa Zone and comparable agro-ecologies. Seven durum wheat varieties were used as planting material. The experiment followed a Randomized Complete Block Design (RCBD) with three replications. Each plot measured 2.5m × 1.2m (3 m2), consisting of 6 rows with a row spacing of 0.20 m and a replication spacing of 0.50m, with 1m between blocks. Data on yield and related factors were collected and analyzed. Both the main effects of genotype and environment, as well as the interaction effect of genotype x environment, were found to be significant for durum wheat. According to the AMMI model, the environment contributed to 51.27% of the total variation, GXE 11.99%, and variety 23.41%. The substantial influence of the environment suggests it plays a key role in durum wheat yield performance. The first two IPCAs are the most accurate models for predicting variety stability, explaining 67.99% (IPCA-I) and 21.92% (IPCA-II) of GEI. Based on stability parameters (ASV and GGE-Biplot), the mean yield results indicated that Dirre and Alemtena are the most stable varieties across test locations. Consequently, Dirre and Alemtena are recommended for the study area and similar agroecological settings.

Keywords: Durum wheat; Genotype by Environment Interaction; Stability; AMMI; GGE-Biplot

Introduction

Durum wheat is the second most cultivated wheat species in the world next to bread wheat (Pena et al, 2002). Worldwide, the current annual average production of durum wheat is approximately 651 million metric tons (International Grains Council, 2010). Whereas in the case of Ethiopia, it is difficult to accurately estimate the production of durum wheat since statistics showed the average production of wheat instead of showing the average production of bread and durum wheat separately. In Ethiopia, durum wheat has been under cultivation for thousands of years. Small-scale farmers grow the crop on heavy black clay soils (vertisols) under rain-fed conditions [1].

In Ethiopia, durum wheat is consumed as leavened bread, common bread, macaroni, spaghetti, biscuits, pastries, and in various indigenous food preparations. Durum wheat is an economically important cereal crop grown throughout the world, although not as extensively as bread wheat. To date with the expansion of agro-industries, a good processing quality durum wheat grain has demanding become increasing and more production in the country will be mandatory [2]. Know days the government of Ethiopia under way the construction of Bulbula complex Agro-industry in East Shewa Zone. By the completion of construction, the industry needs more production and use of improved durum wheat in the area. However, the proximate farmers to the industry produce low yield of durum wheat because the use of unimproved local cultivars and biotic and biotic stresses are partially attributed to the low yield of the crop. Therefore, there is need to increase production by adapting released improved varieties. Therefore, this study of was initiated with the following objective [3].

Objectives

To identify high-yielding and desirable yield and yield of durum wheat that is suitable for agro-ecologies and farming systems.

Materials and Methods

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and conducted during main cropping season at ATARC, and Dudga and Lume Districts. About 7 durum wheat improved varieties were collected from DzARC. Experimental unit comprised six rows of 2.5 meters length with row-to-row distance of 20 cm and plant-to-plant distance of 5 cm. Weeding and all other recommended agronomic practice was followed for all locations [4] (Table 1).

Data collection

The following data were collected according to its procedure; Plant height (cm): Peduncle length (cm), Spike length (cm), Kernel number per spike, Days to heading, Days to maturity, Grain yield (kg/ha), Thousand kernel weights (g).

Table 1: Lists of varieties used as experimental material.

No	Variety	Source
1	Bulalla	SARC
2	Dirre	SARC
3	Tate	SARC
4	Alemtena	DzARC
5	Toltu	DzARC
6	Utuba	DzARC
7	Mangudo	DzARC

***Corresponding author:** Temesgen Dinsa, Adami Tulu Agricultural Research Center, Batu, Ethiopia, E-mail: temesgendinsa@gmail.com

Received: 02-June-2024, Manuscript No: acst-24-139325, **Editor Assigned:** 05-June-2024, pre QC No: acst-24-139325 (PQ), **Reviewed:** 19-June-2024, QC No: acst-24-139325, **Revised:** 23- June-2024, Manuscript No: acst-24-139325 (R), **Published:** 30-June-2024, DOI: 10.4172/2329-8863.1000707

Citation: Dinsa T (2024) Adaptation Studies of Durum Wheat Varieties for Yield and Yield Components in East Shewa Zones. Adv Crop Sci Tech 12: 707.

Statistical Analysis

AMMI Model: AMMI is used for analyzing GEI to identify patterns of interaction and reduce background noise. It combines conventional ANOVA with principal component analysis. 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. To select genotypes with good adaptation in targeted breeding environments (Angela et al 2016).

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 [5].

GGE- biplot

GGE-bi-plot methodology, which is composed of two concepts, the biplot concept (Gabriel, 1971) and the GGE concept (Yan et al., 2000), was used to visually analyze the METs data. This methodology uses a bi-plot 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 (Yan, 2001).The GGE-bi-plot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan et al., 2000).

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 (Purchase, 1997). 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:

Where, SSIPCA1/SSIPCA2 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 valuesindicate more stable genotypes across environments (Purchase, 1997) [6].

Genotype Selection Index (GSI): Stability is not the only parameter for selection as most stable genotypes would not necessarily give the best yield performance. Therefore, based on the rank of mean grain yield of genotypes (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 (Farshadfar, 2008). Analysis of variance was carried out using statistical analysis system (SAS) version 9.2 software (SAS Institute Inc., 2008). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis was performed using Gen Stat 15th edition statistical package VSN International (2012) [7].

Result and Discussion

Analysis of variance

The combined analysis of variance revealed that both random environments and genotypes had significant main effects on grain yield, indicating variability in genotypes and diversity in growing conditions across different environments. This analysis aimed to assess the impact of environment (location), genotype, and their interactions on the grain yield of durum wheat varieties. The main effects of environment (E) and genotypes (G) were highly significant, with a significant GE interaction at P <0.05. Various researchers have noted variations among durum and bread wheat genotypes (Alemayehu et al., 2024; Mohamed, 2013; Mohammadi & Amri, 2009) (Table 2).

Yield performance of durum wheat varieties across locations

The mean performance of the tested durum varieties is shown in Table 3. It was observed that certain varieties consistently excelled in specific environments, while others showed inconsistencies across different settings. The average grain yield varied from 3265.14 kg/ha at Lume in 2021 to 4803.17 kg/ha at Dugda in 2021, with an overall mean of 3908.29 kg/ha. Grain yield across environments ranged from 3370.37 kg/ha for Utuba varieties to 4485.92 kg/ha for Dirre varieties. This considerable variation could be attributed to the genetic potential of the different varieties. Dirre and Alemtena varieties exhibited higher yields compared to others in the study, whereas Utuba varieties showed the lowest yield potential among the locations tested. Variability in yield response between durum and bread wheat genotypes due to environmental factors has been documented by previous studies (Alemu et al., 2019; Megerssa et al., 2024; Mohammadi & Amri, 2009). Variations in yield rankings of the varieties across locations indicated significant genotype-by-environment interactions (Yan and Hunt, 2001; Asrat et al., 2009) (Table 3) [8].

AMMI analysis of variance for G, E, and GxE Interactions

The AMMI analysis of variance for durum wheat varieties assessed in six environments (three locations and two years). It indicated highly significant variations (p<0.01) for environments (E), and genotypes (G), and notable variability (p<0.01) was noted for the interaction between environments and genotypes (GEI), IPCA1, IPCA2, and IPCA3. Environments made a significant contribution, with 51.27% to the total variation in durum wheat yield, while genotype variances represented only 23.41% of the total variation. The GEI's role in explaining yield performance variation was 21.99%, highlighting the significant impact of GEI in MET trials [9].

The vast array of squares in the environment indicated significant differences between natural conditions, leading to variations in genotype performance. This heterogeneity could be attributed to differences in soil type and altitude affecting the performance of genotypes. Previous studies have suggested that environmental factors account for 80% of the observed variation, while genotype and genotype-environment interaction explain 10% (Sabaghnia et al., 2013); Abay et al. (2009) and Gebremedhin et al. (2014) have also reported substantial environmental effects in Durum wheat production.

The AMMI analysis showed a significant interaction of principal

Table 2: Combined analysis of variance for Durum wheat yield of seven durum wheat varieties.

S. Variation	Df	Sum Sq	Mean Sq
Environment (E)	5	3.7E+07	7406517**
Replication/E	12	6832258	569355**
Genotype (G)	6	2.1E+07	3454716**
GxE	30	1.2E+07	390112*
Residuals	72	1.6E+07	225214

Table 3: Across location mean performance of grain yield (kg/ha) of durum wheat varieties.

Genotype	ATARC		Dugda		Lume		Mean
	2020	2021	2020	2021	2020	2021	
Alemtena	4654.33	4544.44	3511.11	5277.78	3944.44	3861.11	4298.87
Bullala	5253.33	3694.44	3622.22	4983.33	4677.78	3527.78	4293.15
Dirre	5132.11	4266.67	4222.22	5366.67	3866.67	4061.21	4485.92
Mangudo	3210.37	3711.11	3733.33	4338.89	3722.22	3111.11	3637.84
Tate	4521	3044.44	3188.89	4994.44	3655.56	2750.33	3692.44
Toltu	4409.89	2922.22	2966.67	4461.11	3888.89	2827.78	3579.43
Utuba	3755.56	3205.56	2922.22	4200	3422.22	2716.67	3370.37
Mean	4419.51	3626.98	3452.38	4803.17	3882.54	3265.14	3908.29
LSD 0.05	815.17	772.04	663.99	588.76	516.17	739.66	263.59
CV (%)	12.67	14.63	13.22	8.42	9.14	15.57	12.14
CV = coefficient of variation, LSD = Least Significant Difference							

Table 4: The Additive and multiplicative interaction Analysis of variance.

S. Variation	Df	Sum Sq	Mean Sq	Pr(>F)	Explained % SS
Total	112	1.09E+08			
Environment (E)	5	3.7E+07	7406517	0.0001689 ***	51.27
Replication/E	6	6832258	569355	0.00774	6.45
Genotype (G)	12	2.1E+07	3454716	1.366e-05 ***	23.41
GxE	30	1.2E+07	390112	0.0300909 **	11.99
PC1	10	7113895	711390	0.0021000 **	67.99
PC2	8	2738789	342349	0.01654000*	21.92
Residuals	72	1.6E+07	225214		

Table 5: IPCA1, IPCA2 scores, AMMI stability value and Genotype Selection Index of durum wheat varieties.

Variety	Mean yield	RYi	IPCA1	IPCA2	ASVi	RASVi	GSI
Alemtena	4298.87	2	10.1949	16.0987	17.345	2	4
Bullala	4293.15	3	-16.761	-8.3271	34.7486	5	8
Dirre	4485.92	1	4.91744	12.6733	12.8162	1	2
Mangudo	3637.84	5	26.6589	-16.691	45.7336	6	11
Tate	3692.44	4	-13.833	2.6825	71.3829	7	11
Toltu	3579.43	6	-14.709	-7.3052	30.5029	4	10
Utuba	3370.37	7	10.5312	-5.1309	22.216	3	10
Key: RYi =Rank of grain yield, IPCA = Interaction principal component axis, ASV = AMMI Stability value, ASVi = Rank of AMMI Stability value, GSI= Genetic Selection index							

components. The two multiplicative principal components were significant ($P<0.01$), while the remaining interaction principal component was not. According to Yan (2007), the AMMI model using the first two IPCAs adequately predicts genotype by environment interaction and assesses model fitness of the additive main effect and multiplicative interaction (AMMI). IPCA1 accounted for 67.99% of the variation and IPCA2 explained 21.92%, together, these three interaction principal components explained 89.91% of the genotype by location interaction (Table 4) [10].

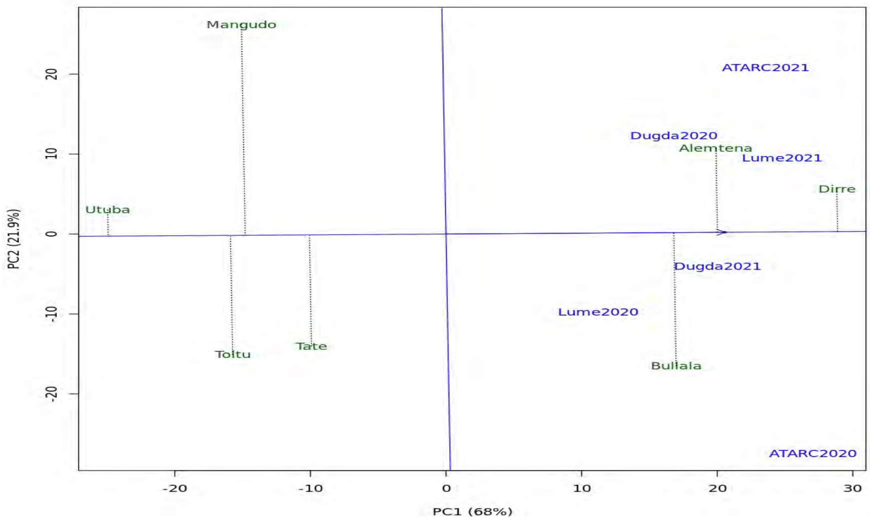
AMMI Stability Value (ASV): The significance of the AMMI show lies in reducing disturbances if the primary component does not cover a large part of the GE sum of squares (Gauch, 1992; Gauch and Zobel 1996). It is the deviation from zero in a two-dimensional scatter of IPCA1 score against IPCA2 scores. Since the IPCA1 score contributes more to the GEI sum of squares, it should be adjusted by the difference between IPCA1 and IPCA2 scores to account for their relative contributions to the overall GEI sum of squares. According to the stability parameter, a genotype with the lowest ASV score is the most stable. Varieties like Dirre and Alemtena had the lowest ASV values and were the most stable respectively. The high interaction of genotypes with the environment was indicated by high ASV values and differences in ranking order, suggesting inconsistent performance across environments. The most unstable varieties Toltu and Utuba (Table 5).

GGE biplot analysis

GGE biplot design of the 'mean vs. stability' investigation showed that PCA1 and PCA2 explained 68.1% and 21.9% of the GGE variation, respectively. This visualization helps understand durum wheat yield performance and genotype stability. The average environment coordinate (AEC) or average environment axes (AEA) line intersects the biplot's origin when SVP=1 (single value partitioning). According to Yan and Rajcan (2002), the mean of PC1 and PC2 of the environmental scores is calculated. The 'mean vs stability' perspective, often represented as AEC and SVP, aids in simplifying genotype evaluation based on average performance and stability across various environments (Figure 1). The arrow symbol on the AEC abscissa line shows the genotypes' positioning in increasing order with higher Durum wheat yield values. In this research, the genotype Dirre followed by Alemtena displayed high yield and consistent performance across evaluated conditions on the horizontal line (Figure 1).

Evaluation of genotypes based on the GGE-biplot model

Genotype stability estimation was conducted using the average



GGE biplot: Mean vs. Stability of Durum Wheat Varieties

Figure 1: Mean vs stability' pattern of GGE biplot illustrating interaction effect of durum wheat varieties.

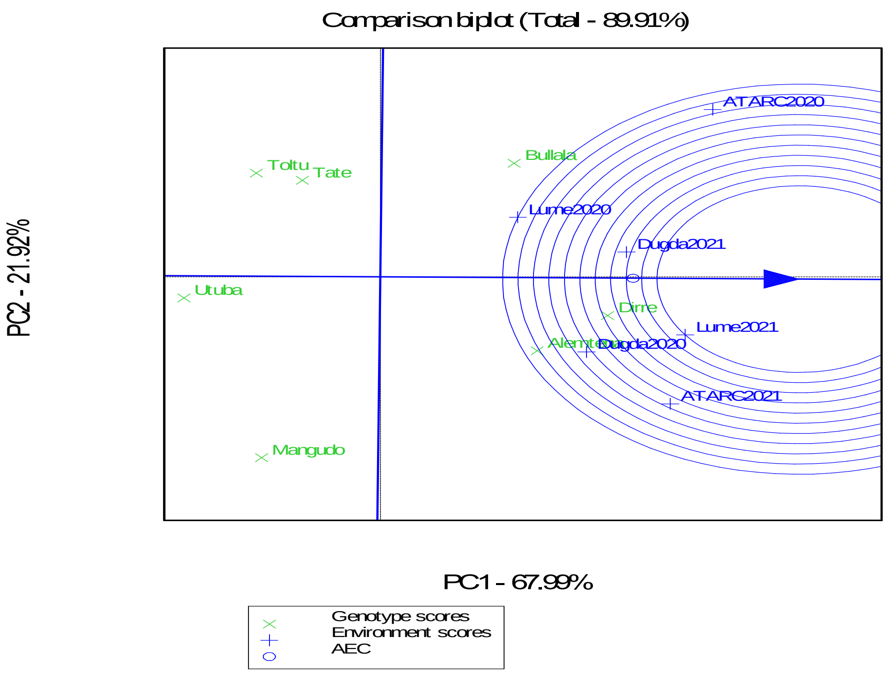


Figure 2: GGE biplot based on Varieties focused scaling for comparison for their grain yield potential and stability.

environment coordination (AEC) methods (Yan, 2001; Yan and Chase, 2001). The average environment is determined by the mean values of PC1 and PC2 across all conditions and is depicted as a circle. The average ordinate environment (AOE) is shown as the line perpendicular to the AEA (average environment axis) line, intersecting at the origin.

This categorizes varieties into those with higher yields than normal and those with lower yields than normal. When varieties are plotted on an AEA axis, they are organized by yield, with yields increasing in the direction of the arrow. The varieties Dirre and Alemtena showed the highest yields, while Utuba and Toltu had lower yields. Genotype stability is determined by their distance from the AE axis. Varieties closer to or near the center of the concentric circle indicate greater stability. Therefore, the most stable varieties within the high-yielding group were Dirre and Alemtana. The varieties ranking is illustrated on the chart of the "ideal" variety. An ideal variety is the highest yielding across test conditions and consistently performs well, ranking highest in all test conditions; in this case, varieties Dirre and Alemtena meet this criterion (Figure 2) [11].

Conclusion

The importance of durum wheat lies in its culinary versatility, nutritional value, and economic significance in agriculture and food production. The genotype and environment had primary impacts on the nourishment of durum wheat varieties. AMMI analysis revealed that the variation was mainly due to environmental factors. The high level of environmental variation indicates that the environment is the key factor affecting the performance of nourishment Durum wheat genotypes. Dirre and Alemtena were identified as desirable genotypes based on GGE bi-plot analysis, showing stability and high yield. In contrast, Toltu and Utuba were considered unstable genotypes with poor performance across different areas. Dirre and Alemtena varieties exhibited low AMMI stability and genotypic selection index values, making them versatile and consistently high-yielding varieties, and were recommended for study areas and similar agroecology.

References

1. Alemayehu Z, Yewubdar S, Mekuria T, Shitaye H, Wasihun L, et al. (2024) Genetic variability and stability analysis of multi environments trials for durum wheat grain yield in Ethiopia. Journal of Plant Breeding and Crop Science 16: 8-14.
2. Alemu G, Mohammed H, Asnake D, Alemu T (2019) Genotype X Environment Interaction and Yield Stability of Bread Wheat Genotypes in central Ethiopia. Journal of Plant Breeding and Genetics 7: 87-94.
3. Megerssa SH, Ishetu YS, Hailu M, Lemma AZ (2024) Genotype by environment interaction and stability analyses of durum wheat elite lines evaluated in Ethiopia. Crop Breeding and Applied Biotechnology, 24: e45542417.
4. amed M (2013) Genotype by environment interactions for grain yield in bread wheat (Triticum aestivum L.). Journal of Plant Breeding and Crop Science, 7:150–157.
5. Mohammadi R, Amri A (2009) Analysis of Genotype × Environment Interactions for Grain Yield in Durum Wheat. Crop Science 49: 1177-1186.
6. Purchase JL, Hatting H, Deventer CS (2000) Genotype ×environment interaction of winter wheat (Triticum aestivum L.) in South Africa: II. Stability analysis of yield performance. South African Journal of Plant and Soil 17:101-107.
7. Purchase JL, Hatting H, Vanden venter CS (1997) Genotype x environment interaction of winter wheat in South Africa: II. Stability analysis of yield performance. South Afr J Plant Soil 17: 101-107.
8. Yan W, Hunt LA (2001) Interpretation of genotype x environment interaction for winter wheat yield in Ontario. Crop Sci 41: 19-25.
9. Yan W, Rajcan I (2002) Biplot analysis of test sites and trait relations of soybean in Ontario. Crop science 42: 11-20
10. Yan W, Hunt LA, Sheng Q, Szlavnics Z (2000) Cultivar evaluation and mega environment investigation based on the GGE biplot. Crop Science 40: 597-605.
11. Yang W, Kang MS, Ma B, Woods S, Cornelius PL, et al. (2007) GGE biplot vs AMMI analysis of genotype-by-environment data. Crop Science 47:643-653.