Journal of
Biodiversity & Endangered Species

Gebru and Abay, J Biodivers Endanger Species 2013, 1:2
DOI: 10.4172/2332-2543.1000104

Research Article Open Access

Evaluation of Bread Wheat Genotypes for their Adaptability in Wheat Growing Areas of Tigray Region, Northern Ethiopia

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Abstract

Ten genotypes were tested for their adaptability study at five wheat growing areas of Tigray region, Northern Ethiopia. The elite varieties were arranged in RCB design with three replications. Data on grain yield was taken and subjected in to analysis of variance using Genstat 12 statistical software. Univariate stability analysis was also computed using different stability models. The combined analysis of variance showed that there were significant variations among genotypes, locations and their interaction. Based on grain yield, Mekelle-03 (3.24 t/ha) and FRET1 (3.15 t/ha) had scored the highest yield, while the local check yielded the least (2.35 t/ha). With respect to the univariate stability parameters, the different models identified the stability performance of the varieties. Based on the overall rank sum of stability parameters, the local check, M20ESWYT-46, Picaflor and FRET1were the most stable varieties, while HAR-1668, HAR-2501 and JEFERSON the least stable once. Since the tested varieties had shown differential yield responses across the environments, it is concluded that varietal recommendation should be based not only on overall mean yield, but also on their stability performance.

Keywords: Bread wheat; adaptability; stability; Tigray; Ethiopia

Introduction

In Ethiopia, wheat is one of the most important small cereal crop which ranks fourth in terms of area after teff, maize and sorghum and also ranked fourth in terms of production after maize sorghum and teff [1]. Ethiopia is the second largest producer of wheat in sub-Saharan Africa, following South Africa [2]. The crop is also one of the most important cereal crops being cultivated in the mid and high land areas of Tigray region.

The productivity of the crop in the region however has been very low mainly due to lack of improved varieties, soil fertility problems, and moisture stress. In Tigray region, so fare very few improved varieties of bread wheat are being cultivated despite of the many improved varieties released at national level. In the mean time, the performance of the improved varieties being cultivated in the region is getting low. There could be various reasons attributed for this lower performance. Genotype by environment interaction for instance is one of those constraints which results in failure of adaptation of those improved varieties to the real farmers' field.

Genotype by Environment interaction can be defined by differential yield response of varieties in different locations. In such circumstances it is difficult to select and suggest one better genotype across various locations. When a genotype performs consistently over a wide range of environments, then the genotype is considered as widely adaptable. On the other hand, a genotype showing considerable genotype by environment interaction effects is not suited for diverse environments [3] and is said to have specifically adapted variety. Therefore, it is paramount important to evaluate and determine the adaptability of the candidate bread wheat varieties prior to varietal recommendation.

Experimental Design and Methods

The study is conducted in 2011/2012 production season at five wheat growing locations of Tigray region, Northern Ethiopia. Ten varieties viz. Mekelle-01, Mekelle-02, FRT1, Mekelle-03, HAR-2501, HAR-1868, Picaflor, Jeferson, M20ESWYT-46 and Shehan were used. The design of the experiment was randomized complete block design replicated thrice. Each experimental unit was eight rows of 1.5 meters long and 20 cm spacing with the seeds hand sown in drilling. Sowing dates ranged from 28 June to 7 July 2003 depending on the onset of the main growing season. The seeding rate was 125 kg/ha and the plots were equally fertilized with Urea and DAP at the rate of 50 and 100 kg/ha, respectively. All agronomic managements were implemented equally as per the recommendation. Finally grain yield data was taken from the central six rows and subjected in to analysis using Gen Stat 12th [4] statistical soft ware.

To detect the presence GEI and to partition the variation due to genotype, location and genotype by location interaction, a pooled analysis of variance was also computed. After confirming a significant genotype by environment interaction, univariate stability parameters were performed in accordance with the coefficient of regression (b_i) [5], mean square deviation from regression (S^2d_i) [6,7] (W_i^2) ecovalance, [8] coefficient of variability (CV_i), superiority index (P_i) and coefficient of determination (R^2). A genotype with a regression coefficient (b_i) greater than 1.0 is responsible to increasingly favorable environmental conditions. Whereas, a genotype with b_i <1.0 is considered not responsive and suitable for low yielding environments and a variety is considered stable if it has b_i value of 1.0. Genotypes with small values of CV, P_i and a coefficient of determination near 1.0 (100%) are considered to be more stable. In addition Spearman's coefficient of rank correlation was computed for grain yield and the stability parameters of each pair of the possible pair-wise comparison and the significance of the rank correlation coefficient was tested according to Steel and Torrie [9].

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Received May 07, 2013; **Accepted** June 14, 2013; **Published** June 21, 2013

Citation: Gebru H, Abay F (2013) Evaluation of Bread Wheat Genotypes for their Adaptability in Wheat Growing Areas of Tigray Region, Northern Ethiopia. J Biodivers Endanger Species 1:104. doi:10.4172/2332-2543.1000104

Result and Discussion

Variance estimation, GLI analysis and yield performance of genotypes

A combined analysis of variance was performed for grain yield to partition the variation due to genotype, location and genotype by location interaction (GLI). The results for combined analysis of variance suggested that the differences among genotypes, locations and genotype by location interactions were statistically different (Table 1). As shown in Kang [10], a significant genotype by environment interaction for grain yield can reduce the usefulness of subsequent analyses, restrict the significance of inferences that would otherwise be valid, and seriously limit the feasibility of selecting superior genotypes, and thus seriously limit efforts to improved variety development.

The present investigation revealed that location was the most important source of grain yield variation, accounting for 62.4 % of the total variation followed by genotype (10.7%) and GLI (9.8%). Gauch and Zobel [11] pointed out that in normal multi location trails, the environment accounts for about 80 % of the total variation while the genotype and the genotype by environment interaction (GEI) each account for about 10%. However, the variation due to location (Environment) obtained from the current research was less than what previously reported by the above mentioned authors. The large sum of square for locations indicated that the locations were diverse, with large differences among location means causing most of the variation in grain yield. The present result is in agreement with the study made on investigating cause of GEI on ten barley varieties in different locations of Ethiopia [12]. Moreover, variation in environmental factors such as rainfall, temperature, and soil characteristics in the present study might have played an important role in genotypic performance of the varieties. In fact, the current result concurred with the findings of many genotypes by environment interaction studies [13-20] which have shown the proportion of sum of square due to variations among sites ranging from 57% to 90%.

The current study also demonstrates that in all of the five locations, mean grain yield of the tested varieties varied from 2.35 to 3.24 ton/ha, among which G4 (Mekelle-03) had the highest yielding performance followed by G3 (FRET1) and G1 (Mekelle-01). In contrast, the local check (Shehan) was the low yielding variety (2.35 t/ha) (Table 2). In a similar manner, mean grain yield varied among locations and ranged from 1.98 t/ha at location Atsbi to 3.66 at Quiha. In Atsbi, the overall average grain yield of the varieties was the lowest and varied from 1.54 to 2.32 t/ha for an early maturing standard check (HAR-2501/Hawi) and Picaflor, respectively.

On the other hand, a highest yield performance of the candidate materials was observed at Quiha, a location suitable for better yield, with maximum grain yield for the newly released variety Mekelle-01 (4.25 t/ha) followed by Mekelle-02, while the lowest yield was recorded for the local check, known as Shehan (3.07 t/ha).

Source of variation	d.f	SS	MS
Replication	2	55.86	27.93
Variety	9	1107.00	123.00***
Location	4	6460.58	1615.14***
Variety x location	36	1011.76	28.10*
Residual	98	1721.65	17.57
Total	149	0356.85	

d.f degrees of freedom, SS sum of square, MS mean square, *p<0.05, **p<0.01, *** p<0.001, d.f=degree of freedom, SS=sum of square, MS=mean square

Table 1: Combined analysis of variance for grain yield tested in five locations.

Varieties	Grain yield (ton/ha)	%increase over Shehan	%increase over Hawi	%increase over Shina
Mekelle-01	3.10^{efg}	31.94	18.50	21.32
Mekelle-02	$2.96d^{efg}$	25.95	13.12	15.82
FRT1	3.15^{fg}	34.15	20.48	23.35
M17SWSN-79	3.24^{g}	37.63	23.61	26.56
Hawi	2.62^{abc}	11.34	-	-
Shina	2.56^{ab}	11.34	-	-
Shehan	2.35^{a}	-	-	-
Picafor	2.91^{cdef}	23.87	13.91	13.90
Jeferson	2.69^{bcd}	14.27	2.60	5.07
M20ESWYT-46	2.84^{bcde}	17.11	8.35	10.93

Means connected by same letter are significantly different

Table 2: Mean comparison and percentage increase of genotypes over checks.

The overall mean grain yield of the entries across locations declared that Mekelle-03 had shown yield increments of 37.63%, 23.61%, and 26.56% over local check, HAR-2501 and HAR-1868, respectively. Moreover, FRET1 had also yield advantages of 34.15%, 20.48%, and 23.35% over Genotypes G7, G5, and G6, respectively (Table 1). This result is in agreement with Hintsa et al. [21] on their study of searching and testing bread wheat genotypes in northern Ethiopia. A similar result was also observed in Egypt on determining agronomic performance and genotype by environment interaction of sorghum [22]. In general, this combined analysis of variance had quantified the genotype by location interaction and described the main effects.

Univariate stability analysis

Stability analysis provides a general summary of the response patterns of genotypes to environmental change. There are different univariate stability parameters, among which four stability estimates are considered in this study (joint linear regression, coefficient of variation, Superiority index, and Wrick's ecovalence).

1. Regression analysis for yield stability

   To determine the genotype by location interaction (GLI) and stability of the genotypes, a regression analysis was computed in which mean grain yield of individual genotypes was regressed on to environmental indices (over all mean grain yield of all location). The linear regression coefficient (b_i) of the relationship between yield for genotype at each location and the yield for mean location is the measure of the linear responses to environmental change. The mean square for deviation from the regression (S^2d_i) measures the consistency of this response.

   Hence, Finlay and Wilkinson [5] and Eberhart and Russell [6] stated that genotypes with high mean yield, regression coefficient equal to unity (b_i=1) and deviation from regression as small as possible (S^2d_i=0) are considered as widely adapted or stable genotype.

   In this study, values for regression coefficient ranged from 0.74 to 1.47 for grain yield (Table 3). The regression coefficients for all genotypes were significantly different from unity. Accordingly, G10 had a regression coefficient of 0.97, with small S^2d_i and is considered as the most stable genotype across the five locations. Similarly, G8 was also the second most stable genotype with B_i=0.92 and S^2d_i=0.157. In contrast, genotypes G3 and G4 had the smallest regression coefficient of 0.79 and 0.74, respectively which is much lower than unity and provides a measurement

Genotype code	Genotype name	Regression equation	R^2 (%)	Sig.
G1	Mekelle-01	$Y=1.469\ I_i-10.56$	89.32	***
G2	Mekelle-02	$Y=1.35\ I_i-8.68$	91.24	***
G3	FRET1	$Y=0.78\ I_i+9.51$	68.13	***
G4	Mekelle-03	$Y=0.74\ I_i+11.32$	60.01	***
G5	HAR-2501(HAWI)	$Y=1.23\ I_i-9.10$	86.06	***
G6	HAR-1668 (SHINA)	$Y=0.89\ I_i+0.01$	68.62	***
G7	SHIHAN	$Y=0.796\ I_i+0.96$	95.05	***
G8	PICAFLOR	$Y=0.92\ I_i+3.06$	73.20	***
G9	JEFERSON	$Y=0.8\ I_i+2.88$	66.25	***
G10	M20ESWYT-46	$Y=0.97\ I_i+0.62$	77.95	***

*** Highly significant at P<0.001, $I_{i=}$ Environmental index, Y=grain yield

Table 3: Regression equation for the 10 genotypes in Finlay and Wilkinson method

of greater resistance to environmental changes (above average stability). These genotypes could be recommended for cultivation under unfavorable growing environments which in fact were less efficient in taking advantage of better conditions. On the other hand, the slops of genotypes Mekelle-01 and Mekelle-02 were significantly greater than unity, suggesting increasing sensitivity to environmental change, and is associated with below average stability. The result is consistent with earlier study by Khan et al. [23] in which they found out a coefficient of regression value in bread wheat inbreed lines ranged from 0.87 to 1.20.

The present study demonstrated that these genotypes had above average grain yield, exhibiting a specific adaptability to favorable environments (Table 4). However, this is against the findings of Hintsa et al. [24], in which their result on a multi location trial in the drought prone wheat growing areas of Tigray region revealed the two genotypes to be specifically adapted to the moisture stress areas.

Furthermore, the regression for grain yield of varieties G1, G2, G5, and G7 showed a good fit with R^2 exceeding 85%. The coefficient of determination (R^2) according to Pinthus [25] could be used as a measure of stability with high R^2 value being the most stable while least R^2 showing most unstable Accordingly, the local check (G7) was ranked first as the most stable genotype, followed by G6 and G10. Whereas, G4 and G9 were ranked as the most unstable genotypes, as they have least R^2 values.

Moreover, is clearly shown that there was a differential response of the genotypes across the testing locations. Because the yielding performance of the varieties across the locations varied markedly, so this makes difficult to recommend best genotype for all the locations. In low yielding locations for instance (up to 3.0 ton/ha), G3 and G4 were superior, but when yielding potential of the areas gets improved then genotypes G1 and G2 became the best genotypes. G10 on the other hand, had a wide adaptability to the trial sites.

Therefore, in such circumstances varietal selection should receive due attention hence, a best variety should be identified for an appropriate mega environment. The study is in fact in agreement to the findings of Fetien and Bjornstad [12].

2. Coefficient of variability, Superiority index, and Wrick's ecovalence

The coefficient of variation varied from 21.13 % for G4 to 36.64% for G5 (Table 4). The genotypes with low variability across the locations are normally considered as stable/widely adapted genotypes, while high CV indicated narrowly adapted genotype [8]. Hence according to this parameter, the study showed that G3 and G4 were the most stable genotypes across all the locations; whereas genotypes G5, G1 and G2 were least stable and narrowly adapted genotype. With respect superiority index (P_i), the genotypes with the lowest (P_i) values are considered as the most stable [26]. Accordingly, G4 was ranked as the most stable genotype, and genotypes G3, G1 and G2 were also identified as the next most stable genotypes. On the other hand, genotypes G7, G6 and G5 were ranked as less stable and more sensitive to environmental changes. But according to Albert as cited by Hagos [13], the superiority index normally indicates performance than stability.

Based on the coefficient of determination (R^2), G7 was the most stable genotype, followed by G2 and G3. But, genotypes G6, G9, and G5 had specific adaptability to the varying locations and were unstable. Wricks' ecovalance (W_i) [7] also identified the local check (G7) as the most stable, followed by genotypes G6 and G10. But, Mekelle-01 (G1) was ranked the most unstable genotype.

When genotype ranking is considered, there is inconsistency within the stability estimates. Therefore, over all univaraite stability performance of the candidate genotypes is determined by adding individual rank of each stability parameter for each genotype. Accordingly, genotypes having least sum rank were considered as most stable and widely adapted to five of the locations. On the contrary, genotypes with highest rank sum are considered as most unstable. Therefore, genotypes G7, G10, G8 and G3 were the most stable genotypes (Table 3). Genotypes G6 and G9 on the other hand were considered as less stable and specifically adapted to the testing locations.

Relationships between mean grain yield and univariate stability parameters

Spearman's coefficient of rank correlation [9] was determined for each of the possible pair wise comparisons of the ranks of the different stability statistics and grain yield and the significance of the rank-correlations of any two stability estimates in each trial was compared using student's t-test. The correlation between mean grain yield (GY) and five stability parameters varied considerably. The association between GY and P_i was a perfect positive and highly significant (P<0.01) with r value of 0.99, indicating that they had strong correlation as the rank-correlation coefficient was near to 1.0. Similarly, the mean grain yield (GY) had a non significant weak positive correlation with CV having an r value of 0.297. In contrast, GY had a negative correlation with the remaining stability parameters: R^2, B_i, S^2d_i, W_i with r value of -0.382, -0.479, -0.243, and -0.86, respectively (Table 5). This non significant negative correlation between GY and B_i suggested that many high yielding genotypes negatively respond to increased environmental productivity. The absence of this positive rank correlation was in accordance with the findings of Mut et al. (2010).

High significance (P<0.01) negative and strong spearman rank correlation coefficient was also noted between Wrick's ecovalance and grain yield (Table 5). But, R^2, B_i, and S^2d_i had weak association with grain yield. This was in agreement with the study of Adugna [27].

Genotype	Grain yield (t/ha)	Rank	P_i	Rank	S^2d_i	Rank	CV	Rank	B_i	Rank	R^2	Rank	W_i	Rank	Total rank
G1	3.10	**3**	9	**3**	0.14	**5**	35.68	**9**	1.47	**10**	89.32	**3**	10378.26	**10**	**43**
G2	2.96	**4**	11	**4**	0.12	**3**	34.06	**8**	1.35	**9**	91.24	**2**	2406.27	**7**	**37**
G3	3.15	**2**	5	**2**	0.14	**5**	21.36	**1**	0.79	**6**	68.13	**8**	3251.35	**8**	**32**
G4	3.24	**1**	4	**1**	0.16	**9**	21.13	**2**	0.74	**8**	60.01	**10**	3574.49	**9**	**40**
G5	2.62	**8**	21	**8**	0.11	**2**	36.64	**10**	1.24	**7**	86.06	**4**	2178.20	**5**	**44**
G6	2.56	**9**	24	**9**	0.17	**10**	30.39	**7**	0.89	**3**	68.62	**7**	1830.82	**2**	**47**
G7	2.35	**10**	35	**10**	0.04	**1**	24.76	**3**	0.80	**5**	95.05	**1**	1723.52	**1**	**31**
G8	2.96	**5**	11	**4**	0.15	**7**	26.33	**4**	0.92	**2**	73.20	**6**	2131.15	**4**	**32**
G9	2.69	**7**	20	**7**	0.16	**8**	27.55	**5**	0.83	**4**	66.25	**9**	2375.65	**6**	**46**
G10	2.84	**6**	12	**6**	0.13	**4**	27.88	**6**	0.97	**1**	77.95	**5**	2112.73	**3**	**31**

Table 4: Results of the univariate stability parameters.

	GY	B_i	S^2d_i	CV	Pi	W_i	R^2
GY	1						
B_i	-0.4790^{ns}	1					
S^2d_i	-0.2430^{ns}	-0.2304^{ns}	1				
CV	0.2970^{ns}	0.2610^{ns}	-0.2430^{ns}	1			
Pi	0.995***	-0.4300^{ns}	-0.259^{ns}	0.3116^{ns}	1		
W_i	-0.867***	0.74000*	0.1700^{ns}	0.0061^{ns}	-0.840***	1	
R^2	-0.3820^{ns}	-0.2364^{ns}	0.813***	-0.4909^{ns}	-0.3830^{ns}	0.2850^{ns}	1

^{ns}=non significant at p=0.05, * significant at P<0.05 *** highly significant at P<0.01

Table 5: Spearman rank correlation among grain yield and stability parameters.

Moreover, the rank correlation between R^2 and S^2d_i, W_i and Pi were strong and highly significant (P<0.001), with positive and negative rank correlation in the former and later respectively (Table 5). In addition, there was a middle high and significant positive rank correlation between (r=0.74*) Wrick's ecovalance and coefficient of regression (P<0.05). This positive rank correlation implies their closer similarity and effectiveness in detecting stable genotypes and they are equivalent in measuring stability. In general, grain yield was positively associated with type-1 stability parameters (CV, Pi), while negatively correlated with type-2 stability models (W_i, B_i) and type-3 stability parameters.

Conclusion and Recommendation

Though varieties Mekelle-03 and FRET1 had the highest overall mean grain yield, but it is difficult to recommend those varieties to all of the five wheat growing locations mentioned in this study. This is because of the fact that these varieties had shown a considerable genotype by environment interaction. Hence, varietal recommendation should be based not only on overall mean grain yield, but also on their stability performance. Those varieties which had shown specific adaptability (HAR-1668, HAR-2501 and JEFERSON) could be recommended for specific locations; while others showing general adaptation (local check, M20ESWYT-46, Picaflor and FRET1) could be grown in wider areas.

As the correlation between grain yield and the univariate stability parameters is concerned, the present investigation revealed that association between grain yield and type-1 stability parameters (CV, Pi) was positive, while yield was negatively correlated with type-2 (W_i, B_i) and type-3 stability parameters.

In general, the different univariate stability parameters considered here in single year multi-location trail declared stability performance of the tested varieties. But there is differential stability ranking when each stability parameter is considered. Therefore for making a concrete conclusion, an overall rank sum of all parameters is quite important.

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Citation: Gebru H, Abay F (2013) Evaluation of Bread Wheat Genotypes for their Adaptability in Wheat Growing Areas of Tigray Region, Northern Ethiopia. J Biodivers Endanger Species 1:104. doi:10.4172/2332-2543.1000104