Stability Analysis of Durum Wheat (*Triticum Durum* Desf) Genotypes by Regression Measurement In Ethiopia

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**ABSTRACT**

In this study, 13 advanced lines with 4 standard and a local check of Durum wheat (*Triticum turgidum var. durum* Desf.) were evaluated for two consecutive cropping seasons (2014-2015) at six research stations for grain yield in Ethiopia. The combined analysis of variance indicated that the main effects of location and genotype and interaction effects of genotype × year, genotype × location and genotype × year × location were highly significant for grain yield. GE interaction was analyzed using linear regression techniques. There was a considerable variation in grain yield among genotypes and environments. Stability was estimated using the Eberhart and Russell method. Stability analysis of grain yield in deferent environments showed that the variance of genotypes and genotypes × environment interactions were significant. Due to the stability analysis, Genotypes 2, 3, 4 and 15 have b value close to one, i.e. genotypes are responsive to good environments, and it may be considered stable for grain yield in all of the environments. The deviation from regression for G7, G9, G10 and G11 are also low and because of the low value of the genotypic mean, these genotypes are intermediate stable and poorly adapted to all environments. None of the genotypes evaluated was perfectly stable in all of the environments due to lack of b- the value equal to unity. The broad sense heritability was 69.2%, indicating selection should give a good response for grain yield.

**Key words**: Durum wheat, heritability, Grain yield, stability, g-e interaction.

1. **INTRODUCTION**

Durum wheat (*Triticum durum* Desf.) produced in most parts of Ethiopia. Durum wheat productivity in developing countries is generally low. This may be attributed to the fact that the crop is grown under low inputs in high rain fall and other marginal areas characterized by sharp annual fluctuations in cropping conditions. Under favorable environments where moisture and other resources are not limiting, higher yield levels, approaching or surpassing bread wheat, are obtained (CIMMYT, 1992). Wheat is grown in the all regions of Ethiopia mostly under the rain fed conditions including Eastern shewa regions. Therefore, annual production is affected to large extent by the annual and seasonal distribution of precipitation, environmental states and crop managements like sowing time, soil fertility, etc. Like to the other crops, increasing the potential of yield is an important target of durum wheat improvement programs production. However, durum wheat yields in most production regions seem to be no more than the potential yields of the cultivars and far below the theoretical maximum yields (Rharrabi, Y., L. F et al., 2003). The improved genotypes evaluated in multi-environment trials to test their performance across different environmental conditions. In most trials, crop yield fluctuates due to suitability of genotypes to different conditions which is known as genotype × environment interaction (GxE) (. Kang M. S. 1998). G ×E can be defined as the difference between the phenotypic value and the value expected from the corresponding genotypic and environmental values (Baker, R. J .1988). Modern agriculture requires determining the stable genotypes and high performance (Becker, H. C. and J. Leon. 1988). In order to increase total production, while wheat cultivars are tested for their yield performances in the different locations and different agriculture practices via sowing time. A genotype is considered to be stable if (i) its variance among the environments is small (static or a biological stability), (ii) its response to environments is parallel to the mean response of all genotypes in the experimental (dynamic or agronomic stability) or (iii) the residual mean square from the regression model on the environmental index is small (Lin et al., 1986).

Methods of Eberhart and Russell (1966), Perkins, and Jinks (1968) are the methods to describe the third type of stability. Lin and Binns(1988) proposed stability concepts on the basis of predictable and unpredictable non-genetic variation. The predictable component related to locations and the unpredictable component related to years. They suggested the use of regression approach for the predictable portion and the mean square for years × locations for each genotype as a measure of the unpredictable
variation. Afzal Arain et al. (2011) was applied the regression analysis to estimate the grain yield stability parameters viz., regression coefficient (b) and deviation from regression coefficients ($S^2_d$) for each genotype and indicated wide adaptation and stability of performance of Msh-14 in all environments according to its regression coefficient (b) close to unity (0.86) and $S^2_d$ close to zero (0.7923). Pompiliu et al. (2009) used coefficient of variation (CV%), the regression intercept(a), Ecovalence (W2), regression slope (b) and Deviations from regression ($S^2_d$) for evaluation of fourteen Romanian winter wheat cultivars in 52 testing environments. The current investigation was carried out evaluate the performance of durum wheat genotypes and to investigate their yield stability by several stability parameters across a range of environments over two consecutive years.

2. MATERIALS AND METHODS

2.1. Plant materials and experimental designs
The experimental materials consist of eighteen genotypes selected from the joint project of ICARDA and CIMMYT and four standard checks (Hitosa, Mangudo, Ude and Yerer) and a local check were evaluated during two cropping seasons (2014–2015) at six research sites.

Table 1: Durum wheat cultivars included in the study

| Code | Selection history | Origin          |
|------|-------------------|-----------------|
| G1   | IDON-MD-2009_off/12/2009 | ICARDA         |
| G2   | IDON-MD-2009_off/34/2009 | ICARDA         |
| G3   | IDON-MD-2009_off/53/2009 | ICARDA         |
| G4   | DSP2009_off.F3.2H.22_meh.1H.26 | CIMMYT       |
| G5   | DSP2009_off.F4.1H.783_meh.4H.259 | CIMMYT       |
| G6   | DSP2009_off.F4.1H.785_meh.2H.262 | CIMMYT       |
| G7   | DSP2009_F6off/1508/2009 | CIMMYT         |
| G8   | IDON-MD-2009_off/25/2009 | ICARDA         |
| G9   | DSP2009_off.F4.1H.378_meh.4H.187 | CIMMYT       |
| G10  | DSP2009_off.F4.3H.639_meh.1H.240 | CIMMYT       |
| G11  | DSP2009_off.F4.2H.712_meh.1H.248 | CIMMYT       |
| G12  | DSP2009_off.F4.2H.735_meh.2H.251 | CIMMYT       |
| G13  | DSP2009_off.F4.3H.976_meh.2H.292 | CIMMYT       |
| G14  | Hitossa | CIMMYT         |
| G15  | Mangudo | ICARDA         |
| G16  | Ude | CIMMYT         |
| G17  | Yerer | CIMMYT         |
| G18  | Local | Ethiopia       |

*CIMMYT = International Centre for Wheat and Maize Improvement
ICARDA = International Center for Agricultural Research in the Dry Areas

The genotypes were grown in a randomized complete block design with four replications at each site. Plot size was 3 m2, 6 rows with 2.5 m long, and 1.2 cm between rows. Where 4 rows harvested to estimate grain per plot and then converted to kg ha$^{-1}$. At harvest grain yield was determined for each genotype at each environments

2.2. Description of experiment
The seed was drilled by hand at seed rate of 125 kg/ha which is equivalent of 45gm/3m$^2$ and planting depth was ~5cm. Planting carried out at appropriate planting time for each location and fertilizer applied according to the specific recommendation (150kg/ha of Urea and 150kg/ha of DAP) of each location. All phosphorous, in the form of Diamonium phosphate (DAP) was applied at planting while nitrogen, in the form of Urea was applied half at planting and the rest half during tillering stage of crop development. Weeding done twice at tillering and at booting stage of the crop by hand..

2.3. Description of experimental sites
The experiment conducted in six locations namely: Debrezeit, Haromaya, Chefe Donsa, Denbi, Manjra and Hosanna for national Durum wheat research project and is representative of different wheat growing agro- ecologies of Ethiopia. Locations are represent the high land zone (1800-3000 Meters above sea level) and are received high rainfall (>750-1300mm) and drained to poorly drained black (vertisol) soils.
Generally, the experimental sites vary considerably in their edaphic and climatic conditions. Maximum and minimum monthly temperature (°C) and monthly rainfall (mm) was considered during the growing periods.
Table 2. Description of experimental sites

| Sl. No | Location  | Altitude Meters above see level | Soil type       | Recommended Dates of sowing |
|--------|-----------|--------------------------------|-----------------|-----------------------------|
| 1      | Minjar    | 1600                           | Light soil      | July 10                    |
| 2      | Denbi     | 1900                           | Pellicvertisol  | July 30                    |
| 3      | Debrezeit | 1860                           | Pellicvertisol  | July 15                    |
| 4      | Haromaya  | 2900                           | Pellicvertisol  | July 21                    |
| 5      | Chefe Donsa | 2460                         | Pellicvertisol  | July 25                    |
| 6      | Hosaena   | 1875                           | Light soil      | July 15                    |

2.4. Statistical Procedures

Combined analysis of variance was done on grain yield that obtained from twelve environments according to the Comstock and Moll (1963) Method. Three stability parameters were applied to assess stability performance of genotypes and to identify superior genotypes; bi, the linear regression of the phenotypic values on environmental index (Finlay and Wilkinson, 1963), S’d, the deviation mean square from regression (Eberhart and Russell, 1966) and coefficient of determination (R2). All analysis was performed using the statistical package GEA-R and SAS 9.2.

The statistical model was given for experimental design is:

\[ Y_{ijkl} = \mu + E_i + R(E)_{j(i)} + G_k + GE_{ik} + e_{ijk}, \]

Where

\[ \mu \] general mean,
\[ E_i \] effect of \( i \)th Environment (\( i = 1, 2, \ldots, 3 \)),
\[ R(E)_{j(i)} \] Effect of \( j \)th block within the \( i \)th Environment (\( j = 1, 2, 3, 4 \)),
\[ G_k \] effect of \( k \)th genotype (\( k = 1, 2, \ldots, 20 \)),
\[ GE_{ik} \] effect of the interaction of the \( k \)th genotype with the \( i \)th environment,
\[ e_{ijk} \] Experimental Error.

3. RESULT AND DISCUSSION

Stability analysis of grain yield in different environments indicated that the variance of genotypes and genotypes × environment (linear) interactions were significant at 1% probability, the average yield across all of environments and some of stability parameters such as coefficient of regression (bi) and deviation from regression \( S \)d presented in Table 4. Mohammad et al. (2013) also found significant differences in grain yield across different wheat genotypes in response to different environmental conditions. This indicates the big influence of environmental effects on grain yield performance of durum wheat genotypes in six considered station. The equal proportion of genotype × year and genotype × year × location variance with genotypes main effect is an important consequence and indicating the significance of genotype × environmental interaction effects. The highest grain yield obtained from genotype 3(Utuba), while the lowest grain yield obtained from genotype 18. Seven genotypes (G2, G3, G9, G10, G11, G14, and G15) provided yields above the average yield.

The combined analysis of variance indicated that the main effects of location and genotype and interaction effects of genotype × year, genotype × location and genotype × year × location were all highly significant (\( P < 0.01 \)) for grain yield. Karimizadeh et al. (2012) considered stability parameters of twenty durum wheat genotypes in twelve environments and indicated that genotype × environment interaction effects significantly influenced genotypes yield. Environment mean yield for all of the genotypes ranged from 2364.92 kg/ha in Denbi to 3854.60 kg/ha in Haromaya.

### Table 3. Analysis of variance (ANOVA) for grain yield of 18 durum wheat genotypes in six locations

| Source     | DF | SS            | MS            |
|------------|----|---------------|---------------|
| Bloc       | 3  | 176947.7      | 58982.6 ns    |
| Year       | 1  | 5208352.8     | 5208352 ***   |
| loc        | 5  | 222169158.3   | 44433831.7 ***|
| Trt        | 17 | 79811795.8    | 4694811.5 *** |
| trt*Year   | 17 | 5517594.1     | 324564.4 ***  |
| loc*trt    | 85 | 91228137.9    | 1073272.2 *** |
| loc*trt*Year | 90 | 70046006.5    | 778289.0 ***  |

Coefficient of Variation 11.3

ns, non-significant, *** significant at 0.01 probability level.

Abbreviations: CD= Chefedonsa, MN= Minjar, DN= Denbi and DZ= Debrezeit
Figure 1. Plot of Eberhart and Russell deviation from regression and coefficient of regression.

Table 4. Mean grain yields and estimates of stability parameters for yield of 18 durum wheat genotypes during 2014 to 2015 in Ethiopia

| GEN | Mean  | Sd   | CV(%) | Eberhart & Russell | Wricke's Ecovalence |
|-----|-------|------|-------|---------------------|---------------------|
|     | Mean  |      |       | Mean  |       |       |       |       |       |       |
| G1  | 3090.91 | 908.2327 | 29.384 | 1.5465 | 57110.55 | 0.8945 | 895806.659 |
| G2  | 3455.598 | 589.6763 | 17.0644 | 0.9431 | 39939.12 | 0.7892 | 371430.3448 |
| G3  | 3818.898 | 681.9023 | 17.856 | 1.0598 | 96431.72 | 0.7452 | 597922.7393 |
| G4  | 2920.826 | 651.2114 | 22.955 | 1.0655 | 40602.7 | 0.8259 | 375711.3667 |
| G5  | 3009.208 | 550.9641 | 18.3093 | 0.7116 | 132517.6 | 0.5146 | 865098.8942 |
| G6  | 3005.188 | 897.8703 | 29.8773 | 1.4929 | 96552.06 | 0.8529 | 967622.2319 |
| G7  | 3086.748 | 701.9114 | 22.7395 | 1.205 | 4154.181 | 0.9094 | 288159.4113 |
| G8  | 2895.762 | 590.3657 | 20.3872 | 0.8861 | 81198.24 | 0.695 | 551495.9 |
| G9  | 3151.915 | 772.5518 | 24.5105 | 1.347 | -5348.66 | 0.9379 | 371021.5855 |
| G10 | 3115.43 | 830.2525 | 26.6497 | 1.4574 | -9137.09 | 0.9506 | 492847.2481 |
The deviation from regression for G7, G9, G10 and G11 are also low and because of low value of genotypic mean, these genotypes are intermediate stable and poorly adapted to all environments. A desirable genotype with stability and above average grain yield should have a regression line with a positive intercept and slope equal to 1.0 (Eberhart and Russell, 1966). Mohammadi et al. (2012) used linear regression and deviations from the regression model for estimation of stability of twenty durum wheat genotypes in dry land conditions and determined the stable genotypes. However, according to Eberhart and Russell (1966), an ideal genotype would have both a high average performance over a wide range of environments and stability. Therefore, the genotypes including G2, G3 and G14 have good performance and stable cultivars.

Coefficient of determination ranged from 30 to 95% (Tab.3). The coefficient of determination of some durum wheat genotypes was very high. Genotypes 2, 3, 4 and 15 have $\beta$ value close to one, i.e. genotypes are responsive to good environments. I.e. Genotypes are agronomic stable.

The regression analysis as one of the important parameter which has been frequently employed by plant breeders for stability analysis, showed that there were wide ranges of deviations in genotypes. Deviation from regression for any of the genotypes were tested in response to the environment. None of the genotypes evaluated was perfectly stable in a season. Farmers near East shewa saw their neighbors’ bread fields completely wiped by stems rust, but with Utuba, even the worst rust infections only affected 5% of the stem. This high level of resistance to rust was one of the most visually compelling decision points for farmers to adopt the variety. Protein content in this variety tends to be high, the gluten is strong, and the color of the semolina is excellent amber yellow.

Heritability of a trait is important for plant breeders, because it reflects its response to selection. The broad sense heritability (phenotypic variance due to genetic variability) was 69.2% indicating genotype plays a significant role in the expression of the phenotype and selection should give a good response. The important purpose for breeders is to find genotypes with good and stable not only for end-users, but also to provide parents in the future breeding programs. The results of this study indicated that grain yield was significantly influenced by changes in environmental conditions because there were significant variations in grain yields of the genotypes were tested in response to the environment. None of the genotypes evaluated was perfectly stable in all of the environments due to lack of $b$ value equal to unity.

The stability parameter also favors G2, G3, G11 and G14 for their stability in high yielding environment (Haromaya and Chefe donsa). None of the genotypes was favored to low yielding environment (Denbi).

### Table 5. Grain yield (kg/ha) of 18 durum wheat genotypes in the six environmental conditions during 2014 to 2015 in Ethiopia

| Genotypes | CD     | DN     | DZ     | HM     | HN     | MN     |
|-----------|--------|--------|--------|--------|--------|--------|
| 1.IDON-MD-2009_off/12/2009 | 3804.69 | 2384.63 | 2998.75 | 4631.90 | 2543.88 | 2244.32 |
| 2. IDON-MD-2009_off/34/2009 | 3567.50 | 2918.46 | 3407.14 | 4597.04 | 3284.86 | 3037.01 |
| 3. IDON-MD-2009_off/53/2009 | 4089.29 | 3154.16 | 4444.27 | 4695.22 | 3088.90 | 3483.39 |
| 4. DSP2009_off.F3.2H.22_meh.1H.26 | 3706.25 | 2078.21 | 3218.13 | 3445.81 | 2392.43 | 2686.31 |
5. DSP2009_off.F4.1H.783_meh.4H.25 9  
   3071.38  3068.85  3058.85  3965.82  2771.08  2309.40
6. DSP2009_off.F4.1H.785_meh.2H.  
   3290.31  1591.47  3550.88  4194.89  2707.21  2799.54
7. DSP2009_F6off/1508/2009  
   3974.69  2044.68  3077.94  4194.89  2707.21  2799.54
8. IDON-MD-2009_off/25/2009  
   3974.69  2044.68  3077.94  4194.89  2707.21  2799.54
9. DSP2009_off.F4.1H.378_meh.4H.  
   3890.00  1939.41  3434.00  3927.19  2988.01  2687.83
10. DSP2009_off.F4.3H.639_meh.1H.  
    4179.02  1890.93  3143.57  3990.89  2874.79  2774.33
11. DSP2009_off.F4.2H.712_meh.1H.  
    3834.13  3505.12  3482.71  4238.39  3716.65  3458.88
12. DSP2009_off.F4.2H.735_meh.2H  
    3677.38  2530.79  2656.80  3439.27  2568.95  2371.69
13. DSP2009_off.F4.3H.976_meh.2H  
    3640.56  1798.71  3499.52  3607.43  2383.45  2797.83
14. Hitossa  
    3669.69  2872.50  2877.41  4219.10  3302.47  2913.63
15. Mungodo  
    3579.85  2080.50  3618.29  3685.88  3558.49  2431.33
16. Ude  
    2745.00  2626.16  2686.56  4028.51  3209.95  2785.60
17. Yerer  
    3548.69  2868.66  2803.50  3283.18  2945.74  2525.76
18. Local  
    3508.38  1534.10  2154.44  2698.02  2486.50  2597.74

Grand Mean 3611.84  2378.45  3158.33  3890.59  2925.78  2765.39

LSD (0.05%)  
   633.39  333.58  551.79  441.01  355.70  555.26
CV%  
   16.90  12.46  16.18  10.35  11.11  18.01

Broad sense Heritability 0.53  0.94  0.77  0.85  0.84  0.67

*CD=Chefe donsa,DN=Denbi,DZ=Debrezeit,MH=Haromaya,HN=Hosana,MN=Minjar

4. CONCLUSION
Eighty durum wheat genotypes, including 13 advanced lines with 3 standard and a local check were evaluated during two cropping seasons (2014–2015) at six research sites, representative of major durum wheat producing areas of Ethiopia. Stability parameters were applied to assess stability performance of genotypes and to identify superior genotypes; bi, the linear regression of the phenotypic values on environmental index, S2d, the deviation mean square from regression and coefficient of determination. Genotypes 2, 3, 4 and 15 have β value close to one, i.e. genotypes are responsive to good environments, considered stable for grain yield in all of the environments. G7, G9, G10 and G11 are also low and because of low value of genotypic mean, these genotypes are intermediate stable and poorly adapted to all environments.

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