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# Yield Stability of Some Soybean Genotypes Across Diverse Environments

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**Abstract** : Five soybean genotypes (Giza 35, Crawford, Giza 82, Clark and Giza 111) were evaluated in six sowing dates (Feb. 25, Mar. 25, Apr. 25, May 25, June 25 and July 25) during the two consecutive growing summer seasons of 2000 and 2001 at Agricultural Experimental Research Station in Dirab, Saudi Arabia to explore the genotypes x environment effects and stability in performance of soybean genotypes for seed yield. Genotypes, years, sowing dates and their interaction were highly significant for the studied traits. The significant G x E interaction for seed weight per plant (g) and seed yield (t $ha^{-1}$) indicated that the tested genotypes ranked differently across diverse environments. The response of seed weight and seed yield varied from genotype to another across different environmental conditions. This may offer raw material for improving soybean performance under the investigated conditions. Giza 111 and Clark had high means performance and had high phenotypic stability and they could be grown over wide range of environments. Results showed that Giza 111 and Clark have the highest mean values, while Giza 82 and Giza 35 had the lowest mean values over all environments and poorly adapted. The results suggested that to maximize seed yield potential, genotypes which have a consistently high yield performance across diverse growing environments should be selected and more than one year of evaluation. Genotype x environment interactions proved to play a significant role in the success of any breeding programs for development of genetic materials adapted to wide range of environments.

**Key words:** Soybean (*Glycine max* L.) genotypes, stability, seed yield, G x E environment interactions, yield potential, genetic materials

## INTRODUCTION

The main goal when growing crops everywhere is to maximize net profit mainly through increasing seed yields. However, in semi-arid regions with unstable weather conditions, in which the variability among locations, years and seasons can severely affect the yield of soybean. Using stable genotypes for high seed yield is an important objective for sustainable agriculture[1]. Soybean (*Glycine max* L. Merr.), is one of the most important crops that has the potential to provide the world's increasing demand for food and forage. The spread of soybean from its native land of origin has been mainly due to its adaptability and predominant use as a food crop for human nutrition, source protein for animals, medicinal plant and lately as an industrial crop[2]. Developing high yielding early maturing cultivars under a wide range of different environments is of vital importance to increase soybean area and production. A knowledge of the genetic variability is most important in plant improvement programs. Further, the breeding material should be evaluated under different environments, because in the absence of information on genotype x environment interactions (GE), estimation of heritability and prediction of genetic advance become biased[3].

Allard and Bradshow[4] indicated the best genotype is the one that has consistently high performance over several environments. Genotype x environment interaction plays a significant role in the phenotypic performance of any cultivar and in the success of any breeding programs for the development of genetic material, adapted to a wide range of environments. Finlay and Wilkinson[5] stated that the regression coefficient of varietal means on environmental means could be used as an indicator for phenotypic stability.

Eberhart and Russell[6] noted that regression techniques allow the genotype x environment interactions of each genotype to be partitioned into two parts: (1) the portion of GE interaction due to the response in performance of the genotype to environments of varying levels of productivity, and (2) the portion due to deviations from regression.

Beaver and Johnson[7] noted that soybean breeders have traditionally emphasized wide adaptation rather than specific adaptation in their breeding programs and select genotypes that perform well over a wide range of climatic

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and adapted conditions. Radi *et al.*[8] evaluated five soybean genotypes under different locations and years. Their results revealed that seed yield was remarkably affected by varying locations and years. The ratio between linear and non-linear response was found to be high by reflecting a considerable role of the linear response in stability reactions. Deka and Talukder[9] reported that some soybean genotypes showed average degree of stability, whereas one genotype had above average degree of stability.

Al-Assily *et al.*[10] evaluated five soybean genotypes at different locations in two seasons. Results showed that, three genotypes namely; Giza 35, H2L12 and Giza 111 had a high seed yield performance with high degree of stability and it could be grown over wide range of environments.

Mohamed[11] and Ali[12] reported that sowing date plays an important role in crop productivity. Seed yield of soybean genotypes decreased with delayed sowing. They added that higher yields were associated with seed weight per plant.

Bakheit[13] evaluated fifteen soybean genotypes during three seasons under three sowing dates. Data confirmed the fact that high yielding genotypes, were more likely to have lower stability and vice versa low yielding genotypes tend to have high stability at different environments. According to Gebeyehu and Assefa[14] selection based on the highest yielding genotypes appeared less stable than the average of all lines, and selection solely for seed yield could result in discarding several stable genotypes. In soybean crops, yield variation of cultivars across locations and years has been associated with changes in number of seeds per unit area[15]. Hence the yield component is largely determined during a period that begins in flowering and extends through pod setting[16].

In fact crop performance is strongly influenced by weather conditions. So, vulnerability of cultivars to environmental variation can be also viewed as a barrier to imposing yield potential. This is apparent when considering the fact that any breeding program, no matter how localized, must create lines which are adapted to a range of environments, at the very least those representing yearly weather fluctuations as well as those imposed by varying farmers practices. If soybean yield potential is to meet future demands, targeting the underlying physiological causes of genotype x environment interactions for genetic improvement would be worthwhile investment[17].

Because of scarce information regarding the stability of soybean genotypes in Saudi Arabia, the present study was initiated. The aimed was to determine the nature of genotype x environment interactions and estimate the phenotypic stability parameters to identify the stable soybean genotypes for seed yield (t $ha^{-1}$) and seed weight per plant under different sowing dates in the Central Region of Saudi Arabia.

## MATERIALS AND METHODS

This investigation was carried out at Dirab Agricultural Experimental Research Station, College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia during 2000 and 2001 summer growing seasons (24°42 N Latitude and 46°44 E Longitude). Maximum, minimum, mean temperature and relative humidity during the study of 2000 and 2001 seasons are shown in Table 1.

Five soybean genotypes (Giza 35, Crawford, Giza 82, Clark and Giza 111) were evaluated in six sowing dates (Feb. 25, Mar. 25, Apr. 25, May 25, June 25 and July 25). The experimental design was laid out in a split-plot design with three replications. Main plots were devoted to sowing dates and sub-plot to soybean genotypes. Each plot consisted of 5 rows, three meters long with 50 cm apart (plot size = 7.5 $m^2$). Standard cultural practices were applied. At harvest, ten guarded plants were randomly taken from each sub-plot to measure seed weight per plant (g). Seed yield (t $ha^{-1}$) was calculated on the basis of plot area.

**Statistical procedures:** The combined analysis of variance was carried out according to Steel and Torrie[18], to estimate the main effects of the different sources of variation and their interactions. Then, a combined analysis was again conducted over 12 environments (six sowing dates and two seasons), to estimate the effect of genotype by environment interaction on yielding ability. Evaluation of yield stability of soybean genotypes was carried out with coefficient of variance within the six sowing dates at two seasons. The coefficient of variance is a relative measure since it depends in the level of yield (cv=s/x) where, s is standard deviation and x is an average yield.

The phenotypic stability analysis was conducted using the model suggested by Eberhart and Russell[6] where genotypes were considered fixed, while years and sowing dates were random variables. The model provides two stability parameters: The first estimate was the linear regression coefficient (b) of genotype mean on the average of all genotypes in each environment; The second estimate was the mean squares of deviation from regression ($S^2d$) for each genotype. However, the ideal variety is one with a high mean performance, unit

Table 1: Monthly maximum, minimum, mean temperature and relative humidity during 2000 and 2001 seasons

| | Temperature (°C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | | Minimum | | Mean | | Relative humidity % | |
| Months | 2000 | 2001 | 2000 | 2001 | 2000 | 2001 | 2000 | 2001 |
| February | 25.9 | 27.3 | 11.7 | 11.3 | 18.8 | 19.3 | 18.9 | 18.4 |
| March | 28.5 | 29.3 | 11.9 | 11.6 | 20.2 | 20.5 | 24.5 | 20.5 |
| April | 36.1 | 35.4 | 19.1 | 16.5 | 27.6 | 26.0 | 16.8 | 13.2 |
| May | 41.1 | 41.3 | 23.6 | 22.0 | 32.4 | 31.7 | 10.7 | 10.0 |
| June | 43.9 | 43.9 | 25.8 | 25.0 | 35.1 | 34.5 | 10.1 | 10.3 |
| July | 44.3 | 45.4 | 26.2 | 26.0 | 35.1 | 35.7 | 10.8 | 10.9 |
| August | 44.7 | 45.1 | 27.5 | 26.7 | 36.1 | 35.9 | 10.9 | 10.8 |
| September | 41.6 | 43.5 | 24.2 | 22.0 | 32.9 | 32.8 | 11.1 | 11.2 |
| October | 36.9 | 36.6 | 18.7 | 16.7 | 27.8 | 26.7 | 11.3 | 11.4 |

regression coefficient (b=1) and the deviation from regression approaching zero as possible as ($S^2d = 0$)[19].

Evaluation of crop adaptability to yielding capacity of particular years was conducted by linear regression analysis. This method uses the regression coefficient slope of each cultivar on the average yield of all cultivars evaluated in different environments (sowing dates) as a measure of cultivars yield responsiveness, and conceptually a reciprocal of yield stability, interpreted as: a) slope<1 indicating higher stability, low responsiveness. b) Slope =1, average stability, average responsiveness. c) Slope>1 lower stability, higher responsiveness, adapted to high yielding environments[20].

The regression coefficient (Bi) and genotype mean yield were used together as a measure of adaptation according to Bilbro and Ray[20]. Genotype with b = 1.0 was considered adapted for all environments; while genotype with b<1.0 was considered adapted for low yielding environments and genotype with b>1.0 was considered better adapted for high yielding environments, depending upon the genotype mean yield.

Table 2: Pooled analysis of variance for seed yield (t/ha) and seed weight/plant (g) of five soybean genotypes based on two seasons and six sowing dates

| | | Mean of squares | |
|---|---|---|---|
| Source of variation | Df | Seed yield (t ha$^{-1}$) | Seed weight/plant (g) |
| Years (Y) | 1 | 0.007 | 50.43** |
| Sowing dates (S) | 5 | 3.490** | 135.55** |
| Y x S | 5 | 0.110** | 5.94** |
| Genotypes (G) | 4 | 3.950** | 364.70** |
| G x Y | 4 | 0.020 | 1.80 |
| G x S | 20 | 0.110** | 4.93** |
| G x Y x S | 20 | 0.050** | 1.19 |
| Pooled error | 96 | 0.020 | 1.25 |

*, ** indicates significant at 5 and 1% level of probability, respectively

Table 3: Analysis of variance for some studied traits of five soybean genotypes under 12 environments

| | | Mean of squares | |
|---|---|---|---|
| Source of variation | Df | Seed yield (t ha$^{-1}$) | Seed weight/plant (g) |
| Environment (E) | 11 | 1.64** | 68.89** |
| Reps/Env. | 24 | 0.01 | 1.53 |
| Genotypes (G) | 4 | 3.95** | 364.69** |
| G x E | 44 | 0.07** | 2.95 |
| Error | 96 | 0.01 | 1.41 |

*, ** indicates significant at 5 and 1% level of probability, respectively

## RESULTS AND DISCUSSION

The combined analysis of variance (Table 2) revealed that genotypes, years, sowing dates and their interactions were significant at 1 and 5% level of both agronomic traits. This indicated that the interaction of genotypes with environments was considerable importance in determining relative yield. These results are in agreement with those obtained by Comstock and Moll[3].

The analysis of variance of combined data for seed yield (t ha$^{-1}$) and seed weight per plant (g) over 12 environments (Table 3) indicated that mean squares due to environments, genotypes and genotype x environments interactions were highly significant among the two traits. This indicated that genotypes responded differently with the environments. So, environments effects were significant with the highest value for seed yield (2.807 t ha$^{-1}$) was obtained from May 25 (Env.10) while the lowest value from Feb. 25 (Env.7). Therefore, The significance of environment on the performance of agronomic traits showed strong influence of environment on the performance of soybean genotypes.

Regarding seed yield (t ha$^{-1}$), results indicated that yield ranged from 1.868 tons in Env. 7 (Feb. 25) during 2001 season to 2.807 tons in Env. 10 (May 25) during the same season. Over all environments (sowing dates), Giza 111 and Clark recorded the highest seed yields with an average of 2.588 and 2.536 t ha$^{-1}$, respectively (Table 4). On the other hand, the genotype, Giza 82 gave the lowest yield (1.784 t ha$^{-1}$). As far seed weight/plant, data suggested that maximum seed weight/plant (19.54 g) was obtained from planting on June 25 during 2001 season (Env. 11), while planting on Feb. 25 during the 2000 gave the lowest seed weight/plant (13.10 g/plant).

Highly significant differences were detected among the tested genotypes, suggested that the presence of

Table 4: Mean seed yield (t ha$^{-1}$) and seed weight/plant (g) of five soybean genotypes evaluated under six sowing dates during 2000 and 2001 seasons

| | Seed yield (t ha$^{-1}$) 2000 | | | | | | 2001 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Env.1 | Env.2 | Env.3 | Env.4 | Env.5 | Env.6 | Env.7 | Env.8 | Env.9 | Env.10 | Env.11 | Env.12 | Mean |
| Giza 35 | 1.900 | 2.040 | 2.200 | 2.750 | 2.543 | 1.630 | 1.998 | 1.861 | 2.037 | 2.942 | 2.707 | 1.585 | 2.183 |
| Crawford | 2.150 | 2.417 | 2.463 | 2.843 | 2.658 | 2.147 | 1.997 | 2.433 | 2.547 | 2.662 | 2.802 | 2.183 | 2.442 |
| Giza 82 | 1.585 | 1.603 | 2.080 | 2.167 | 1.802 | 1.528 | 1.197 | 1.523 | 1.958 | 2.535 | 2.063 | 1.362 | 1.784 |
| Clark | 2.183 | 2.767 | 2.405 | 2.847 | 2.715 | 2.185 | 2.072 | 2.395 | 2.708 | 2.898 | 2.900 | 2.362 | 2.536 |
| Giza 111 | 2.212 | 2.673 | 2.767 | 3.070 | 2.890 | 2.155 | 2.075 | 2.370 | 2.890 | 2.997 | 2.713 | 2.242 | 2.588 |
| Mean | 2.006 | 2.300 | 2.383 | 2.735 | 2.522 | 1.929 | 1.868 | 2.116 | 2.428 | 2.807 | 2.637 | 1.947 | 2.307 |
| C.V. % | | | | | | | | | | | | | 3.10 |
| LSD $_{0.05}$ | | | | | | | | | | | | | |
| Genotype (G) | | | | | | | 0.058 | | | | | | |
| Environments (E) | | | | | | | 0.900 | | | | | | |
| G x E | | | | | | | 0.202 | | | | | | |
| | Seed weight/plant (g) 2000 | | | | | | 2001 | | | | | | |
| | Env.1 | Env.2 | Env.3 | Env.4 | Env.5 | Env.6 | Env.7 | Env.8 | Env.9 | Env.10 | Env.11 | Env.12 | Mean |
| Giza 35 | 9.83 | 11.33 | 12.47 | 17.67 | 16.63 | 10.83 | 10.30 | 11.43 | 12.13 | 17.77 | 17.30 | 11.87 | 13.30 |
| Crawford | 15.50 | 16.77 | 17.40 | 19.03 | 18.63 | 16.37 | 15.93 | 16.67 | 17.33 | 20.53 | 23.50 | 16.53 | 17.85 |
| Giza 82 | 7.80 | 9.70 | 11.20 | 13.43 | 12.43 | 9.43 | 9.53 | 11.57 | 12.53 | 15.17 | 15.20 | 9.47 | 11.46 |
| Clark | 16.50 | 17.93 | 18.23 | 18.17 | 17.77 | 16.03 | 17.00 | 18.57 | 18.80 | 20.37 | 20.80 | 15.93 | 18.01 |
| Giza 111 | 15.87 | 17.53 | 18.43 | 19.53 | 19.43 | 15.77 | 16.83 | 18.27 | 18.53 | 22.40 | 20.90 | 16.23 | 18.31 |
| Mean | 13.10 | 14.65 | 15.55 | 17.57 | 16.98 | 13.69 | 13.92 | 15.30 | 15.87 | 19.25 | 19.54 | 14.01 | 15.79 |
| C.V. % | | | | | | | | | | | | | 4.09 |
| LSD $_{0.05}$ | | | | | | | | | | | | | |
| Genotype (G) | | | | | | | 0.55 | | | | | | |
| Environments (E) | | | | | | | 0.86 | | | | | | |
| G x E | | | | | | | 1.92 | | | | | | |

Table 6: Stability parameters for seed yield (t ha$^{-1}$) and seed weight/plant (g) of five soybean genotypes over 12 environments

| Genotype | Mean/(x) | Regression coefficient (b) | Deviation from registration ($S^2d$) | t-test of significant for (b) b = 0 | b = 1 | Mean/(X) | Regression Coefficient (b) | Deviation from regression ($S^2d$) | t-test of significant for (b) b = 0 | b =1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Giza 35 | 2.183 | 1.256 | 0.028 | 10.13** | 2.07 | 13.30 | 1.35 | 0.87 | 12.41** | 3.21 |
| Crawford | 2.442 | 0.792 | 0.003 | 6.39** | -1.68 | 17.85 | 1.00 | 0.22 | 9.25** | 0.04 |
| Giza 82 | 1.784 | 1.079 | 0.019 | 8.70** | 0.64 | 11.46 | 1.09 | -0.16 | 9.99** | 0.79 |
| Clark | 2.536 | 0.845 | 0.001 | 6.81** | -1.25 | 18.01 | 0.64 | 0.12 | 5.87* | -3.33 |
| Giza 111 | 2.588 | 1.028 | 0.008 | 8.29* | 0.23 | 18.31 | 0.92 | -0.14 | 8.50** | -0.71 |

*, ** indicates significant at 5 and 1% level of probability, respectively

genetic variability among the cultivars for the two tested agronomic traits (Table 5). Significance of interaction suggested that some genotypes were more stable than others across environments. Partitioning of G x E interaction into its components ($\delta^2$) revealed that Giza 35 was unstable genotype for seed yield (t ha$^{-1}$) and seed weight/plant. On the other hand, Giza 111 was highly stable for the two characters. This finding are in agreement with those of Eberhart and Russell[6], who suggested that the mean performance coupled with the regression coefficient values and deviation from regression would provide a useful parameters for studying the adaptation of genotypes. This finding are in line with those of Finlay and Wilkinson[5] who suggested that reported that when the regression coefficient was associated with high means, the genotypes have general adaptability; however, when associated with low means, the genotypes are poorly adapted to all environments. Moreover, they reported the ideal variety is one with a high mean performance, unit regression coefficient

Table 5: Analysis of variance and partitioning of genotype x environment interaction into components assigned to each genotype for seed yield (t/ha) and seed weight/plant (g)

| Source of variation | Df | Mean of squares: Seed yield (t ha$^{-1}$) | Seed weight/plant (g) |
|---|---|---|---|
| Genotype | 4 | 1.317** | 121.57** |
| Env. (G*Env) | 55 | 0.129** | 5.38** |
| a) Env. (linear) | 1 | 6.006** | 252.59** |
| b) G* Env. (linear) | 4 | 0.042 | 3.35** |
| c) Pooled deviation | 50 | 0.019** | 0.60 |
| Giza 35 | 10 | 0.033** | 1.29** |
| Crawford | 10 | 0.008 | 0.63 |
| Giza 82 | 10 | 0.024** | 0.25 |
| Clark | 10 | 0.015 | 0.54 |
| Giza 111 | 10 | 0.013 | 0.27 |
| Pooled error | 96 | 0.005 | 0.42 |

*, ** indicates significant at 5 and 1% level of probability, respectively

(b = 1) and the deviation from regression ($S^2d$) close to be zero as possible as. Accordingly to Eberhart and Russell[6] a stable genotype is that which has a (b) value insignificantly different from unit (one) and ($S^2d$) value insignificantly different from zero. Estimate of the stability parameters for the characters under study are shown in Table 6.

The results clearly, indicated that all the genotypes had regression coefficient estimates that did not differ significantly from unit (b = 1) but it differed significantly from zero (b = 0). According to these assumptions, it can be generally concluded that Giza 111 followed by Clark exhibited regression coefficients equal to one, low values of $S^2d$, high mean yield and were characterized by general stability for high seed yield (t $ha^{-1}$) and seed weight per plant. Moreover, The genotypes Giza 111 and Clark have the highest mean values for the studied characters , while the two genotypes Giza 82 and Giza 35 had the lowest mean values over all environments and showed poorly adaptation.

It can be concluded that soybean breeders should consider environmental conditions and general stability as a criteria for selecting high yielding genotypes. These results are in agreement with those obtained by Comstock and Moll[3], Mohamed[11], Radi *et al.*[8], Bakheit[13] and Al-Assily *et al.*[10].

Finally, it can be concluded that a): Genotype x environment interactions play a significant role in the success of any breeding programs for development of genetic materials adapted to wide range of environments, b): Two genotypes namely; Giza 111 and Clark had a high mean performance and had high phenotypic stability and it could be grown over wide range of environments; c) The highest performing genotype was not necessarily has the highest stable level and selecting the best genotypes can not be based upon the means a lone but the stability of these genotypes should be examined and d) Seed yield by itself may not be the best criteria for selection.

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