

Research paper

Soybean (*Glycine max* .L) genotype and environment interaction effect on yield and other related traits

ABSTRACT

Aims: To evaluate genetic variability of some genotypes, and to assess genotype and environment interaction effect on seed yield and other related traits.

Study design: The design was Split-plot, replicated three times. Genotypes were considered as fixed effect while plots (main 60 m² and subplot 12 m²) were random effects. The Sub-plot consists of 4 rows 5 m long at a distance of 60 cm between rows and 10 cm between plants was used.

Place and Duration: El Gantra, Range and Pasture Farm in Sennar State of the Sudan between 2009 and 2010 cropping season.

Methodology: Five soybean genotypes NA 5009 RG; TGx 1904-6F, TGx 1740-2F, TGx 1937-1F and Soja were evaluated in ten environments. A strain of *Rhizobium japonicum* was used for inoculation at a rate of 10 g per kg of soybean seed using a sugary solution in 2009. Inoculation was not carried out due to the assumption that the field had the remnant of inoculum effect. The recommended soybean agronomic practices were equally applied. Number of days to 50 % flowering was scored at plot basis when almost half of the sub-plot flowers. Ten plants were randomly selected at plot basis to quantify these traits. Plant height was measured as from ground surface to the base of meri-stem of the mother plant. Number of branches was computed as the average count of branches per plant. Leaf area was computed using lamauti (1995) empirical relationship. The first pod height was measured at full bloom. Number of seeds per pod was counted at physiological maturity of the crop. 100-seed weight was determined randomly from a seed bulk using a digital weighing machine. Seed yield was quantified after harvest and converted into kg/hectare.

Results: The effect of genotype (G), environment (E) and G × E interactions on pod number per plant; plant height, first pod height, number of branches per plant, leaf area, number of days to 50 % flowering and seed yield were found significantly at (P=0.05). The mean highest seed yield was obtained from TGx 1937-1F (0.98 t/ha). Beside TGx 1740-2F, TGx 1904-6F and Soja were good performers in all environments for seed yield. TGx 1937-1F was good in terms of number of pods per plant, number of branches per plant, and leaf area. TGx 1740-2F was outstanding in terms of plant height and first pod height, whereas Soja has the highest number of seeds per pod and heaviest 100-seed weight. NA 5009 RG was the lowest yielder in all environments.

Conclusion: It can be deduced from the study that the best genotype for seed yield across the environments was TGx 1937-1F compare to the intermediate performers TGx 1740-2F, TGx 1904-1F and Soja. The lowest was NA 5009 RG. Thus, partitioning G × E into adaptability and phenotypic stability will positively address the information gap about the performance of these genotypes. Eventually it will play significant role in breeding for adaptation at diverse environment.

Keyword: Soybean × E interaction, genetic variability and yield

1. INTRODUCTION

Soybean (*Glycine max* L) is one of the oldest world grown crops. It contains 20 to 22 % essential amino acids 40 % protein and 18 – 22 % oil of 85 % cholesterol free (Azhari 1987 and Malik *et al.*, 2006). The crop is an important legume with multifarious uses. Its cost effectiveness is ensured through biological nitrogen fixation and rotation with exhaustive crops. It replenishes and maintains soil fertility.

In the Sudan, soybean trials started as early as 1925 at Gezira Research Farm where a low yield of 500 kg/ha was obtained. This low yield was attributed to lack of cultivars adaptable to the Sudan agro-ecological conditions. Thus, researchers at the stations were reluctant to work on soybean. Nevertheless, in early 1980's several attempts were made one at Agadi Experimental Farm where a yield of 500 – 1000 kg/ha was obtained (Faisal 1986). Furthermore, he reported that in Damazin an area of 1260 hectares was used for commercial

production, but the crop failed to meet the desired objective of the project. Lack of adaptable cultivar to the Sudan agro-ecological conditions has enormously contributed into the existing information gap on association of traits with seed yield. This association is of great importance to define selection criteria for yield improvement.

Seed yield is a complex trait determined by several traits having positive or negative effects on yield. However, it is important to examine the contribution of each of the traits in order to give more attention to those having the greatest influence on seed yield. According to Soldati (1995) the expression of the traits is determined by genetic and environmental factors and their interaction. Therefore, to determine variability of quantitative traits caused by genetic, environmental and interaction under Sudan agro-ecological conditions, the study was designed to:

- i. evaluate the genetic and environmental variability of the genotypes and
- ii. assess the genotype $\times$ environment effect on yield and other related traits

2. MATERIALS AND METHODS

Five soybean genotypes namely: TGx 1740-2F, TGx 1904-6F and TGx 1937- were obtained from International Institute of Tropical Agriculture (IITA) Nigeria and NA 5009 RG and Soja from ORNAS Company in Khartoum, were studied under five different sowing dates over two years at El – Gantra, in Range and Pasture Farm of Sennar State. Sennar State lies between latitude 14° 24' N and longitude 33° 29' E. The soil is best described as heavy clay (60%) with low organic content of 0.5%, 0.05% nitrogen, and 2.8 mg/kg available phosphorus with a pH of 8.2. and was disc ploughed, levelled and ridged before sowing. The site was pre-irrigated three days prior to experimentation.

The design of the study was Split-plot replicated three times. Planting date was a main plot factor and genotype was a subplot. The sizes of the main and subplots were 12 m $\times$ 5 m and 2.4 m $\times$ 5 m. These subplots consisted of 4 rows 5 m long each distance of 60 cm between rows and 10 cm between plants. In addition, all soybean cultural practices were equally applied across the five sowing dates over two years. Two seeds were planted per hill on the ridged then thinned to one after three weeks. The seed was inoculated once in 2009 with *Rhizobium japonicum* strain at a rate of 10 g per 1 kg of soybean seed using a sugary solution to ensure the sticking of the strain on the seed surface to initiate nodulation upon establishment. The experiment was repeated in the same site without further inoculation because it was assumed to have remnant of inoculum effect. Number of days to (P=0.5) flowering was scored at plot basis when almost half of the sub-plot flowered. Ten plants were randomly selected at plot basis to quantify these traits. Plant height was measured as from ground surface to the base of meri-stem of the mother plant. Number of branches was computed as the average count of branches per plant. Leaf area was computed using lamauti (1995) empirical relationship. The first pod height was measured at full bloom. Number of seeds per pod was counted at physiological maturity of the crop. 100-seed weight was determined randomly from a seed bulk using a digital weighing machine. Seed yield was quantified after harvest and converted into kg/hectare.

In the ten environments (five sowing dates in 2009 and 2010), both morphological, yield and yield components traits were recorded. Plant height, first pod height, days to 50 % flowering, number of branches per plant, leaf area, number of pods per plant, number of seeds per pod, 100-seed weight and seed yield was noted down.

All data collected were subjected to Statistical Analysis System (SAS, 2000) package for computing analysis of variance (ANOVA) and mean performance of genotypes were compared using Duncan's Multiple Range test (DMRT) by Ashraf (2008). In ANOVA, each sowing date and year was considered as an environment. Genotype was considered as a fix effect while plots (main and sub-plots), and replications as random effects.

3. RESULTS AND DISCUSSION

Combined ANOVA for soybean seed yield and agronomic traits across the two years (2009 and 2010) are presented in Table 1). Almost all traits showed significant difference between genotype $\times$ year except for 1st pod height, number of seeds per pod and 100-seed weight, but $G \times S$ had significant differences at ($P=0.05$) for all traits with exception of 1st pod height, number of branches per plant, number of seeds per pod, 100-seed weight (Table 1). This high variability among the genotypes was due their response to climatic changes in the ten environments. This accentuate Kang (1998) findings that environment played major role in phenotypic expression of agronomic traits.

The seed yield of individual genotypes across the ten environments, showed that TGx 1937-1F (1.86 t/ha) was the highest yielder and NA 5009 RG (0.12 t/ha) was the least (Table 2). On the other hand, NA 5009 RG had the heaviest 100-seed weight (12.67 and 8.67 g) and like-wise the lightest across ten environments (Table 3). In all the environments, plant height range between 21.0 – 40.3 cm, first pod height 4.1– 6.8 cm, number of branches 2.0 – 4.6, number of pods per plant 24.9 – 61.8, number of seeds per pod 2.0 – 2.2, leaf area 68.7 – 135.5 cm², number of days to 50% flower 17.7 – 40.0, 100-seed weight 12.6 – 14.6 g and seed yield 0.48 – 0.98 t/ha (Table 3). Hence, the compared mean of the traits across the five sowing dates over two years are revealed that all traits of the genotypes responded differently with exception of number of seeds per pod (Table 3).

Table 1. Mean square of analysis of variance of five genotypes across sowing dates averaged over two years

Source of Variation	DF	Plht (cm)	1stpdht (cm)	Branchpp (no.)	Podpp (no.)	Seed ppd(no.)	Larea (cm ²)	Dflower (day)	Tswgt (g)	Seedyld (t/ha)
Replication (R)	2	0.1	3.9	0.07	169.6	0.02	368.5	5.6	2.0	0.03
Sowing date (S)	4	734.8**	6.5**	14.56**	3334.3**	0.11	5929.0**	174.1**	7.9	3.59*
Year (Y)	1	1143.4**	72.8**	60.42**	9964.0**	1.13**	53069.0**	0.1	988.2**	0.39
$S \times Y$	2	66.1**	14.1*	3.45**	529.8**	0.04	4784.0**	34.8**	10.1	0.15
$R \times Y \times S$	18	8.9	5.7**	0.52	44.9	0.04	260.4	5.6	4.8	0.16
Genotype (G)	4	1591.0**	28.0**	38.64**	7435.4**	0.09	22246.5**	917.9**	23.7	0.93**
$G \times Y$	4	177.9**	1.3	2.7**	634.1**	0.05	830.2**	61.0**	6.9	1.42*
$G \times S$	16	16.9	1.1	0.68	318.33**	0.07	545.0**	34.6**	9.6	0.11
$G \times Y \times S$	16	45.7**	2.1	1.34**	194.1**	0.06	676.1**	29.8**	17.1	0.29**
Pool error	80	12.8	1.5	0.47	58.8	0.04	182.8	5.6	10.0	0.11

- * and ** significantly at 0.05 and 0.01 probability level respectively

Table 2. Mean seed yield (t/ha) and 100-seed weight (g) of five soybean genotypes evaluated under five sowing dates during 2009 and 2010 seasons

Seed yield (t/ha)

Genotype	2009					2010				
	Env.1	Env.2	Env.3	Env.4	Env.5	Env.6	Env.7	Env.8	Env.9	Env.10

NA 5009 RG	0.64	0.36	0.49	0.26	0.12	0.90	1.00	0.40	0.41	0.25
TGx 1740-2F	1.11	0.89	0.68	0.89	0.48	1.15	0.96	0.70	0.43	0.32
Soja	1.48	0.79	0.41	0.75	0.32	1.01	0.83	0.75	0.55	0.41
TGx 1937-2F	1.86	1.64	1.36	0.36	0.38	1.27	0.91	0.69	0.65	0.44
TGx 1904-6F	0.61	0.19	0.56	0.25	0.17	1.87	1.78	0.84	0.71	0.47
C.V. %										44.49
S.E.						0.33				
Genotypes (G)						0.74				
Environment (E)						3.59				
G × E						0.11				

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125 **100 seed weight (g)**

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Genotype	2009					2010				
	Env.1	Env.2	Env.3	Env.4	Env.5	Env.6	Env.7	Env.8	Env.9	Env.10
NA 5009 RG	12.67	11.00	11.00	12.00	8.67	12.71	20.00	19.33	16.00	16.67
TGx 1740-2F	10.33	10.33	10.00	9.67	10.00	20.00	14.67	13.33	16.67	13.67
Soja	11.60	10.67	10.33	12.33	10.33	15.33	20.00	20.00	15.33	16.67
TGx 1937-2F	11.00	11.33	10.67	10.33	10.67	16.71	17.33	17.33	12.33	12.00
TGx 1904-6F	9.67	9.67	11.67	10.25	10.67	18.33	13.33	12.33	13.67	15.00
C.V. %										23.61
S.E.						3.17				
Genotypes (G)						13.41				
Environment (E)						7.9				
G × E						9.6				

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130 **Table 3. Mean performance of five soybean genotypes across five sowing dates averaged over**

131 **two years**

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Genotype	Plht (cm)	1stpdht (cm)	Branches (no.)	Podpp (no.)	Seed ppd (no.)	Larea (cm ²)	Dflower (day)	Tswgt (g)	Seed yield (t/ha)
NA5009 RG	21.0d	4.1c	2.0c	24.9d	2.0a	68.7d	27.7d	14.10a	0.48c
TGx 1740-2F	40.3a	6.8a	3.3b	50.8b	2.1a	90.8c	37.7b	12.77b	0.76b
Soja	33.4b	6.0a	2.0c	28.4c	2.2a	84.0cd	31.4c	14.60a	0.74b
TGx 1937-1F	28.6bc	5.5b	4.6a	61.8a	2.1a	135.5a	40.0a	12.97b	0.98a
TGx 1904-6F	26.9c	5.5b	3.7b	49.2b	2.1a	119.7b	40.0a	12.60b	0.74b
C.V	11.9	22.1	22.0	17.8	9.6	13.6	6.7	23.61	44.49
S.E.	3.6	1.2	0.7	7.7	0.2	13.5	1.6	3.17	0.33
Mean	30.0	5.6	3.1	43.0	2.1	99.7	35.4	13.41	0.74

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134 Apparently, the mean square of analysis of variance showed significant difference at (P=0.05) among the

135 genotypes and sowing date for all traits except for number of seeds per pod, 100-seed weight and first pod

136 height over the two years (Table 1). The genotype (year and sowing date) interaction clearly demonstrated that

137 genotype and environment interaction across the environment clearly plays a significant role in breeding

138 adaptable genotypes to the wide environment. This interaction was validated by the highly significant

139 difference at (P=0.5) for plant height, number of pods per plant, number of branches per plant, leaf area,

140 number of days to 50% flowering and seed yield. Genotype and environment interaction was also highly

141 significant at (P=0.05) for number of pods per plant, leaf area, days to 50% flowering whereas it was non-

142 significant for plant height, first pod height, number of branches per plant, number of seeds per pod, 100-seed

143 weight and seed yield (Table 1).

Gebeyehu and Assefa (2003) reported that selection based on the highest yielding genotypes appeared less stable than the average of all lines. Furthermore, they reported that selection solely for seed yield could result in rejection of several stable genotypes. TGx 1937-1F out yielded others because of its yield components such as, number of pods per plant and number of seeds per pod and some other growth traits like leaf area, days to 50 % flowering that do contribute the highest yield (Table 1).

Arslanoglu and Aytac (2010) had reported contrary finding on the effect of genotype (G), environment (E) and G x E interactions on pod number per plant, plant height, seed yield and 1000-seed weight were four significantly at ($P=0.01$). furthermore they reported that among the experiment locations, the pod number per plant ranged between 87.34 - 33.87, plant height 100.41 - 68.71 cm, 1000-seed weight 210.06 - 133.66 g and seed yield between 379.49 - 211.85 kg/ha

The non-significant exhibited by genotype and environment interaction on various other traits indicates their response to climatic condition and planting date. From the findings of the study, (Table 2) it was very evident that seed yield and 100-seed weight declined in the same trend. Thus, early planting was observed to be essential in the efficient crop husbandry. Salem (2004) confirmed the finding by reporting that date plays an important role in the crop productivity as the seed yield of genotypes decreased with delayed sowing date. The mean performance analysis revealed that high yielding genotypes across the sowing dates over the two years were TGx 1937-1F (0.98 t/ha) and TGx 1740-2F (0.76 t/ha) whereas TGx 1904-6F and Soja registered (0.74 t/ha for each) and NA 5009 RG was the lowest yielder (0.48 t/ha). Thus, TGx 1937-1F was the best performer across five sowing dates over two years (Table 3).

Egli (1998) explanation for soybean performance was that yield variation across environments and years was associated with changes in number of seeds per unit area. A contrary explanation is that an ideal soybean cultivar was one that achieves the greatest yield across many environments (Fasoula and Fasoula 2002). The exhibited non-significance by these traits: first pod height, 100-seed weight, seed per pod, plant height, number of branches per plant on G x E interaction was confirmed by (Baker 1988) who defined the non-significant difference as failure of genotypes to achieve the same relative performance in different environment. Thus, the G x E interaction might have made it difficult for breeder to identify the best genotypes, during selection and recommendation.

To overcome G x E effect, Cucolotto *et al.*, (2007), partitioned G x E interaction into two: adaptability and phenotypic stability. These researchers defined adaptability as the capability a genotype has to make use of the environmental effects to warrant a high yield level, and phenotypic stability was related to yield maintenance or yield predictability in diverse environment. However, in the present study, G x E was not partitioned. The non-significant difference posed by G x E interaction was confirmed by (Faisal 1986). He stated that delaying sowing date to late July do influence performance and yield per unit area reducing it to 0.5 t/ha or even less.

4. CONCLUSION

Partitioning genotype and environment into adaptability and phenotypic stability would have checked the adaptability of the genotypes. However, it could be concluded that genotype and environment interaction had a highly significant association with number of pods per plant, leaf area and number of days to 50% flowering. The mean separation ranked TGx 1937-1F as the highest yielder across the ten environments. These results

too suggested that high seed yield potential was associated with number branches per plant, number of productive pods per plant and leaf area. These strongly associated traits could be used in crop improvement and as criteria for selection. One more year trial is required to validate the trend of performance across the environment.

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