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Performance of soybean *(Glycine max* L Merrill*)* genotypes under different planting dates in Sennar State of the Sudan

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ABSTRACT

Objective: The experiment was conducted to test five soybeans (*Glycine max* L. Merrill) genotypes at El-Gantra farm in Sennar State, Sudan. The objectives of this study were to (i) evaluate genetic variability in performance of five soybean genotypes under different sowing dates; (ii) determine the appropriate sowing date for high seed yield; and (iii) select genotype(s) with high yield potential for release to local farmers in Sennar State.The genotypes were tested at five different sowing dates in 2009 and 2010.

Methodology and results: The experiment was arranged in a Split-plot designed replicated three times, with planting date as main- plot and genotype as subplot. The combined analysis of variance over two years showed significant differences (P<0.5%) among the genotypes and sowing dates for all the measured traits, with the exception of number of seeds per pod in both years. The highest seed yield (1.19 t/ha) was obtained from a sowing on 10th August in 2009 and on 12th July (1.03 t/ha) and 26th July (0.93 t/ha) sowing dates in 2010. The trend of genotypic performance in terms of seed yield and other agronomic traits were consistent in both years. Days to 50% flowering attained at different time could be a useful classification trait. Genotype NA5009RG attains 50% flowering at 28 days from sowing and could be classified as extra-early maturing, Soja early maturing and TGx 1740-2F as intermediate whereas (TGx 1937-1F and TGx-1904-6F) reached 50% flowering at 40 days and could be classified as late maturing. The strongest and positive relationship was detected between productive pods and number of branches per plant whereas the weakest relationship was noticed between yield and first pod height. The highest yielding soybean genotype was TGx 1937-1F (1.17 t/ha) in 2009 and TGx 1904-6F (1.13 t/ha) in 2010. The medium yielders were Soja (0.81 t/ha) and TGx 1740-2F (0.75 t/ha) and NA 5009 RG (0.48 t/ha) the lowest yielder in both years. These agronomic traits, number of pods per plant, number of seeds per pod, leaf area and number of branches per plant contributed to the yield performance.

Conclusion and application: These traits could be used as selection indices to select soybean genotypes with high yield potential. In this study, genotypes TGx 1937-1F and TGx 1740-2F demonstrated consistent high yield potential across the two years and could be subjected to additional one year test to confirm its yield potential for release.

Key words: Soybean, genetic variability, sowing date, yield potential.

INTRODUCTION

Soybean (*Glycine max* L. Merrill) is one of the oldest crops grown in the world. The plant is classed more as an oil seed crop than a pulse. It is an annual plant that has been used in at least 3000 BC by ancient Chinese who considered soybean as an important and sacred crop (Vaughan and Geissler 2008). Soybean is an important legume with multifarious uses. Its cost effectiveness is ensured through its biological nitrogen fixation and in rotation with exhaustive crops such as maize and sorghum; it helps in replenishing and maintaining the soil fertility. It provides a large amount of edible vegetable oil as well as soybean cake and meal which are high protein supplements in mixed feed rations for livestock**.** Azhari (1987) reported that soybean contains 20 to 22% of essential amino acids, and 40% of protein. The study by Malik *et al.,* (2006) revealed that soybean contains 18-22% oil which comprises of 85% cholesterol free unsaturated fatty acids in comparison to conventional vegetable and animal fats. Soybean also has many food and industrial uses. Soy food has been reported to provide protection against heart disease, cancer and other diseases (Carter and Wilson 1987).

Owning to its nutritional value there is a growing demand for soy foods such as soymilk, several types of tofu, soybean sprouts, soy nuts, cottage cheese like soybean curd rich in protein, and various vitamins and minerals (Rao *et al.,* 2002). The medicinal nature of soybean (genistein, photochemical and iso-flavon content) is extremely essential in building body immune system. Soybean almost outshines all other oil crops due to its massive economic values. Recently, soybean is found to be an industrially important crop used as anti-corrosion agent, core oil, and bio-fuel due to less or no nitrogen element in the oil, and as disinfectant, in pesticides, printing inks, paints, adhesives, antibiotics and cosmetics (www.soy2020.ca/pdfs/Canadas-Soybean - Value-Chain-pdf.

According to six years (2000-2005) average data of FAO (2007), 82.8 million ha was allocated for soybean production in the world and 188 million tons of seed yield was obtained. Hailu (2007) reported that the annual productions of soybean in USA, Brazil and Argentina are 77.3, 44.5 and 30.3 million tons, respectively. Productivity of soybean in these countries was more than twice that of Africa's average. In Africa, a total of 21 countries produce varying quantities of soybean, as an introduced legume (Mayo, 1945). In the Sudan, the first soybean trials were carried out as early as 1925 at Gezira Research Farm, where a poor yield of 500 kg/ha was obtained (Faisal, 1986). Subsequent studies conducted from 1931-35 and in the year 1939/40 also failed due to poor performance of the introduced cultivars (Faisal, 1986). Since then studies on soybean were irregular and not consistent**,** depending on the researchers' interest. Ageeb (1979) postulated that examination of genetic variance is important for plant breeder in general and particularly in a new introduced crop like soybean, which is not grown commercially in Sudan. However, of recent, work on the soybean has been revived which could be attributed to the increasing utilization and universal importance of the crop. As a result**,** its introduction is expected to contribute towards diversification of cash crops in the Sudan.

Although research on soybean in the Sudan started more than fifty years ago with introduction of genotypes from USA**,** there are no released cultivars adapted to Sudanese local conditions. Records of some introduced cultivars tested under both rain fed and irrigation conditions at Agadi experimental plots showed that seed yield produced ranged from 500 to 1000 kg/ha. Faisal (1986) concluded that delaying the sowing date up to beginning of August severely reduced the yield and number of pods per plant. He recommended mid June and early July as suitable sowing dates for soybean as it provides more days for flowering and maturity than when sowing is delayed exposing the crop to terminal drought.

Dong *et al*. (2001) argued that new genotypes are an important source to help and meet the national food/oil demand as well as in the development of commercial varieties on the basis of desirable plant traits in Sub -Saharan Africa (SSA). In Sudan, commercial production of soybean started in 1982/83 season whereby an estimated area ranging from 1,260 to 2,100 ha was put under soybean production by Sudanese – Egypt Integration Agricultural Project in Damazin (Faisal, 1986). Although, Sudan has suitable climatic conditions for soybean cultivation, consumer preference, and lack of technical knowhow, high fuel consumption, and access to regional and international markets are the main constraints that hindered its cultivation.

The knowledge of genetic variability is the most important aspect of plant improvement program. It is of equal importance for a soybean breeder to evaluate soybean genotypes from different genetic backgrounds under different environments. Specht *et al.,* (1999) put the yield potential of soybean productivity at 8 t/ha, based on the amount of light energy available in the field under optimum condition. Baker (1988) suggested that evaluation of soybean genotypes under different planting dates is vital in boosting production. Nevertheless, varietal screening and selection for adaptation under local conditions can be considered of prime importance. This study was, therefore, designed to (i) evaluate genetic variability in performance of five soybean genotypes under different sowing dates; (ii) determine the appropriate sowing date for obtaining high seed yield**;** and (iii) select genotype(s) with high yield potential for released to local farmers in Sennar State.

MATERIALS AND METHODS

Genetic material: Five genotypes of soybean (Table 1) obtained from (i) International Institute of Tropical Agriculture (IITA) Nigeria; and (ii) ORNAS Company Khartoum, were studied under five different sowing dates at El Gantra (Um Dabiliba), Sennar State, Sudan.

Table 1: Five genotypes of Soybean evaluated under five planting dates in 2009 and 2010 at Range and Pasture Farm at El Gantra (Um Dabiliba village) in Sennar State

S.N	Genotype	Origin	Source	Code	Year of Introduction
1	NA 5009 RG	Argentina	ORNAS	G1	2008
2.	TGx 1740-2F	Nigeria	IITA	G2	2009
3.	SOJA	Argentina	ORNAS	G3	2009
4.	TGx 1937-1F	Nigeria	IITA	G4	2009
5.	TGx 1904-6F	Nigeria	IITA	G5	2009

Experimental sites: The trial was carried out during 2009 and 2010 main cropping seasons at the El Gantra Range and Pasture farm located at latitude 14˚ 24´N, and longitude 33˚ 29´E with an altitude of 411 feet. The soil of the experiment site can be described as heavy clay (60%) or cotton soil with a pH of 8.2; low organic content (0.5%), nitrogen 0.05% and available phosphorus 2.8 mg/k.

Design of experiment: The experiment was arranged in a split-plot design with three replications. Sowing date was considered as the main plot factor and genotype as sub-plot. The main plot size was 12 m × 5 m and the sub plot size was 2.4 m × 5 m. The sub-plot consisted of 4 rows, 5 m long each with 60 cm spacing between the rows and 10 cm spacing between the hills within a row. All recommended cultural practices for growing soybean were applied equally to all the plots.

Cultural practices: The land was disc ploughed, levelled and ridged before sowing. The prepared site was pre-irrigated two to three days ahead of the experiment to ensure sufficient moisture during planting. Seeds of the five genotypes were inoculated with *Rhizobium japonicum* before planting to ensure nodulation. A sugary solution was used for inoculation to ensure the sticking of the strain on the seed surface. Inoculation was done once, only in 2009 season, and the following season (2010) no inoculation was carried out because the trial was conducted in the same field assumed to have the remnant inoculums' effect in the soil. The seeds were inoculated with a strain of *R. japonicum* at the rate of 10 g per one kg of soy bean seed. Two seeds were planted per hill on the ridges and irrigation is applied. However, in the first year (2009) of the study, the first sowing date trail could not be irrigated immediately after planting due to unavailability of water, and consequently all the sowing dates of the subsequent trails were delayed by four weeks. In 2010, the first sowing date trial was immediately irrigated and other sowing date trials followed with two weeks intervals. Re-sowing was carried out seven days after planting followed by the second irrigation. Four weeks later, the crop was thinned to one seedling per hill by cutting off the weak plant. The crop was weeded twice manually for every sowing date (first in two weeks and the 2nd six weeks after planting) with continuous scouting to ensure clean field.

Data collection*:* The morphological growth characteristics were recorded on plot basis. Seedling emergence was recorded two weeks after planting as the number of seedlings that emerged in a plot. Plant height was measured as from the ground surface to the base of meri-stem of the mother plant taken from 10 randomly selected plants. The Number of branches was recorded as the average count of branches of 10 randomly selected plants in a plot. Leaf area was computed using Iamauti (1995) empirical relationship. The first pod height was measured at full bloom plant whereas lodging, number of pods/plant, number of seeds/pod was recorded at physiological maturity of the crop. 100-seed weight was determined by randomly counting 100 seeds from a bulked seed and weighed using a digital weighing-scale. Grain yield was quantified after harvest and converted into kg per hectare (kg ha^{-1}).

Data Analysis: All data collected were subjected to Statistical Analysis System (SAS, 2000) package for computing analysis of variance (ANOVA) of mean performance of genotypes, planting dates and their interaction over the two years. 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. Correlation coefficients between the various characteristics traits were also computed using the mean performance of genotypes averaged over two years (2009 and 2010).

RESULTS

The combined analysis of variance (ANOVA) averaged over two years showed significant differences among the soybean genotypes and sowing dates for all the traits measured. The interactions between the genotypes and the sowing dates revealed highly significant differences for days to 50% flowering; leaf area and seed yield (Table 2). Genotypes also interacted significantly with year for most of the measured traits, except for the pod height. Sowing dates interacted significantly with year for all the traits. The interactions between the genotypes, sowing date and year revealed highly significant differences for most of the measured traits (Table 2).

Table 2: Mean squares from analysis of variance of five soybean genotypes across five sowing date over two years 2009 and 2010

Source	**DF**	**PH (cm)**	**FstPdht (cm)**	**Branchpp (no.)**	**Podpp (no.)**	**Seedppd (no.)**	**Larea (cm²)**	**Dflower (day)**	**Tswgt (g)**	Seedyld (t/ha)
REP	2	0.1	3.9	0.07	169.6	0.02	368.5	5.6	2	0.03
Sowing date	4	734.8**	6.5**	14.56**	3334.3**	0.11	5929.0**	174.1**	7.9	3.59**
Year	1	1143.4**	72.8**	60.42**	9964.0**	1.13**	53069.0**	0.1	988.2**	0.39
Sowing date(Year)	2	66.1**	14.1**	3.45**	529.8**	0.04	4784.0**	34.8**	10.1	0.15
Rep (Year x Sowing date)	18	8.9	5.7**	0.52	44.9	0.04	260.4	5.6	4.8	0.16
Genotype	4	1591.0**	28.0**	38.64**	7435.4**	0.09	22246.5**	917.9**	23.7	0.93**
Genotype (Sowing date)	16	16.9	1.1	0.68	318.3**	0.07	545.0**	34.6**	9.6	0.11
Genotype(Year)	4	177.9**	1.3	2.71**	634.1**	0.05	830.2**	61.0**	6.9	1.42**

Genotype (Year x Sowing date)	16	45.7**	2.1	1.34**	194.1**	0.06	676.1**	29.8**	17.1	0.29**
Pooled Error	80	12.8	1.5	0.47	58.8	0.04	182.8	5.6	10	0.11

* & ** significantly different at 0.05& 0.01 level of probability, respectively sowing dates averaged over two years

Table 3: Mean performance of five soybean genotypes across five sowing dates averaged over two years

Genotype	PH (cm)	FstPdht (cm)	Branch/p (no.)	Podpp (no.)	Larea (cm²)	Dflower (days)
1	21.0	4.1	2.0	24.9	68.7	27.7
2	40.3	6.8	3.3	50.8	90.8	37.7
3	33.4	6.0	2.0	28.4	84.0	31.4
4	28.6	5.5	4.6	61.8	135.5	40.0
5	26.9	5.5	3.7	49.2	119.7	40.0
C.V.	11.9	22.1	22.0	17.8	13.6	6.7
S.E.	3.6	1.2	0.7	7.7	13.5	1.6
Mean	30	5.6	3.1	43	99.7	35.4

The five genotypes, in most cases, attained 50% flowering at different time. Genotype (NA5009RG) reached 50% flowering at 28 days after planting classified as an extra-early maturing, while two genotypes, (TGx1937-1F) and (TGx1904-6F) attained 50% flowering at 40 days after sowing and can be classified as late maturing. The plant height of the genotypes ranged from 21 to 40 cm, with average of 30 cm. Genotype (TGx1937-1F) was the tallest whereas (NA5009RG) was the shortest. The trend for first pod height was similar to that expressed by plant height (Table 3). Genotypes varied in their ability to produce number of branches and productive pods per plant. On the average, the number of braches per plant ranged from 2 to 4.5 and number of productive pods per plant ranged from 25 to 62. Genotype (TGx1937-1F) was the most proliferous in terms of number of branches and productive pods, while (NA5009RG) had the least number of branches and productive pods (Table 3).

Mean leaf area of genotypes was 99.7 cm^2 with (TGx1937-1F) scoring the largest leaf area (136 cm^2) and (NA5009RG) had the smallest (69 cm^2) leaf area. Since grain yield is a function of assimilate accumulation in the source (leaf) and translocation to the sink (seed), the seed yield among the genotypes reflected the same pattern of leaf area with (TGx1937-1F) giving the highest seed yield (0.98 t/ha) and (NA5009RG) the lowest seed yield (0.48 t/ha).Correlation coefficients among agronomic traits measured across five sowing dates averaged over two years is presented in Table 4.

Table 4: Correlation coefficients among measured traits of five soybean genotypes across five sowing dates averaged 2009 and 2010

	Seed YLD	**100-seed wt**	**Days50 %FL**	**LA**	**No. Seed/ Pod**	**No. Pods/Pl**	**No. Branch/Pl**	**FPdht**	**PHt**
Seed yield	1								
100 seed weight	0.11	1							
Days 50%FL	0.37*	0.16	1						
Leaf Area	0.45**	0.61**	0.66**	1					
No. Seed/Pod	0.21	0.22	-0.28	-0.03	1				
No. Pods/Plant	0.23	0.55**	0.71**	0.79**	-0.1	1			
No. Branch/Plant	0.05	-0.22	0.55**	0.74**	-0.14	0.85**	1		
First Pod height	-0.02	0.47**	0.02	-0.35	0.34	-0.23	-0.35	1	
Plant Height	0.33	0.16	0.09	0.16	0.44*	0.32	0.18	0.19	1

The strongest and positive relationship was detected between number of productive pods per plant and number of branches per plant (0.85**), whereas the weakest relationship was observed between seed yield and the first pod height. Seed yield, the trait of primary interest, was significantly and positively correlated with leaf area (0.45**) and days to 50% flowering (0.37*). Plant height, number of productive pods and branches per plant had weak but positive relationships with seed yield (Table 4). Days to 50% flowering, in turn, had highly significant and positive correlations with number of productive pods per plant, leaf area and number of branches per plant.

DISCUSSION

The effects of sowing dates on soybean genotypes were evident as expressed agronomic traits measured in this study. Seed yield and some yield components like number of productive pods per plant, number of branches per plant and leaf area declined from the first sowing date to the last (fifth) sowing date. These results suggest that early sowing dates, around early to mid-July, gave the highest seed yield and could be recommended as the optimum planting time for soybean in Sennar Sate. Late sowing date around September affected the plant statue resulting in pre-mature flowering before the plant could attain its full size. Soybean planted late in the season had less time to fully develop vegetatively but compensate this stage by completing its life cycle for seed yield. Salem (2004) pointed out that sowing date plays an important role in soybean productivity. These results confirmed the early findings of Faisal (1986) recommended mid-June and early July as the optimum sowing date for soy bean. The variability among the soybean genotypes for days to flowering, plant height, seed yield and some yield components indicate differences in genetic background and heterotic pattern among the genotypes. Accordingly, the five genotypes can reasonably be classified, based on their maturity groups, as extra-early (NA5009RG), early (SOJA), intermediate (TGx1740-2F) and late [(TGx1937-1F); (TGx1904-6F)] maturing. The extra-early genotype attained 50% flowering at 28 days after planting. Other agronomic traits of extra-early materials such as shortness and low seed yield were clearly expressed in (NA5009RG). On the other hand, one of the late maturing genotype, (TGx1937-1F), had tall plants with proliferous branches and productive pods expressed high yield potential. These results demonstrated that the extra-early genotype had shorter time to complete its life cycle as compared to late maturing genotype with longer time to complete its life cycle and hence yielded twice as much. The variability of agronomic traits among soybean genotypes observed in this study corroborate with those reported by earlier workers (Ghatage and Kadu, 1983; Linyanage and Martin, 1983; Rasaily et al., 1986; Malik et al., 2006). The relationships between seed yield and some yield components identified some agronomic traits that were closely associated with seed yield. The seed yield had strong and positive relationships with leaf area (0.45**) and days to flowering (0.37*), suggesting that these traits could be used as selection index for yield improvement of soybeans. This relationship was clearly demonstrated by (TGx1937-1F) which had the largest leaf area and also the highest seed yield. These results reflected the physiological processes of assimilate accumulation, translocation and relationship of source and sink as shown by leaf area (source) and seed yield (sink). Greater leaf area improved seed yield due to increased interception of solar radiation and enhanced carbon exchange rate (Kumudini et al., 2001). These results suggest that high seed yield potential was associated with large leaf area, days to flowering, high number of productive pods and branches per plant.

This study demonstrated that the optimum sowing date of soybean in Sennar State is early July. The five genotypes used in this study can be classified into four maturity groups as extra-early, early, intermediate and late maturing. Each of the first three groups had only one genotype while the last group had two genotypes. High seed yield was associated with lateness, leaf area, number of productive pods and number of branches per plant which could be used as selection index for improving yield potential of soybean genotypes.

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