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Screening of soybean (*Glycine max* (L.) Merrill) genotypes for resistance to lodging and pod shattering

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Abstract

Soybean yield reduction has been attributed to many factors including lodging and shattering. Detection of soybean genotypes/varieties that are tolerant to lodging and shattering would be of help to farmers and breeder in selecting variety for cultivation or cultivar development. Therefore, this study was conducted between July and November, 2014 growing season to evaluate soybean genotypes for lodging and pod shattering resistance at Tampola, Navrongo in the Kassena Nankana District in the Upper East Region of Ghana. The soybean genotypes used for the study were thirty four, consisting of 32 breeding lines and two local varieties. The field experiment was laid out in randomized complete block design (RCBD) with three replications. Pod shattering screening was done using oven dry method in the laboratory. Lodging was scored using International Institute of Tropical Agriculture (IITA) descriptors when the crop attained at R8 (full maturity) when 95 % of the pods have reached mature pod colour. Six genotypes, namely SIT-M TGx1904-6F, SIT-E TGx1835-10E, SIT-M TGx1987-40F, TGx1903-7F, SIT-E TGx1448-2E and ANIDASO were found to be moderately resistant to pod shattering. It was revealed that 53 % of the genotypes shown either erectness or slight lodging. Soybean genotypes SIT-M TGx1904-6F, SIT-M TGx1987-40F, SIT-E TGx1448-2E and ANIDASO were identified to have some degree of resistance to lodging and shattering and could also be incorporated in soybean breeding programmes for improvement.

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Introduction

Soybean (*Glycine max* (L.) Merrill) belongs to the family Leguminosae, in the subfamily Papilionideae. It grows in the tropical, subtropical and temperate climate conditions, growing almost all over the world. It is now widely grown due to its high protein and oil content containing approximately 40 - 42 % protein and 18 - 22 % oil and also good amount of nutrients such as carbohydrate, minerals, vitamins and dietary fibre (Antalina, 1999), and adaptation to diverse conditions. In Ghana, soy proteins are also being used in baby foods to avoid kwashiorkor (protein deficiency) in children (Asafo-Adjei *et al*., 2005).Soybean production is concentrated in the three northern regions of Ghana, which falls within the Guinea savannah agro-ecological zones (Lawson *et al*., 2008), where the crop has been instrumental in social, economic and environmental benefits.

Soybean research and production in Ghana are besieged with a lot of constraints arising from biotic and abiotic factors, preventing farmers from attaining the optimal yield potential. Seed viability, pod shattering, lodging, pests, diseases and narrow genetic base, among others, are examples of constraints affecting production of soybean (Brink and Betay, 2006). Lodging can decrease soybean yields and seed viability by up to 30 % and it is primarily a problem in high-yielding soybeans. The extent of yield reduction attributed to pod shattering may vary also from negligible to significant levels in the range of 1 to 100 % shattering (Agrawal *et al*., 2004).

Identification of soybean genotypes with some level of lodging resistance is important because lodging results in yield reduction. Also, lodging prior to pod filling, leads to partial fruit or seed development and makes the use of mechanized harvesters very difficult or impossible (Acquaah, 2007). Earlier researchers (Sindhan and Parashar, 1986; William, 2008) discovered that, good agronomic management such as adequate supply of potassium can alleviate lodging degree or incidence. However, this put stress on the resource poor farmers. Therefore, screening soybean genotypes to identify resistance to lodging and pod shattering will help to increase production to a greater extent.

Materials and methods

Genetic materials

Thirty four soybean genotypes were used for the study. Information about the genotypes and source of collection is presented in Table 1.

Experimental site

The experiment was conducted at Tampola, Navrongo in the Kassena-Nankana District of the Upper East Region of Ghana. The area is located in the Sudan Savannah Agro-ecological Zone which experiences a unimodal rainfall pattern. The annual rainfall, temperature, relative humidity, wind speed, sunshine hours and solar radiation of the area are 885 mm, 28.6 °C, 54 %, 81 km day^{-1}, 7.9 h and 20.4 M J $m^{-2}day^{-1}$, respectively (Ghana Meteorological Agency, 2013). The research work was carried out between July and November, 2014.

Land preparation, layout, experimental design, and planting

The land was not ploughed but manually slashed with cutlass. Stumping was done with mattocks and hoes. The debris was also manually collected. Linning and pegging were done at a planting distance of 75 cm between rows and 10 cm within rows. The experimental design used was randomized complete block design (RCBD) with three replications partitioned by two alleys of 1 m each. The two central rows were the test row from which data was taken. Each plot had four rows which was four meters long. Three seeds were planted per hill.

Screening for lodging resistance

Lodging was scored using IITA descriptors. Lodging scores were based on the average erectness of the main stem of plants at R8 (full maturity) when 95 % of the pods have reached mature pod colour. The rating system for lodging was scored using the scale 1 - 5 according to the scores: 1 = all plants erect, 2 = 25 % of plants lodged, 3 = 50 % of the plants lodged, 4 = 75 % of plants lodged and 5 = all plants lodged.

The lodging score were described as 1 = all plant erect, 2 = slight lodging, 3 = plants lodged at 45 degree angle, 4 = severe lodging and 5 = all plants flat.

Screening for pod shattering resistance

The genotypes used in the study were characterized for pod shattering to confirm their resistance level. The pod shattering was recorded at R8 when 95 % of the pod had attained maturity. The screening was done using the oven dry method in the laboratory. Twenty samples were collected from each genotype and were put in a paper bag (5 x 10 x 20 cm) for 10 days at room temperature for moisture content to equilibrate. The pods were then oven dried at 80 °C for 12 h. Pods that opened to release the seeds or opened but did not release seeds were considered shattered.

The shattering percentage was calculated as the number of shattered pods per total number of pod expressed as percentage.

The percentage pod shattering was determined on a scale 1 - 5 recommended by Asian Vegetable Research and Development Centre (AVRDC, 1977). The scale was described as 1 = very resistant, 2 = resistant, 3 = moderately resistant, 4 = moderately susceptible and 5 = very susceptible according to the scores as: 1 = 0 %, 2 = 1 - 10 %, 3 = 11 - 25 %, 4 = 26 – 50 % and 5 = ≥ 50 %.

Statistical analysis

Data collected were analyzed, using Statistic 9.0 statistical package. Analysis of Variance (ANOVA) table was computed and treatment differences were compared using the Least Significant Difference (LSD) procedure at 5 % level of probability.

Results

Screening for lodging resistance

The soybean genotypes varied significantly ($p < 0.05$) to lodging (Table 2). Genotypes SIT-E TGx1989-21F, SIT-E TGx1835-10E, SIT-E TGx1987-86F and SIT-E TGx1990-3F were lodged at 45 degree angle (50 % of the plants lodged). Genotypes SIT-E TGx1987-62F, SIT-M TGx1440-1E, SIT-M TGx1990-97F, SIT-E TGx1990-5F, SIT-E TGx1988-3F, ANIDASO, SIT-M TGx1987-40F, SIT-E TGx1990-8F, TGx1909-3F, SIT-M TGx1990-67F, SIT-E TGx1987-11F, SIT-M TGx1904-6F, SIT-M TGx1987-91F and SIT-E TGx1987-96F had slight lodging (25% of plants lodged). Genotypes SIT-M TGx1989-46F, SIT-E TGx1988-5F, SIT-M TGx1989-42F, SIT-E TGx1990-2F, NANGBAAR (the check), SIT-E TGx1740-2F, SIT-E TGx1989-20F, SIT-E TGx1448-2E, SIT-E TGx1990-15F, SIT-E TGx1987-10F, SIT-E TGx1989-19F, SIT-E TGx1989-4F, SIT-M TGx1987-14F, SIT-M TGx1989-45F, TGx1903-7F and SIT-M TGx1990-45F had all plants erected.

Table 1. Soybean genotypes/varieties and their sources used for the study.

Genotypes/Varieties	Source/Institution*	Country
TGx1909-3F	IITA	Nigeria
SIT-M TGx1990-67F	IITA	Nigeria
SIT-E TGx1987-11F	IITA	Nigeria
SIT-E TGx1988-3F	IITA	Nigeria
TGx1903-7F	IITA	Nigeria
SIT-E TGx1987-86F	IITA	Nigeria
SIT-M TGx1990-45F	IITA	Nigeria
NANGBAAR	CSIR-CRI	Ghana
SIT-E TGx1990-3F	IITA	Nigeria
SIT-E TGx1990-15F	IITA	Nigeria
SIT-E TGx1987-10F	IITA	Nigeria
SIT-E TGx1989-19F	IITA	Nigeria
SIT-M TGX1904-6F	IITA	Nigeria

SIT-E TGx1989-4F	IITA	Nigeria
SIT-M TGx1989-46F	IITA	Nigeria
SIT-E TGx1988-5F	IITA	Nigeria
ANIDASO	CSIR-CRI	Ghana
SIT-M TGx1987-91F	IITA	Nigeria
SIT-M TGx1989-42F	IITA	Nigeria
SIT-M TGx1987-14F	IITA	Nigeria
SIT-E TGx1740-2F	IITA	Nigeria
SIT-E TGx1989-21F	IITA	Nigeria
SIT-E TGx1987-62F	IITA	Nigeria
SIT-E TGx1990-97F	IITA	Nigeria
SIT-M TGx1989-45F	IITA	Nigeria
SIT-E TGx1989-20F	IITA	Nigeria
SIT-E TGx1990-2F	IITA	Nigeria
SIT-M TGx1448-2E	IITA	Nigeria
SIT-E TGX1835-10E	IITA	Nigeria
SIT-M TGx1987-96F	IITA	Nigeria
SIT-M TGx1987-40F	IITA	Nigeria
SIT- E TGx1990-8F	IITA	Nigeria
SIT-E TGx1990-5F	IITA	Nigeria
SIT-M TGx1440-1E	IITA	Nigeria

*IITA: International Institute of Tropical Agriculture

CSIR-CRI: Council for Scientific and Industrial Research – Crop Research Institute.

The data presented above revealed that, pod shattering percentage ranged from 13.33 (TGx1903-7F and SIT-E TGx1448-2E) to 96.67 per cent (SIT- E TGx1990-8F and SIT-E TGx1987-96F). Results indicated that none of the genotype was very resistant or resistant to pod shattering. However, genotypes SIT-M TGx1904-6F, SIT-E TGx1835-10E, SIT-M TGx1987-40F, TGx1903-7F, SIT-E TGx1448-2E and ANIDASO (the check) were found to be moderately resistant to shattering (11 – 25 % pods shattered). Genotypes SIT-E TGx1990-8F, SIT-E TGx1987-96F, SIT-E TGx1989-21F, SIT-E TGx1989-20F, SIT-E TGx1989-4F, SIT-E TGx1988-5F, SIT-E TGx1987-11F, SIT-E TGx1989-19F, SIT-M TGx1989-45F, SIT-E TGx1988-3F, SIT-M TGx1989-46F, SIT-M TGx1990-67F, SIT-E TGx1987-10F, SIT-E TGx1987-86F, SIT-M TGx1989-42F, SIT-E TGx1740-2F, SIT-M TGx1990-97F, SIT-E TGx1990-3F, SIT-E TGx1990-5F, SIT-M TGx1440-1E, SIT-E TGx1990-2F and TGx1909-3F were very susceptible to shattering (≥ 50 % pods shattered). Genotypes SIT-M TGx1987-14F, SIT-E TGx1987-62F, SIT-M TGx1987-91F, SIT-M TGx1990-45F, SIT-E TGx1990-15F and NANGBAAR were moderately susceptible to shattering (26 – 50 % pods shattered).

Discussion

Screening for lodging resistance

There was a differential response of the genotypes in resistance to lodging across the 34 soybean genotypes. This could be due to differences in the genetic composition of soybean genotypes and is essential for selecting agronomic traits for breeding programmes (Wang *et al*, 2010).Majority of soybean genotypes evaluated exhibited good stand ability for lodging. Soybean genetic enhancements have also led to higher yields due in part to increase lodging resistance (Kumudini *et al*., 2001; Cober *et al*., 2005). Some of the early releases were yielding 534 kg ha^{-1} according to Shurtleff and Aoyagi, (2007) but now, the existing varieties have yield potential varying

4000 to 5000 kg ha^{-1} which represents highly significant breeding gains over seven decades with lodging constraints almost overcome.

This is confirmed by the results obtained with 53 % of the genotypes showed erectness to lodging and no genotypes recorded as severe lodging or all plants flat.

Table 2. Lodging characteristics of soybean genotypes.

Soybean genotypes	No. of plant lodged	Response
TGx1903-7F	1.0	Erect
SIT-M TGx1987-14F	1.0	Erect
SIT-M TGx1989-45F	1.0	Erect
SIT-M TGx1990-45F	1.0	Erect
NANGBAAR (the check)	1.3	Erect
SIT-E TGx1990-15F	1.3	Erect
SIT-E TGx1987-10F	1.3	Erect
SIT-E TGx1989-19F	1.3	Erect
SIT-M TGx1989-46F	1.3	Erect
SIT-E TGx1988-5F	1.3	Erect
SIT-E TGx1989-4F	1.3	Erect
Soybean genotypes	No. of plants lodged	Response
SIT-M TGx1989-42F	1.3	Erect
SIT-E TGx1990-2F	1.3	Erect
SIT-E TGx1740-2F	1.3	Erect
SIT-E TGx1989-20F	1.3	Erect
SIT-E TGx1448-2E	1.3	Erect
SIT-E TGx1988-3F	1.6	Slight lodging
ANIDASO	1.6	Slight lodging
SIT-M TGx1987-40F	1.7	Slight lodging
SIT- E TGx1990-8F	1.7	Slight lodging
TGx1909-3F	1.7	Slight lodging
SIT-M TGx1990-67F	1.7	Slight lodging
SIT-E TGx1987-11F	1.7	Slight lodging
SIT-E TGx1987-96F	1.7	Slight lodging
SIT-M TGx1904-6F	1.7	Slight lodging
SIT-M TGx1987-91F	2.0	Slight lodging
SIT-E TGx1990-5F	2.0	Slight lodging
SIT-M TGx1440-1E	2.0	Slight lodging
SIT-M TGx1990-97F	2.0	Slight lodging
SIT-E TGx1987-62F	2.3	Slight lodging
SIT-E TGx1989-21F	2.7	Lodged at 45°
SIT-E TGx1835- 10E	2.7	Lodged at 45°
SIT-E TGx1987-86F	2.7	Lodged at 45°
SIT-E TGx1990-3F	2.7	Lodged at 45°
Mean	1.7	
CV (%)	32.7	
LSD ($P < 0.05$)	0.9	

Screening for pod shattering resistance

Shattering evaluation of soybean genotypes did vary significantly ($p < 0.05$) (Table 3).

Screening for pod shattering resistance

Identification of genotypes with potential for lowest pod shattering is one of the most important aspects in the management of pod shattering as it reduces soybean yield and quality. The differences in pod shattering values revealed the existence of genotypic differences among the genotypes evaluated. This is in line with the observations of Tiwari and Bhatnagar (1991), Tukamuhabwa *et al.* (2002) and Agrawal *et al.* (2004) who reported that pod shattering in soybean could be linked to cultivar differences, anatomical structure of pod and genotype by environment (GxE) interaction. Investigations have indicated that there were significant differences ($p < 0.05$) in shattering resistance among different genotypes/varieties (Caviness, 1969; Misra *et al.*, 1980) and the features of pod shattering is genetically determined (Saxe *et al.*, 1996).

Table 3. Percentage (%) shattering of soybean genotypes.

Soybean genotypes	% Shattering	Response*
TGx1903-7F	13.33	MR
SIT-E TGx1448-2E	13.33	MR
ANIDASO (check)	15.00	MR
SIT-E TGx1835- 10E	18.33	MR
SIT-M TGx1987-40F	18.33	MR
SIT-M TGx1904-6F	20.00	MR
NANGBAAR	31.67	MS
SIT-M TGx1990-45F	35.00	MS
SIT-E TGx1990-15F	35.00	MS
SIT-M TGx1987-91F	41.67	MS
SIT-E TGx1987-62F	43.33	MS
SIT-M TGx1987-14F	45.00	MS
TGx1909-3F	51.67	VS
SIT-E TGx1990-2F	51.67	VS
SIT-M TGx1440-1E	56.67	VS
SIT-E TGx1990-5F	61.67	VS
SIT-E TGx1990-3F	66.67	VS
SIT-M TGx1990-97F	66.67	VS
SIT-E TGx1740-2F	70.00	VS
SIT-M TGx1989-42F	71.67	VS
SIT-E TGx1987-86F	73.33	VS
SIT-E TGx1987-10F	76.67	VS
SIT-M TGx1989-46F	80.00	VS
SIT-E TGx1988-3F	80.00	VS
SIT-M TGx1990-67F	80.00	VS
SIT-M TGx1989-45F	81.67	VS
SIT-E TGx1989-19F	90.00	VS
SIT-E TGx1988-5F	91.67	VS
SIT-E TGx1987-11F	91.67	VS
SIT-E TGx1989-4F	93.33	VS
SIT-E TGx1989-20F	93.33	VS
SIT-E TGx1989-21F	95.00	VS
SIT- E TGx1990-8F	96.67	VS
SIT-E TGx1987-96F	96.67	VS
Mean	60.20	
CV (%)	8.48	
LSD ($P < 0.05$)	8.32	

*MR=Moderately resistant, MS = Moderately susceptible, VS = Very susceptible

The environmental conditions such as high temperatures, rapid changes in temperature, low humidity, wetting and drying have been identified to contribute to pod shattering (Tukamuhabwa *et al.*, 2002). Hence, the variation in pod shattering could partly be due to environmental conditions. The varietal differences in terms of pod shattering observed could further be exploited for breeding programme to improve soybean against shattering.

Conclusion

Significant degree of resistance to lodging and shattering were found across the 34 soybean genotypes evaluated. Soybean genotypes TGx1903-7F and SIT-E TGx1448-2E showed erect and genotypes SIT-M TGx1904-6F, SIT-M TGx1987-40F, and ANIDASO were slight lodging, but all were identified as moderately resistant to pod shattering and could be cultivated or disseminated to areas with the high levels of lodging and shattering. They could also be incorporated in soybean breeding programmes for improvement.

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