Received: 02 Mar 2020 | Revised: 14 Jun 2020 | Accepted: 16 Jun 2020

Electronic Journal of Plant Breeding

Research Article

Estimate of genetic consistency, diversity and traits association in late-maturing soybean breeding lines

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Abstract

Soybean (*Glycine max* (L.) Merrill) a multipurpose food and fodder, is an important source of quality protein and oils. Despite this, its breeding-true ability which has implication for seed re-use, association between grain yield and other traits and its suitability for southern guinea savannah of Nigeria are not established. Hence, the objectives of the study are to determine the: i. genetic consistency of seed trait; ii. adaptability of late maturing variety of soybean and iii. establish the association between primary traits and yield. Data collected on growth and yield parameter in 16 genotypes were analyzed using SAS. Path analysis was used to show cause-effect relationship while dendogram depicted the association among line. The result revealed wide genetic diversity among the TGX genotypes and association between farmers seeds and commercial seeds. The lines were also true to type for grain yield and other characters. Hence, resource poor farmers can save good yielding seeds harvested, for planting in subsequent season. Breeders can use traits such as vigor, the number of branches and leaves at 10 weeks, plant height and the number of leaves at 6 weeks with direct positive and significant relation with economic yield to improve yield. Genotypes TGX 2008-2F, TGX 2007-11F and TGX 2009-16F are promising lines and better replacement to the local check. Therefore, further breeding efforts could be carried out to improve the lines for grain yield and fodder in order to achieve dual usage for the soybean lines and hence enhance food and nutritional security and improve livelihood of resource poor farmers in Nigeria.

Keyword

soybean, genetic diversity, true-to-type, food and nutritional security.

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill), a self pollinating crop (Carlson and Lersten 2004), described as miracle bean, is a multipurpose grain food legume (Gibson and Benson, 2005) belonging to the family fabaceae. It is an important source of quality protein and oils (cholesterol-free linolenic unsaturated fatty acid) for man and livestock (Rehm and Espig, 1991). It is a model legume for infant foods as it contains minimal oligosaccharides that often results in flatulence in other grain legumes. Despite its enormous potential, its breeding-true ability and suitability of cultivation in southern guinea savannah of Nigeria is yet to be established. More so, information on association between grain yield and other traits which can provide basis for indirect improvement of grain yield is scarce. To this end, the objectives of the study are to:

i. To determine the genetic consistency of seed trait;
ii. To determine the suitability and adaptability of late maturing variety of soybean to Southern guinea savannah.
iii. To establish the association between primary traits and fodder and grain yield in soybean.

MATERIALS AND METHODS

The research was carried at the Teaching and Research Farm of Kwara State University, Malete in the Southern guinea savannah of Nigeria . Fourteen (14) late maturing soybean varieties were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Two checks, a local check from farmers' source and an improved check (TGX 1448) (See Table 1) were evaluated along with the 14 late maturing varieties.

Land clearing was carried out with minimum disturbance to the top soil. Harrowing and ploughing were done followed by Ridging. The 16 soybean genotypes were laid out in a randomized complete block design (RCBD) in three replications. It was a single row plot of 6.0 m length and 0.75 m inter and 0.10 m intra row spacing. Seed were sown at the rate of two seeds per hole. The first and the last 1 m in each row were left to serve as border row and also to measure the shattering potential of soybean. Also 10% of the plant stands (8 plants) in each row was tagged for data collection. Pre emergent and post emergent herbicide [paraforce and pendimenthalin] followed by supplementary hand weeding were used to control weeds.

Table 1. List of sixteen genotypes used for the experiment

Genotype Pedigree	Maturity Group
TGX 2006 - 3F	late
TGX 2011 -6F	Late
TGX 2010 - 11F	Late
TGX 2009 -16F	Late
TGX -2010 – 12F	Late
TGX -2007- 11F	Late
TGX 2008 -4F	Late
TGX 2008 - 2F	Late
TGX 2004 - 10F	Late
TGX 1987 - 62F	Late
TGX 2004 - 7F	Late
TGX 2009 - 12F	Late
TGX 1	Late
TGX 2	Late
TGX 1448 (Improved check)	Late
Local check	Late

Morphological characteristics were measured on 10 randomly selected seeds from each genotype. The following morphological data were taken; i. Seed colour with the aid of colour chart ii. Weight of 100 seeds in (g) iii. Glossiness of the seed (measured on a scale of 1 to– 5) where 1= highly glossy, 3= moderately glossy, 5= non-glossy iv. Shape of eye of seed v. Uniformity of the seed lots (measured on a scale of 1 – 5) where 1=highly uniform, 3= moderately uniform, 5=highly variable vi. Size of the seed eye (measured on a scale of 1 – 3) where 1=big, 2=medium, 3=small. vii. Germination%: Germination test was carried out to estimate the percentage viability of the seeds. Ten seeds were selected at random and sown at one seed per hole. The number germinated seed were recorded and viii. Vigor refers to the heartiness portrayed by growing seedlings. It is measured on a scale of 1 - 5 (where 1= very vigorous, 3= moderately vigorous and 5= non vigorous).

The following traits were measured as described above: Shape of the seed, colour of the seed, glossiness of the seed, colour of the seed eye, shape of the seed eye, uniformity of the seed lots and size of the seed eye.

The following growth parameters were recorded at two weeks interval:
i. Plant height measured as length in cm from the base of the plant to the base of the tallest branch. ii. Number of leaves: Counts of the number of developed leaves on all branches and iii. Number of branches: Counts of all branches on the stalk.

Reproductive and yield parameters measured include:
i. Days to flowering: Number of days from sowing to when 50% of the soybean in a plot has flowered ii. Weight of dry soybean with pod: Weight in grams of dry soybean with pod.iii. Weight of dry soybean without pod: Weight in grams of dry soybean seed after removing pod. iv. Weight of dry fodder: Weight in grams of total dry biomass excluding pod and seed. v. Weight of 100 dry seeds: Weight of 100 dry seeds in gram. vi. Root nodulation: Number of root nodules that fall off when palm is run on the root after harvest, when root is pulled out of the soil. Nodules are easily rub off with hand compared to root knot due to infection.

Estimated Parameters include:
Harvest index
For harvest index (HI) (%), seed dry mass (g) and total plant dry mass (g) were measured to calculate HI.

$$\text{Harvest index (\%)} = \frac{\text{Seed dry weight (g)}}{\text{Total dry weight (g)}} \times \frac{100}{1}$$

Total plant biomass (TPBIOM) (g), the total dry weight of the plant (including pods and leaves) was measured.

Seed chaff ratio (SCR): This is the ratio of weight of dry seed to weight of dry pod (seeds + chaff)

Biological Yield (BYLD) (g), weight of the dry fodder alone without the pods.

Analysis of variance was performed using SAS 9.4 version. Means showing a significant difference were separated using Duncan's Multiple Range Test (DMRT). T-test was used to compare means. Path analysis and correlation were done to determine the relationship and association between yield and other traits. Dendogram was used to group the soy bean breeding lines.

RESULTS AND DISCUSSION

Table 2 showed that morphological traits preferred by consumers such as seed colour, size and shape remained unchanged before planting and after harvesting. This showed that these traits breed true (Caligari, 2001), with no admixture hence ascertaining the genetic integrity of the breeding lines. Soybean seeds had similar colour in the range of yellow, golden to nude before planting and after harvest. Shape of seeds and shape of seed eye were in the neighbourhood of oval, oblong and sphere before planting and after harvesting. Table 3 showed the mean weight of 100 seeds of soybean before and after planting. It showed that 100 seed weight before planting

Table 2. Pre-planting Morphological Features of Soy Bean Seeds and Seedling Performance

Genotypes	100 seed weight (g)	Seed color	Seed shape	Seed-eye shape	Size of seed-eye	Uniformity of seed lot	Seed	Germ %	VIGOR
TGX 2008 -2 F	13.5	light cream	oval	Sphere	3	2	4	70	0.50b
TGX 2007 - 11F	13.2	pale yellow	oblong	Oblong	1	5	3	40	0.42bc
TGX 2009 - 16F	12.8	Golden	sphere	Oval	2	1	3	70	0.36bc
TGX 2007 - 8F	13.4	golden yellow	sphere	Oblong	1	2	5	40	0.29c
TGX 2006 - 3F	16.5	Nude	sphere	Oblong	3	2	3	80	0.32bc
TGX 2009 - 12F	11.9	pale yellow	Round	Oblong	2	4	4	30	0.33bc
TGX 2010 - 12F	10.3	light yellow	sphere	Oblong	3	5	2	30	0.44bc
TGX 2011 - 6F	11.0	Yellow	sphere	Oval	2	1	2	70	0.39bc
TGX 2004 - 10F	11.2	light yellow	oblong	Oval	3	3	3	20	0.39bc
TGX 2010 - 11F	12.5	fade yellow	sphere	Oval	2	4	4	30	0.50b
TGX 2008 - 4F	12.6	light yellow	sphere	Oval	2	3	4	70	0.42bc
TGX 2004 7F	12.9	Cream	sphere	Oval	1	3	3	80	0.33bc
TGX 1448 - 2E	12.6	Yellow	sphere	Oblong	2	2	2	10	0.34bc
TGX 1987 - 62F	9.0	golden yellow	Round	Oval	3	4	3	20	0.25c
Local check	11.4	Yellow	Round	Oval	2	3	1	50	0.33bc
Improved check	12.1	Yellow	oblong	Oval	3	2	3	80	1.00a

Figure(s) with the same letter(s) are not significantly different from each other.

Table 3. Mean weight of seeds of soy bean before (B4) Sowing and after (@) harvest

Genotypes		100 seed weight B4 sowing (g.)	100 seed weight @ harvesting (g.)	t-value	Av weight per Pod B4 sowing(g.)	Av weight per pod @ harvesting (g.)	t-value
TGX 2008 -2 F		13.43ab	12.47ab	0.25	1.27b	1.47a	0.63
TGX 2007 - 11F		12.67ab	13.23a	0.43	1.43b	1.27a	0.46
TGX 2009 - 16F		12.90ab	14.10a	0.36	1.47b	1.57a	0.22
TGX 2007 - 8F		13.23ab	11.83ab	0.1	1.23b	1.70a	0.18
TGX 2006 - 3F		14.63a	13.77a	0.7	1.40b	1.73a	0.27
TGX 2009 - 12F		12.00b	11.43ab	0.22	1.13b	1.47a	0.06
TGX 2010 - 12F		11.47b	12.70ab	0.2	1.33b	1.17a	0.2
TGX 2011 - 6F		11.03cb	11.30ab	0.69	1.13b	1.37a	0.32
TGX 2004 - 10F		11.07cb	11.77ab	0.37	1.20b	1.23a	0.87
TGX 2010 - 11F		12.60ab	13.77a	0.32	1.33b	1.57a	0.57
TGX 2008 - 4F		12.63ab	11.93ab	0.19	1.27b	1.73a	0.23
TGX 2004 7F		12.03b	13.13a	0.65	5.37a	1.20a	0.43
TGX 1448 - 2E		12.00b	7.83c	0.81	0.73b	1.73a	0.15
TGX 1987 - 62F		9.03c	9.40cb	0.51	0.97b	1.47a	0.19
LOCAL CHECK		11.40b	12.03ab	0.44	1.23b	1.33a	0.73
Improved check		12.10b	12.03ab	0.8	1.20b	1.40a	0.62
Mean		12.14	12.05	-	1.48	1.46	-
t-value		-	-	0.78	-	-	0.86
Source	df						
Rep	2	7.36*	4.05		3.32	0	
Genotype	15	4.70**	7.83*		3.32	0.12	
Error	30	1.6	3.6		3.2	1.13	
CV	4.39	10.43	15.76		120.84	24.29	

*,** = significant at 10 and 5% probability; - not applicable, df= degree of freedom; Rep= replication; av = average, CV= coefficient of variation.

of each genotype differ significantly from each other. This signified the differential weight of each genotype and possibly the size of endosperm and energy reserve in each. TGX -2006-3F with 14.63g has the highest weight while TGX- 1986-62F with 9.03g has the least weight before planting. Post harvest weight of 100 seeds of the 16 genotypes also differ significantly from each other with TGX-2007-11F having highest (14.10g) and TGX-1448-2E having the least (7.83g). Each of the 16 genotypes had non-significant t-value before planting and after harvesting (Table 2). The weight of each genotype was comparable before planting and after harvesting. This implied that these genotypes bred true and were free from genetic admixture and thus pure (Caligari, 2001). Constancy in their weight also implied that they were not segregating and that farmers can save seed for planting without compromising seed weight.

At 2 and 4 weeks after sowing (WAS), there was no significant difference among all the 16 soybean genotypes in terms of number of leaves. The breeding lines and their checks have significantly the same number of leaves. This infers that they do not differ in terms of number of leaves at their early stage of development. However, 6 and 10 weeks after sowing, there were significant differences in number of leaves.

Each genotype differs in its genetic potential to produce leaves. TGX -2007-11F had the highest number of leaves (58) implying higher photosynthetic potential which might translate into greater assimilate production (Anuradha *et al.*, 2017). TGX 2009-16F had the lowest number of leaves. It also imply higher fodder for livestock in dual purpose soybean.

Fig. 1 explained the trends in the in number of branches at 2, 4, 6 and 10 WAS. At 2 and 4 weeks after sowing, there were no significant differences in the production of branches. But at 10 WAS, there was significant variation in the production of branches. TGX 1448 -2E has the highest number of branches at 10 weeks while TGX 2010 -11F has the lowest number of branches.

Fig. 2 showed the trends in plant height at 2, 4, 6 and 10 WAS. At 2 and 4 WAS, the genotypes have little disparity in plant height. Six WAS, there is little differences in the plant height. At 10 WAS, TGX 2010 -11F has the highest plant height (37cm) and hence better placed to trap sunlight during photosynthesis. In contrast, the local check has the lowest plant height (23cm) at 10 week.

Characterization of 16 selected soybean genotype for three vegetative characteristics (plant height, the number

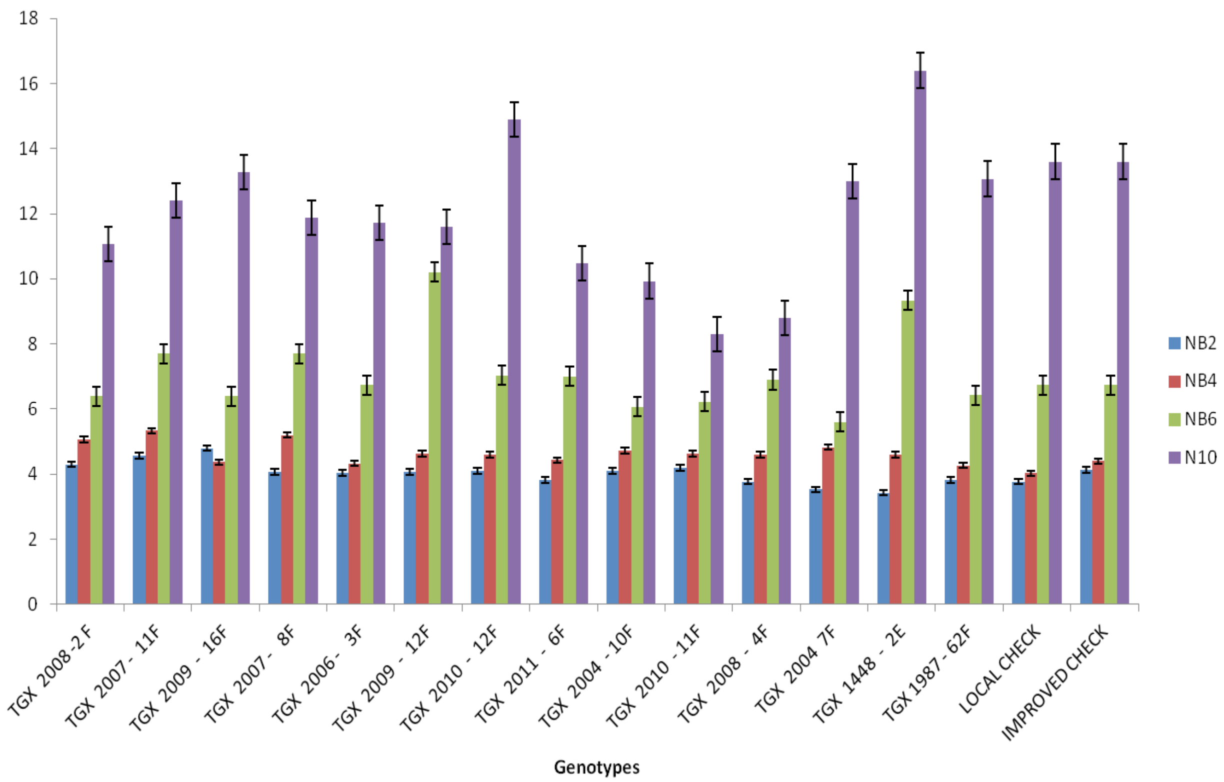

Fig. 1. Trends in number of leaves (NL) at 2, 4, 6 and 10 weeks after sowing (WAS)

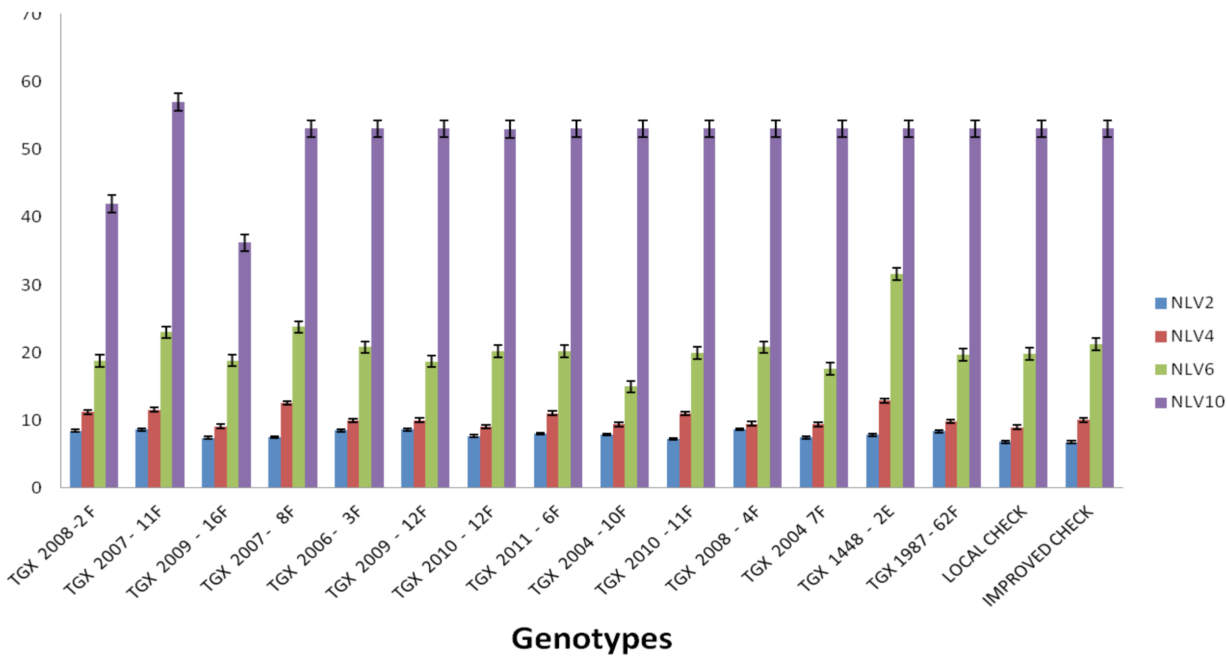

Fig. 2. Trends in number of branches (NB) at 2, 4, 6 and 10 weeks after sowing (WAS)

of leaves and the number of branches) revealed highly significant ($p<0.05$) differences attributable to genotypic differences (fig. 1 – 3) especially at advanced vegetative stage. The wide variability exhibited by these genotypes suggests that is a scope for selection from the collections.

It was observed from this preliminary study that the local check has the lowest plant height which has low tendency to trap light energy for photosynthesis. In contrast, the improved varieties were taller hence, higher tendency to trap light energy for photosynthesis.

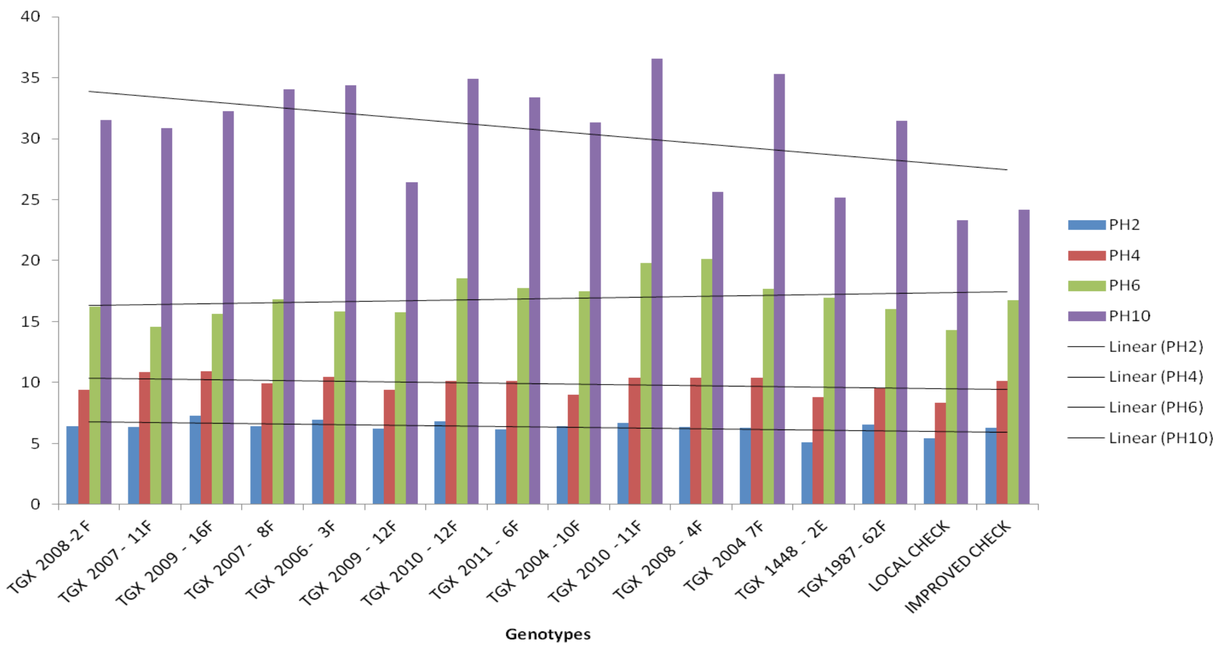

Fig. 3. Trends in Plant height (PH) at 2, 4, 6 and 10 weeks after sowing (WAS)

Table 4. Reproductive characteristic and yield components of soybean

Genotypes		Day to Flowering	Root nodulation	Total biomass	Seed weight	Biological Yield	Harvest Index	Economic yield	Pod Weight	Seed chaff ratio	PPR
TGX 2008 -2 F		47.00cde	0.39abc	993.30abc	98.67bcd	2,483.30abc	0.12a-d	246.67bcd	263.33bcd	0.37abc	0.29bcd
TGX 2007 - 11F		47.33cde	0.36abc	1,110.00ab	127.63b	2,775.00ab	0.13a-d	319.08b	356.67ab	0.36abc	0.34bcd
TGX 2009 - 16F		46.33e	0.26cb	530.00de	98.37bcd	1,325.00de	0.23abc	245.92bcd	230.00bcd	0.44abc	0.47abc
TGX 2007 - 8F		46.00e	0.31abc	720.00a-e	91.63b-e	1,800.00a-e	0.16a-d	229.08b-e	216.67dc	0.44abc	0.36a-d
TGX 2006 - 3F		49.67b-e	0.53a	316.70fe	36.73f	791.70fe	0.15a-d	91.83f	66.67fe	0.64ab	0.23bcd
TGX 2009 - 12F		46.33e	0.33abc	573.30c-e	124.77b	1,433.30cde	0.25ab	311.92b	206.67c-e	0.74a	0.45a-d
TGX 2010 - 12F		50.00b-e	0.39abc	1,143.30a	54.43def	2,858.30a	0.06cd	136.08def	203.33c-e	0.27cb	0.19cd
TGX 2011 - 6F		52.33ab	0.33abc	856.70a-d	40.83ef	2,141.70a-d	0.05d	102.08ef	123.33dfe	0.34cb	0.15d
TGX 2004 - 10F		54.33a	0.33abc	1,020.00abc	70.33c-f	2,550.00abc	0.08bcd	175.83c-f	203.33dce	0.39abc	0.20cd
TGX 2010 - 11F		46.67ed	0.33abc	676.70c-e	60.40def	1,691.70b-e	0.09cdb	151.00def	190.00dce	0.21c	0.27bcd
TGX 2008 - 4F		46.00e	0.26cb	633.30cde	114.40bc	1,583.30cde	0.18a-d	286.00bc	280.00cb	0.41abc	0.46abc
TGX 2004 7F		46.00e	0.33abc	673.30c-e	80.83b-f	1,683.30b-e	0.14a-d	202.08b-f	206.67cde	0.45abc	0.31bcd
TGX 1448 - 2E		48.00cde	0.23c	106.70f	35.17f	266.70f	0.28a	87.92f	46.67f	0.47abc	0.44a-d
TGX 1987 - 62F		51.00cab	0.31abc	440.00def	85.93b-f	1,100.00def	0.23a-d	214.83b-f	276.67cb	0.36abc	0.64a
LOCAL CHECK		50.67a-d	0.31abc	636.70c-e	79.30b-f	1,591.70cde	0.13a-d	198.25b-f	176.67c-e	0.44abc	0.28bcd
IMPROVED CHECK		46.00e	0.50ab	856.70a-d	204.93a	2,141.70a-d	0.24ab	512.33a	450.00a	0.46abc	0.53ab
Mean		48.35	0.34	705.42	87.77	1763.54	0.16	219.43	219.15	0.43	0.35
Source	df										
Rep	2	1.08	0.02	356227.00**	8296.26**	2226419.00**	0.07**	51851.60**	5266.28	0.33**	0.17**
Variety	15	20.91**	0.02	244671.00**	5500.56**	1529191.00**	0.02	34378.50**	29261.10**	0.04	0.06*
Error	30	4.51	0.01	53762.6	758.33	336016.00	0.01	4739.53	5264.39	0.04	0.67
CV (%)		4.39	35.51	32.87	31.37	32.87	58.79	31.37	38.11	45.15	43.26

*,** = significant at 10 and 5% probability; - not applicable, df= degree of freedom; Rep= replication; CV= coefficient of variation, PPR: pod plant ratio, Means root nodulation is multiplied by 10^1

Table 4 showed the reproductive characteristics and yield of soybean. Days to flowering of the 16 genotypes are significantly different (P≤0.5) from each other. Despite all the genotypes being late maturing varieties, they flower at different times and invariably matures at different time. TGX 2004-10F had the highest number of days to flowering while the lowest number of days to flowering were in TGX 2008-4F, TGX 2004-7F and improved check. Generally, late maturing genotypes have greater tendencies to acquire more assimilate on the field, which should translate to greater total biomass and possibly grain yield (White *et al*., 1992). Root nodulation of the genotypes are not significantly different (P≤0.5) from each other, TGX 2006 - 3F has the highest root nodulation (5.3) while TGX 1448 -2E has the lowest root nodulation. High nodulation implies high potential of the genotype to fix nitrogen in the soil and then, enrich the soil and consequently enhance yield (Karikari *et al*., 2015). Genotype (TGX 2006 -3F) with significantly high nodulation however was among the least yielding in terms of economic yield, total plant biomass and low harvest index. Possibly, the nitrogen fixing efficiency of TGX 2006 - 3F might be low or the nitrogen it fixed was most likely not available during that cropping season. The highest yielding genotype (improved check) had nodulation that was significantly comparable to TGX 2006- 3F's. However genotypes (TGX 1448 -2E and local check) with the least nodulation were also the least yielding genotypes. Hence being in agreement with the report of Karikari *et al*. (2015) who asserted that root nodulation help in fixing N and hence enhance yield.

Total plant biomass ranges from 1,143.30g for TGX 2010 -12F and to 106.70g for TGX -1448 2E. TGX 2010-12F has the highest biological yield (2,858.30g) while TGX 1448 -2E has the lowest (266.70g). In TGX 2010-12F, assimilate and photosynthates were channelled to the production of biomass. Hence, it is a good candidate where fodder production is of primary concern especially in feeding livestock. In terms of economic yield, improved check (TGX 1448) has the highest (512.33 Kg/ha) grain yield while TGX1448-2E recorded the lowest (87.92 Kg/ha) seed weight (Table 4). TGX 1448 obviously transferred assimilates and photosynthates to seed production. Harvest index could provide means of identifying genotypes with high biomass and seed quantity (economic yield) for dual purpose of fodder and seeds. Hence genotype such as the improved check (TGX 1448) could fit well.

Table 5. Correlation of vegetative and yield related traits of soybean

	FWR	NLV6	PH6	NB6	NLV10	PH10	NB10	RTNODT	TBIOM	BYLD	WTSP	PPR	EYLD	HI	SCR
FWR	1	-0.19	0.04	-0.11	-0.03	0.13	0.2	-0.06	0.1	0.1	-0.3*	-0.33*	-0.40*	-0.30*	-0.09
NLV6			0.31*	0.45*	0.59*	-0.04	0.25	-0.13	-0.42*	-0.42*	-0.11	0.15	-0.02	0.21	-0.04
PH6				0.25	-0.01	0.23	-0.07	-0.11	0.04	0.04	0.09	-0.15	0.11	-0.09	-0.02
NB6					0.23	-0.04	0.11	-0.02	-0.16	-0.16	-0.2	-0.05	0.04	0.11	0.37*
NLV10						0.03	0.50*	-0.15	-0.30*	-0.30*	-0.27	-0.01	-0.14	0.15	0.07
PH10							0.23	0	-0.02	-0.02	-0.18	-0.13	-0.30*	-0.18	-0.12
NB10								-0.22	-0.40*	-0.40*	-0.3	0.25	-0.13	0.40*	0.17
RTNODT									0.28	0.28	0.13	-0.26	0.1	-0.28	-0.04
TBIOM										0.05	0.48*	-0.42*	0.13	-0.56*	-0.34*
BYLD											0.48*	-0.42*	0.13	-0.56*	-0.34*
WTSP												0.36*	0.74*	0.06	-0.25
PPR													0.41*	0.83*	0.12
EYLD														0.45*	0.35*
HI															0.54*
SCR															1

FWR= days to 50% flowering; number of leaves, number of branches; plant height all at 6 and 10 weeks after sowing; root nodulations; total biomass; biological yield; weight of pod; pod plant ratio; economic yield; harvest index and seed chaff ratio

A summarized matrix of phenotypic correlation analysis for the agronomic traits and yield components is presented in Table 5. There were significant negative correlations between days to flowering and weight of seed with pod, pod plant ratio, weight of seeds, economic yield and harvest index. Also between the number of branches at 10 WAS and total biomass on one hand and between biological yield and pod plant ratio on the other hand. The negative relationship between days to 50% flowering and yield related parameters such as weight of seeds per pod, pod plant ratio and economic yield revealed that the longer the days to 50% flowering and hence maturity, the less the number of seeds per pod, weight of seed per pod and consequently the economic yield. This implies that genotype with longer vegetative period were less yielding, possibly because photosynthate/assimilates that were converted into seeds and pods in early thriving genotypes (improved check, TGX 2009-12F, TGX 2007-11F) were used for luxuriant growth in the late flowering genotype (TGX 2004-10F, TGX 2006-11F and TGX 2006-3F). Alternatively, it could be as a result of terminal drought resulting from the outset of dry season which early flowering genotypes escaped. This corroborates the findings of Shavrukov *et al*. (2017) that earliness is a strategy to escape drought and guarantee good yield more so that it allows planting in two seasons within a year (Bindu *et al*., 2011). However, there were positive correlation between fodder or biomass enhancing traits such as the number of leave 6 WAS and plant height, the number of branches at 6 WAS and biological yield; the number of leaves at 10 WAS and the number of branches at 10 WAS, biological yield and harvest index.

This indicates that the number of leaves, branches, plant height are primary traits in soybean cultivated for fodder.

Harvest index was positively correlated with total biomass, biological yield. The highest relationship (r= 0.83) was obtain between harvest index and plant pod ratio. Soybean with good harvest index have potential for dual purposes.

Path analysis (fig. 4) revealed that plant vigour impact (r= 0.52*) economic yield directly and significantly while the number of branches at 10 weeks impact (r= 0.61*) economic yield through vigour. Hence, the economic yield can be enhanced by improving vigour and the number of branches at 10 weeks. Number of leaves 6 and 10 weeks and plant height at 6 weeks have direct third order impact on economic yield. Similar to this, Patil (2011), also reported a positive association between seed yield of sunflower and plant height while Selvi *et al*. (2016) reported a negative association between grain yield as primary trait and the number of leaves and plant height in pea. Traits with direct association with seed yield provide basis for selection and improvement (Selvi *et al*., 2016; Rasitha *et al*., 2019). Path analysis provided a robust cause-effect relationship than phenotypic correlation (Kumar and Arumugam, 2013).

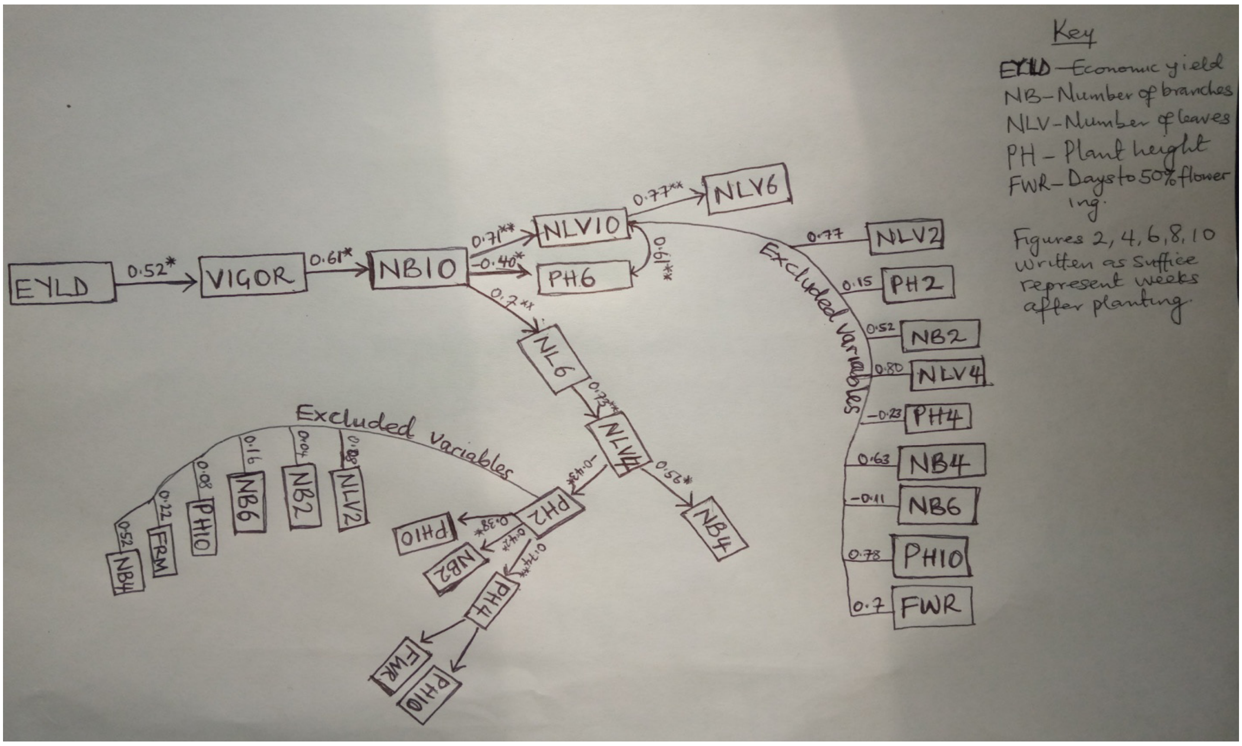

Fig. 4. Path analysis showing the cause and effect relationship between economic yield and vegetative characters.

Keys:
EYLD: Economic yield
NB: Number of braches
NLV: Number of leaves
PH: Plant height
FWR: Days to 50% flowering
Figures 2,4, 6, 8 and 10 written as suffice represent weeks after planting.
Note: Excluded variables do not have significant relationship with economic yield.

Dendogram (fig. 5) used economic yield and other yield parameters related to fodder production and dual usage the group the lines into three clusters hence, attesting to diversity among the breeding lines (Aremu *et al*., 2007). The local check obtained from farmers' source clustered differently with the improved check, a commercial line. The eight breeding lines that clustered with local check implied a close genetic background between the breeding lines and farmers' seed (Aremu *et al*., 2007), hence alluding to possible gene flow or exchange of soybean germplasm between IITA and local farmers. Also, the six lines that clustered with improved check (commercial hybrids) signified that there is genetic association between breeding lines (from IITA) and improved check (from seed company). These breeding lines have wide diversity that captures the two categories of soybean seeds sown in Nigeria, the local seed and improved seed.

Rescaled Distance Cluster Combine

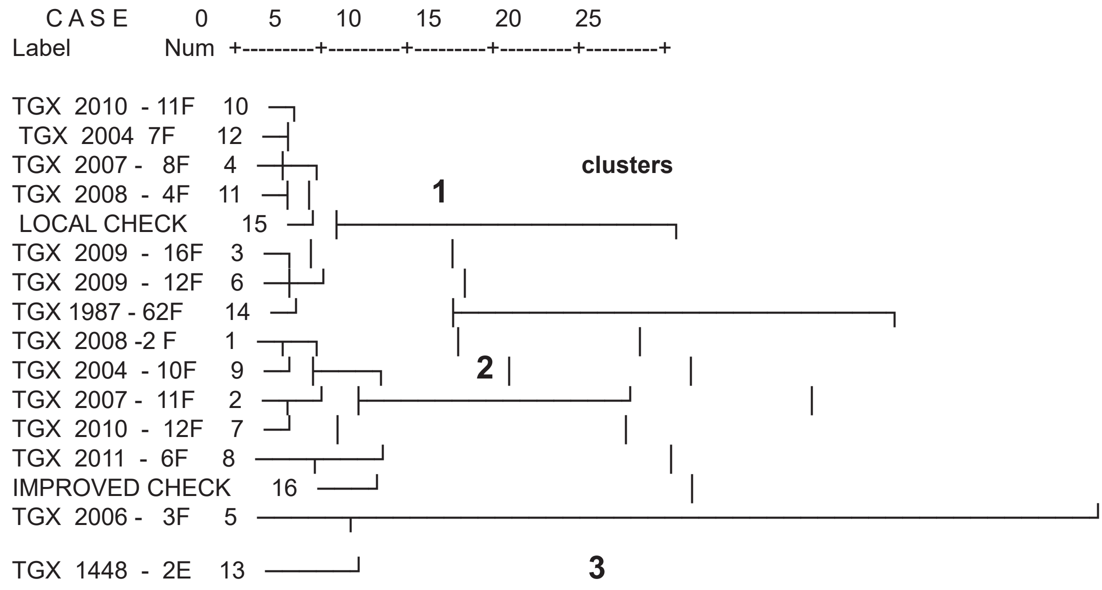

Fig. 5. Dendrogram using average linkage between groups to show the relationship among soybean breeding lines.

The wide genetic variability among the TGX genotypes showed that they can be improved through breeding. Earliness to flowering paved way for guaranteed grain yield and by extension livelihood security to the growers. TGX 1448 (improved check) is the most suitable genotype in agro ecological zone in terms of grain yield. The lines were true to type for grain yield and other characters. Hence, resource poor farmers can save seeds from harvested good yielding lines for planting in subsequent season. Breeders can use traits such as vigour, the number of branches and leaves at 10 weeks, plant height and the number of leaves at 6 weeks with direct positive and significant relation with economic yield to improve yield. TGX 2008-2F, TGX 2007-11F, TGX 2009-16F are promising lines and better replacement to the local check. Therefore, further breeding efforts could be carried out to improve the lines for grain yield and fodder in order to achieve dual usage for the soybean lines.

ACKNOWLEDGEMENTS

The author appreciates Soybean unit of IITA, Ibadan for providing the soybean breeding lines used for the research and Ajiboye Oluwatosin Tayo for helping to oversee the research field.

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