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 legume grains. 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 scattering 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 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.

**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 - 11 F | 13.2                | pale yellow | oblong     | Oblong         | 1               | 5                      | 3           | 40    | 0.42bc|
| TGX 2009 - 16 F | 12.8                | Golden      | sphere     | Oval           | 2               | 1                      | 3           | 70    | 0.36bc|
| TGX 2007 - 8 F  | 13.4                | golden yellow| sphere    | Oblong         | 1               | 2                      | 5           | 40    | 0.29c |
| TGX 2006 - 3 F  | 16.5                | Nude        | sphere     | Oblong         | 3               | 2                      | 3           | 80    | 0.32bc|
| TGX 2009 - 12 F | 11.9                | pale yellow | Round      | Oblong         | 2               | 4                      | 4           | 30    | 0.33bc|
| TGX 2010 - 12 F | 10.3                | light yellow | sphere    | Oblong         | 3               | 5                      | 2           | 30    | 0.44bc|
| TGX 2011 - 6 F  | 11.0                | Yellow      | sphere     | Oval           | 2               | 1                      | 2           | 70    | 0.39bc|
| TGX 2004 - 10 F | 11.2                | light yellow | oblong    | Oval           | 3               | 3                      | 3           | 20    | 0.39bc|
| TGX 2010 - 11 F | 12.5                | fade yellow | sphere    | Oval           | 2               | 4                      | 4           | 30    | 0.50b |
| TGX 2008 - 4 F  | 12.6                | light yellow | sphere    | Oval           | 2               | 3                      | 4           | 70    | 0.42bc|
| TGX 2004 - 7 F  | 12.9                | Cream       | sphere     | Oval           | 2               | 3                      | 4           | 70    | 0.42bc|
| TGX 1448 - 2 E  | 12.6                | Yellow      | sphere     | Oblong         | 2               | 2                      | 2           | 10    | 0.34bc|
| TGX 1987 - 62 F | 9.0                 | golden yellow| Round    | Oval           | 3               | 4                      | 3           | 20    | 0.25c |
| Local check     | 11.4                | Yellow      | Round      | Oval           | 2               | 3                      | 3           | 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 - 11 F | 12.67ab                       | 13.23a                            | 0.43    | 1.43b                           | 1.27a                               | 0.46    |
| TGX 2009 - 16 F | 12.90ab                       | 14.10a                            | 0.36    | 1.47b                           | 1.57a                               | 0.22    |
| TGX 2007 - 8 F  | 13.23ab                       | 11.83ab                           | 0.1     | 1.23b                           | 1.70a                               | 0.18    |
| TGX 2006 - 3 F  | 14.63a                        | 13.77a                            | 0.7     | 1.40b                           | 1.73a                               | 0.27    |
| TGX 2009 - 12 F | 12.00b                        | 11.43ab                           | 0.22    | 1.13b                           | 1.47a                               | 0.06    |
| TGX 2010 - 12 F | 11.47b                        | 12.70ab                           | 0.2     | 1.33b                           | 1.23a                               | 0.87    |
| TGX 2011 - 6 F  | 11.03cb                       | 11.30ab                           | 0.69    | 1.13b                           | 1.37a                               | 0.32    |
| TGX 2004 - 10 F | 11.07cb                       | 11.77ab                           | 0.37    | 1.20b                           | 1.23a                               | 0.87    |
| TGX 2010 - 11 F | 12.60ab                       | 13.77a                            | 0.32    | 1.33b                           | 1.57a                               | 0.57    |
| TGX 2008 - 4 F  | 12.63ab                       | 11.93ab                           | 0.19    | 1.27b                           | 1.73a                               | 0.23    |
| TGX 2004 - 7 F  | 12.03b                        | 13.13a                            | 0.65    | 5.37a                           | 1.20a                               | 0.43    |
| TGX 1448 - 2 E  | 12.00b                        | 7.83c                             | 0.81    | 0.73b                           | 1.73a                               | 0.15    |
| TGX 1987 - 62 F | 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
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.
Table 4. Reproductive characteristic and yield components of soybean

| Genotypes     | Days to Flowering | Root nodulation | Total biomass | Seed weight | Biological Yield | Harvest Index | Economic Yield | Pod Weight | Seed chaff ratio | PPR |
|---------------|------------------|-----------------|---------------|-------------|------------------|---------------|----------------|-------------|-----------------|-----|
| TGX 2008-2F   | 47.00cde         | 0.36abc         | 993.30abc     | 98.67bcd    | 2,483.30abc      | 0.12a-d       | 263.33bcd      | 0.37abc    | 0.29bcd          |     |
| TGX 2007-11F  | 47.33cde         | 0.36abc         | 1,110.00ab    | 127.63b     | 2,775.00ab       | 0.13a-d       | 356.67ab       | 0.36abc    | 0.34bcd          |     |
| TGX 2009-16F  | 46.33e           | 0.26cb          | 530.00de      | 98.37bcd    | 1,325.00de       | 0.23abc       | 229.08b-e      | 0.44abc    | 0.47abc          |     |
| TGX 2007-8F   | 46.00e           | 0.31abc         | 720.00a-e     | 91.63b-e    | 1,800.00a-e      | 0.16a-d       | 216.67dc       | 0.44abc    | 0.36a-d          |     |
| TGX 2006-3F   | 49.67b-e         | 0.53a           | 316.70fe      | 36.73f      | 791.70fe         | 0.15a-d       | 66.67fe        | 0.64ab     | 0.23b            |     |
| TGX 2009-12F  | 46.33e           | 0.33abc         | 573.30c-e     | 124.77b     | 1,433.30cde      | 0.25ab        | 319.192b       | 0.74a      | 0.45a-d          |     |
| TGX 2010-12F  | 50.00eb          | 0.38abc         | 1,143.30a     | 54.43de     | 2,858.30a        | 0.06cd        | 136.08de       | 0.27cb     | 0.19cd           |     |
| TGX 2011-6F   | 52.33ab          | 0.33abc         | 856.70a-d     | 40.83def    | 2,141.70a-d      | 0.05d         | 123.33df       | 0.34b      | 0.15d            |     |
| TGX 2004-10F  | 54.33a           | 0.33abc         | 1,020.00abc   | 70.33c-f    | 2,550.00abc      | 0.08bcd       | 203.33dce      | 0.39abc    | 0.20cd           |     |
| TGX 2010-11F  | 46.67ed          | 0.33abc         | 676.70e       | 60.40def    | 1,691.70b-e      | 0.09cde       | 150.00de       | 0.21c      | 0.27bcd          |     |
| TGX 2008-4F   | 46.00e           | 0.26cb          | 633.30cde     | 114.40bc    | 1,583.30cde      | 0.18a-d       | 286.00bc       | 0.41abc    | 0.46abc          |     |
| TGX 2004 7F   | 46.00e           | 0.33abc         | 673.30c-e     | 80.83bf     | 1,683.30b-e      | 0.14a-d       | 206.67ade      | 0.45abc    | 0.31bcd          |     |
| TGX 1448-2E   | 48.00cde         | 0.23c           | 106.70f       | 35.17f      | 266.70f          | 0.28a         | 87.90f         | 0.47a      | 0.44a-d          |     |
| TGX 1987-62F  | 51.00cb          | 0.31abc         | 440.00def     | 85.90b-f    | 1,100.00def      | 0.23a-d       | 214.83bc       | 0.36abc    | 0.64a           |     |
| LOCAL CHECK   | 50.67a-d         | 0.31abc         | 636.70c-e     | 79.30f      | 1,591.70cde      | 0.13d         | 176.67c-e      | 0.44abc    | 0.28bcd          |     |
| IMPROVED CHECK| 46.00e           | 0.50ab          | 856.70a-d     | 204.93a     | 2,141.70a-d      | 0.24ab        | 450.00a        | 0.46abc    | 0.53ab           |     |
| Mean          | 48.35            | 0.34            | 705.42        | 87.77       | 1763.54          | 0.16         | 219.43         | 0.43      | 0.35             |     |

Source of variation: Replication (Rep), Genotype (Variety), Error (Error), CV (%)

Mean root nodulation is multiplied by 10^1
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) that 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*| -0.02 | 0.36* | -0.01 | -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 | -0.15 | -0.30*| -0.30*| -0.27  | -0.01 | 0.14 | 0.07 |
| NLV10| 0.03  | 0.50* | -0.22 | 0.23  | 0    | -0.02 | -0.02  | -0.18 | -0.13 | -0.30*| -0.18 | -0.12 |
| PH10 |       |      |       |       |      | -0.22 | -0.40* | -0.40* | -0.3  | 0.25 | 0.13 | 0.40* | 0.17 |
| NB10 |       |      |       |       |      |       | 0.28   | 0.28  | 0.13 | 0.26 | 0.1  | -0.28 | -0.04 |
| RTNODT|       |      |       |       |      |       |       | 0.05  | 0.48*| -0.42*| 0.13 | -0.56*| -0.34*|
| TBIOM|       |      |       |       |      |       |       |       | 0.48*| -0.42*| 0.13 | -0.56*| -0.34*|
| BYLD |       |      |       |       |      |       |       |       |       | 0.36*| 0.74*| 0.06  | -0.25 |
| WTSP |       |      |       |       |      |       |       |       |       |       | 0.41*| 0.83* | 0.12 |
| PPR  |       |      |       |       |      |       |       |       |       |       |       | 0.45*| 0.35* |
| EYLD |       |      |       |       |      |       |       |       |       |       |       |       | 0.54*|
| HI   |       |      |       |       |      |       |       |       |       |       |       |       | 0.54*|
| SCR  |       |      |       |       |      |       |       |       |       |       |       |       |       |

**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 was 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 Shavruko 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 leaf 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.

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616
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 branches
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.
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.

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