



Genetic Variability and Heritability of Quantitative Traits in Soybean (*Glycine max* (L.) Merrill)

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Abstract

Soybean (Glycine max) is an economically important crop that exhibits a wide range of quantitative traits, such as yield, seed size and oil content. Understanding the genetic variability and heritability of quantitative traits play a crucial role in soybean breeding programs aimed at improving crop productivity and quality. In this study, we aimed to assess the genetic variability and heritability of various quantitative traits in soybean. To determine this, diverse set of soybean germplasm lines were collected from National Centre for Genetic Resources and Biotechnology (NACGRAB) Ibadan, Oyo State Nigeria. These lines were evaluated for various quantitative traits such as plant height, number of pods per plant, seed weight and yield per plant. The data obtained from these evaluations were subjected to statistical analysis to estimate the genetic variability. Furthermore, we estimated the heritability of these traits to understand the extent to which they are influenced by genetic factors. The heritability estimates were obtained using statistical methods such as broad sense heritability (H^2) which measures the proportion of phenotypic variation that can be attributed to genetic factors, including both additive and non-additive effects. Our findings demonstrated that most of the quantitative traits in soybean exhibited moderate to high heritability, indicating that these traits are influenced by genetic factors to a significant extent. This also suggests that selective breeding programs targeting these traits can be effective in improving soybean varieties. The study provides valuable insights into the genetic variability and heritability of quantitative traits in soybean, the identification of genetic diversity and estimation of heritability can aid in the development of improved soybean varieties with enhanced yield, seed size and oil content.

Keywords: Quantitative Traits, Diversity, Phenotypic Variation, Germplasm, Yield.

INTRODUCTION

Genetic variability refers to the differences in genetic makeup among individuals within a population (Allard, 1960). In the case of soybean (*Glycine max* (L.) Merrill), genetic variability plays a crucial role in determining the range of phenotypic traits observed in the population. These traits can include yield, plant height, seed size, disease resistance, and many others. Heritability, on the other hand, is a measure of the proportion of phenotypic variation in a trait that can be attributed to genetic factors (Osekita and Ajayi 2013). It provides an estimate of how much of the observed variation in a trait is due to genetic differences among individuals. In soybean, heritability estimates can help plant breeders determine the potential for improving specific traits through selective breeding (Akinyele and Osekita, 2008).

Understanding the genetic variability and heritability of quantitative traits in soybean is essential for plant

breeding programs aimed at developing improved cultivars with desirable traits (Osekita and Olorunfemi, 2014). By identifying and selecting individuals with high heritability for specific traits, breeders can increase the likelihood of passing on those traits to future generations. It is worth noting that genetic variability and heritability are influenced by various factors, including the genetic diversity within the soybean population, environmental conditions, and interactions between genes and the environment. Ongoing research in soybean genetics continues to shed light on the complex mechanisms underlying these traits, providing valuable insights for crop improvement efforts. In this study, we aimed to assess the genetic variability and heritability of various quantitative traits in soybean.

MATERIALS AND METHODS

A field experiment for the evaluation of ten soybean genotypes was conducted at the experimental field of Plant

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Science and Biotechnology, Adekunle Ajasin University, Akungba-Akoko Ondo State Nigeria. The soybean genotypes used for the experiment were obtained from National Centre for Genetic Resources and Biotechnology (NAGRAB) Ibadan Oyo State Nigeria and they include; NGB03519, NGB03520, NGB03521, NGB03537, NGB03539, NGB03550, NGB03553, NGB03561, NGB03568 and NGB03579.

The field was cleared, ploughed and ridged, the plots were laid out in a randomized complete block design (RCBD) and the treatments replicated three times. The planting distance adopted was 30cm within by 60cm between rows and the planting depth was 3-5cm deep. Cultural practices such as weeding was done manually while the use of synthetic herbicides was discouraged because of its impact and

residual effect on the environment. Cypermethrin 10% EC at 0.2 Lt/ha in 100 Lt/ha of water was sprayed on the soybean plant to prevent pest infestation.

Data were collected on the following morphological and yield traits; Emergence, plant height, number of days to 50% flowering, number of branches, number of pods per plant, number of seeds per pod, pod weight, 100 seed weight and seed yield per plant.

Data obtained from the above were analyzed statistically using SPSS version 20 for analysis of variance (ANOVA) to test for the significant levels of the quantitative traits, means were separated using Duncan Multiple range test. Estimate of genetic parameters were computed following the procedure of Osekita and Ajayi (2013).

RESULTS

Table 1. Mean squares and coefficient of variation on nine quantitative traits of soybean

Source of variation	Degree of freedom	Plant height (cm)	Days to 50% Flowering	No of pods/plant	No of seeds/pod	Pod weight (g)	Days to maturity	100 seed weight (g)	Seed yield/plant (g)
Genotypes	9	160.08**	6.07**	87.29**	0.55**	0.001**	111.34**	0.87**	14.07**
Replication	2	1.63 ^{ns}	0.63**	6.43 ^{ns}	0.13 ^{ns}	0.000 ^{ns}	18.03**	0.17**	20.83**
Error	18	5.20	0.37	24.14	0.43	0.000	5.29	0.08	9.80
CV		3.26	1.13	5.17	21.64	0.00	1.99	1.78	3.82

Note: ** significant at 1% probability, ns: not significant

The result of mean squares and coefficient of variation obtained from the analysis of variance (ANOVA) using the GLS model at $p \leq 0.05$ of the SPSS version 20 was presented in Table 1. The genotypes showed very high significant difference based on the measured traits. Effect of replication were not significant on plant height, number of pods per plant and number of seeds per pod and pod weight. While the remaining four traits; number of days to 50% flowering, number of days to maturity, 100 seed weight, and seed yield per plant had very high significant effect of replication. However, coefficient of variation ranged from (0.00%) in pod weight to (21.64%) in number of seeds per pod.

Table 2. Mean performance and standard error on eight quantitative traits of soybean

Genotypes	Plant height	Days to 50% Flowering	No of pods/plant	No of seeds/pod	Pod weight	Days to Maturity	100 seed weight	Seed yield/plant
NGB03519	56.33±2.09a	52.33±0.33a	85.33±2.91a	3.33±0.33ab	0.39±0.02c	106.0±3.06a	16.00±0.12bc	83.90±1.61ab
NGB03520	78.50±0.95g	52.67±0.33ab	98.00±1.16bcd	3.00±0.00ab	0.35±0.00ab	113.7±0.88bc	15.73±0.24b	82.10±1.21ab
NGB03521	77.17±1.48fg	53.67±0.33bc	102.00±1.16d	3.67±0.33ab	0.33±0.01a	116.0±1.16cd	15.00±0.25a	79.37±1.80ab
NGB03537	74.37±1.84ef	55.33±0.33d	89.33±4.67ab	3.00±0.00ab	0.38±0.02bc	106.3±0.88a	15.93±0.18bc	85.33±0.74b
NGB03539	60.37±1.24b	54.00±0.58c	94.00±3.46abcd	3.00±0.57ab	0.36±0.01abc	110.0±1.16ab	15.17±0.23a	78.07±4.62a
NGB03550	69.33±0.46cd	55.67±0.33d	93.00±2.08abcd	2.33±0.33a	0.36±0.01abc	120.3±0.88de	16.80±0.17d	81.93±1.04ab
NGB03553	66.33±1.26c	52.33±0.33a	99.33±1.76cd	3.33±0.33ab	0.33±0.01a	120.7±1.33de	16.43±0.20cd	84.13±1.03ab
NGB03561	76.40±1.01fg	52.67±0.33ab	102.00±1.15d	3.33±0.33ab	0.32±0.01a	122.0±1.15e	15.83±0.03b	81.50±1.54ab
NGB03568	68.83±0.35cd	55.67±0.33d	92.67±2.91abc	2.33±0.33a	0.36±0.01abc	121.3±1.76e	16.20±0.06bc	81.53±0.38ab
NGB03579	71.37±0.88de	52.33±0.33a	94.67±3.53bcd	3.00±0.57ab	0.36±0.01abc	116.0±1.15cd	15.70±0.06b	81.77±1.57ab

Note: Means with the same alphabet in the same column are not significantly different from each other.

Table 2 presents the mean performance and standard error on eight quantitative traits of soybean. The genotypes differed from one another in tallness and shortness as indicated from the result of mean separation which ranged from 56.33 ± 2.09 cm in NGB03519 to 78.50 ± 0.95 cm of NGB03520. Days to 50% flowering for all the genotypes were quite close but some genotypes flower early compared to some few others which ranged between 52.33 ± 0.33 days to 55.67 ± 0.33 days. Number of pods per plant ranged from 85.33 ± 2.91 in NGB03519 to 102.00 ± 1.16 in NGB03521. For number of seeds per

pod there is no significant difference between the genotypes as the exhibit nearly the same seed s per pod. The genotypes showed slightly little difference in pod weight as indicated by genotype NGB03561 (0.32 ± 0.01 g) having the lightest weight while the heaviest weight of 0.39 ± 0.02 g was recorded in NGB03519. Genotype NGB03519 had the shortest number of days to maturity (106 ± 3.06 days) while genotype NGB03561 had the longest number of days to maturity (122.0 ± 1.15 days). Genotypes NGB03550 is the heaviest in terms of hundred seed weight 16.80 ± 0.17 g as compared to NGB03521 which has the lightest weight of 15.00 ± 0.25 g. The highest seed yield per plant of 84.13 ± 1.03 g was recorded in genotype NGB03553 while the lowest of 78.07 ± 4.62 g was found in NGB03539.

Table 3. Estimate of genetic parameters on quantitative traits of soybean

Traits	Min.	Max.	Mean	VG	VP	GCV	PCV	H ² B	GA	GAM
Plant height (cm)	52.50	80.10	69.9	51.63	56.83	0.103	0.108	90.85	14.11	20.18
Days to 50% Flowering	52.00	56.00	53.67	1.90	2.27	0.026	0.028	83.70	2.60	4.84
No of pods/plant	80.00	104.00	95.03	21.05	45.19	0.048	0.071	46.58	6.45	6.79
No of seeds/pod	2.00	4.00	3.03	0.04	0.47	0.066	0.226	8.51	0.12	3.97
Pod weight (g)	0.31	0.42	0.35	0.0003	0.0003	0.049	0.049	100.0	0.46	130.29
Days to maturity	100	124	115.2	35.35	40.64	0.052	0.055	86.98	11.42	9.92
100 seed weight (g)	14.70	17.10	15.88	0.26	0.34	0.032	0.037	76.47	0.92	5.78
Seed yield/plant (g)	68.90	86.80	81.96	1.42	11.22	0.015	0.041	12.66	0.87	1.07

Note: VG: Genotypic variance, VP: Phenotypic variance, GCV: Genotypic coefficient of variance, PCV: Phenotypic coefficient of variance, H²B: Heritability in broad sense, GA: Genetic advance and GAM: Genetic advance as percent of mean

Estimate of genetic parameters comprising of Minimum and maximum values of each measured traits, grand mean, genotypic and phenotypic variances, genotypic and phenotypic coefficients of variances heritability in broad sense, genetic advance and genetic advance as percent of mean were presented in Table 3. The genotypic variance (Vg) in most cases is always lower than the phenotypic variance (Vp) because of the influence of the environment component on the quantitative traits, same thing occurs in the case of the genotypic and phenotypic coefficient of variation (GCV and PCV) respectively. Both variances i.e. Vg and Vp; GCV and PCV are the same when the effect of environment has played no significant role on the traits being measured therefore, heritability will always equal to 1.0. Hence, heritability estimate ranged from as low as 8.51% in number of seeds per pod to as very high as 100% in pod weight followed by 90.85% in plant height. Genetic advance for each of the traits measured ranged from 0.12 in number of seeds per pod to as high as 14.11 in plant height. While genetic advance as percent of mean ranged from as low as 1.07% in seed yield per plant to very high as 130.29% in pod weight.

Table 4. Genotypic correlations on quantitative traits of soybean

Traits	Plant height (cm)	Days to 50% Flowering	No of pods/plant	No of seeds/pod	Pod weight (g)	Days to maturity	100 seed weight (g)	Seed yield/plant (g)
Plant height	1	0.057	0.461*	0.033	-0.397*	0.350	-0.119	-0.021
Days to 50% Flowering		1	-0.186	-0.479**	0.239	0.035	0.236	-0.083
No of pods/plant			1	0.142	-0.963**	0.515**	-0.163	-0.373*
No of seeds/pod				1	-0.104	-0.051	-0.356	0.168
Pod weight					1	-0.538**	0.137	0.351
Days to maturity						1	0.317	-0.110
100 seed weight							1	0.452*
Seed yield/plant								1

Note: *, ** significant at 5% and 1% probability respectively

The genotypic correlations on eight quantitative traits of soybean were presented in Table 4. There were significant positive correlations between plant height and number of pods per plant (0.461), but showed negative significant correlation with pod weight (-0.397). Number of days to 50% flowering showed very high negative significant correlation (-0.479) with number of seeds per pod. Number of pods per plant showed very high positive significant correlation (0.515) with number of days to maturity and also showed very high negative significant correlation (-0.963) with pod weight and seed yield per plant (-0.373). There was a very high negative significant correlation (-0.538) between pod weight and number of days to maturity. One hundred seed weight had high positive significant correlation (0.452) with seed yield per plant.

DISCUSSION

Genetic variability refers to the differences in genetic makeup among individuals within a population and this can be observed in traits such as plant height, seed size, yield and disease resistance. These variations arise from differences in the genes present in the soybean population. However, the high mean squares values for most traits (except Days to 50% flowering) indicate significant genetic variability among the different genotypes for these traits, similar results were observed in Osekita and Ajayi (2013). The significant differences suggest that there is genetic diversity among the soybean genotypes, which is important for plant breeding. Breeders can select genotypes with desirable trait values for further improvement. The coefficient of variation which is a measure of relative variability expressed as a percentage of the mean provides an indication of the precision of the measurements for each trait. Traits with higher CV values (e.g., 100 seed weight and Seed yield/plant) have relatively larger variability compared to the mean, which suggests that measurements for these traits are less consistent and might be influenced by various factors. Osekita et al., (2000), Akinyele and Osekita, (2011) in okra and in rice Ajayi et al., (2024). Pod weight and number of seeds/pod with very low CV values have minimal variability indicating that measurements for these traits are more consistent. The implications of the above for crop improvement include; Genetic selection in that significant genetic variability among different genotypes for most traits implies that breeders have a pool of diverse genetic resources to select from and this diversity can be harnessed to develop improved soybean varieties with desirable trait combinations.

Heritability, on the other hand, is a measure of the proportion of phenotypic variation in a trait that can be attributed to genetic differences. It indicates how much of the observed variation in a trait is due to genetic factors rather than environmental factors. Its values range from 0 to 1, with higher values indicating a stronger genetic influence on the trait. In soybeans, heritability estimates for quantitative traits vary depending on the specific trait and population being studied. In this study, number of pods per plant, hundred seed weight and plant height had moderate to high heritability, indicating that genetic factors play a significant role in determining these traits. This is corroborated in the study conducted in cowpea by Ajayi et al., (2024). On the other hand, number of seeds per pod and seed yield which have lower heritability suggests that environmental factors have a greater influence (Osekita et al., 2023). It is important to note that heritability estimates are population specific and can vary across different environments. Traits with higher heritability and significant genetic advance, such as plant height, pod weight, and days to maturity are more amenable to improvement through selection. Traits with lower heritability, like the number of seeds per pod, might require other approaches or a better understanding of genotype x environment interactions for effective breeding.

The findings could guide breeders in setting priorities for trait improvement and selection methods.

Correlation coefficients measure the degree of association between two or more component traits. A positive correlation indicates that as one trait increases, the other trait tends to increase as well. Whereas, a negative correlation indicates that as one trait increases, the other trait tends to decrease. The closer the value is to 1 or -1, the stronger the correlation while values closer to 0 indicate a weaker correlation. Plant height in this study shows positive correlations with the number of pods per plant and days to maturity indicating that taller plants tend to have more pods and longer time to maturity. There's a negative correlation between plant height and pod weight, suggesting that taller plants might produce lighter pods. Days to 50% flowering is negatively correlated with the number of pods per plant, indicating that early flowering plants tend to have fewer pods. There's a negative correlation with seed yield per plant as well, suggesting that early flowering might be associated with lower seed yield. The number of pods per plant has a strong negative correlation with days to 50% flowering, indicating that plants with more pods tend to flower later.

It has a positive correlation with the number of seeds per pod, which makes sense as more pods would lead to more opportunities for seeds. The number of seeds per pod has a weak negative correlation with plant height, suggesting that taller plants might produce slightly fewer seeds per pod; similar results were reported by Singh et al., (2015) in cowpea. Pod weight has a strong negative correlation with days to maturity, implying that pods might become lighter as the plant matures. Days to maturity is positively correlated with plant height and pod weight, indicating that taller plants and heavier pods might take longer to mature. Ajayi et al., (2023) reported similar results in cowpea. There's a positive correlation between 100 seed weight and seed yield per plant, indicating that plants producing heavier seeds might also yield more seeds overall.

In conclusion, the ANOVA results and coefficient of variation provide valuable insights into the genetic variability and heritability of quantitative traits in soybean. These insights are essential for effective plant breeding strategies aimed at developing improved soybean varieties with desirable traits. The genotypic correlations among quantitative traits in soybean provide valuable insights into their relationships and potential effects on plant breeding goals. Careful consideration of these correlations can guide breeders in making informed decisions to develop improved soybean varieties with desired traits.

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