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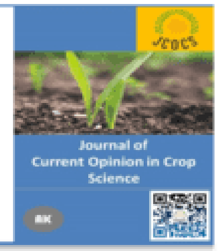


**RESEARCH ARTICLE**

# Variability of heritable characters in some roselles (*Hibiscus sabdariffa* L.) varieties in a forest savanna transition zone of Edo state, Nigeria

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## ABSTRACT

The present study was conducted to assess the variability of heritable traits among four varieties of Roselle (*Hibiscus sabdariffa*), Altisima Dark Red, Altisima Wine Red, Sabdariffa (Indian Sorrel), and White Sorrel, at the Teaching and Research Farm, Emaudo Annexe, Ambrose Alli University, Ekpoma. The experiment followed a Randomized Complete Block Design (RCBD) with four replications. Data were analyzed using ANOVA, and significant means were separated using Least Significant Difference (LSD). Genetic parameters, including heritability (H°), genetic gain (GG), and genetic advance (GA) were estimated. Sabdariffa (Indian Sorrel) showed significantly greater plant height at 12 weeks after planting (WAP), while White Sorrel and Altisima Dark Red differed significantly in leaf number. Altisima Dark Red flowered earlier, whereas Altisima Wine Red matured earlier. Both Altisima varieties exhibited similar branching patterns but differed significantly from other varieties at 6, 9, and 12 WAP. High heritability and genetic advance were recorded for plant height (89.58%–90.04%; GA: 1.84–1.85), leaf area (73.68%–89.80%; GA: 1.51–1.85), and days to 50% flowering (68.38%; GA: 1.40), indicating additive gene effects and suitability for selection. In contrast, the number of branches per plant and 50% flowering showed low heritability and genetic advance, suggesting non-additive gene effects and limited potential for improvement. Sabdariffa (Indian Sorrel) produced the highest dried calyx yield (kg/ha), highlighting its agronomic superiority. These findings provide a basis for varietal selection and improvement in Roselle breeding programs.

***Keywords:*** Hibiscus sabdariffa; Genetic variability; Heritability; Genetic advance; Additive gene effect; Trait selection; Calyx yield

## INTRODUCTION

The origin of wild *Vigna* species spans diverse regions including Africa, Asia, and Australia, where these accessions have adapted to varied ecological niches over time, acquiring unique traits that make them valuable genetic resources for crop improvement (Onuminya et al., 2023). Wild cowpea accessions, considered ancestral forms of cultivated cowpea (*Vigna unguiculata*), harbor extensive genetic diversity with significant potential to enhance agronomic traits, nutritional quality, and resilience to biotic and abiotic stresses. Their utilization could profoundly impact global agriculture and food security. Typically found in marginal environments, wild cowpea populations face increasing threats from land-use change, deforestation, and urbanization (Gerrano et al., 2019). These accessions offer opportunities to improve consumer-relevant traits such as taste, cooking time, and nutrient density (Omoigui et al., 2021).

Despite their importance, wild cowpea accessions remain under-characterized, particularly in Nigeria, one of the world's leading cowpea producers. Limited funding, inadequate research infrastructure, and low awareness of genetic conservation have hindered progress (Ajeigbe et al., 2021). This research gap risks the loss of valuable alleles critical for climate adaptation and sustainable agriculture. Molecular characterization provides a robust framework for assessing genetic variability, identifying distinct populations, and guiding conservation strategies. Techniques such as Random Amplified Polymorphic DNA (RAPD), Simple Sequence Repeats (SSR), and Single Nucleotide Polymorphisms (SNPs) have proven effective in elucidating genetic diversity (Gerrano et al., 2019), yet their application in Nigeria remains limited (Omoigui et al., 2021).

Advanced molecular tools, including DNA sequencing and SNP analysis, offer precise insights into genome composition and trait architecture (Smith et al., 2020; Jones & Brown, 2019). Unlike morphological and biochemical methods, which are influenced by environmental conditions, DNA markers reveal inherent genetic differences among individuals (Adavbiele et al., 2018). Therefore, this study employed SNP markers to characterize selected wild *Vigna* accessions, aiming to uncover intra-specific variation and inform future breeding efforts.

## MATERIALS AND METHODS

### Plant Materials

Four varieties of Roselle (*Hibiscus sabdariffa* L.) were evaluated: Var. Altissima Dark Red, Var. Altissima Wine Red, Var. Sabdariffa (Indian Sorrel), and White Sorrel. These accessions were collected from Zamfara State in Northern Nigeria, a region known for Roselle cultivation.

### Experimental Design

The field experiment was conducted using a Randomized Complete Block Design (RCBD) with four replications. The experimental site was manually cleared using cutlass and hoe, and plots were demarcated according to treatment layout. The field was divided into 16 plots, each measuring 1.5 m × 1.5 m, with a total land area of 11 m × 13.15 m. A 1 m alley separated adjacent plots. Each plot contained nine plant stands, spaced at 45 cm × 45 cm, resulting in a total of 144 plant stands across the entire field.

### Data Collection

Data were collected on key agronomic traits from four randomly selected plants per plot, and average values were recorded for each parameter. Plant height (cm) was measured from the base to the tip using a measuring tape, while the number of leaves and branches per plant were visually counted. Leaf length and breadth (cm) were measured with a ruler, and stem girth (cm) was determined using a measuring tape around the stem. Leaf area ($cm^2$) was calculated by multiplying leaf length and breadth by a constant (2.06). Days to 50% flowering and maturity were recorded as the number of days from sowing until half of the plant population in each plot flowered or matured. Finally, flower weight per plant (g) was obtained by weighing 100 capsules from four plants per plot using a sensitive digital scale.

### Genetic Analysis

Genetic parameters were estimated based on agronomic and yield-related traits, using mean squares from ANOVA. Phenotypic variance ($\delta\_ph^2$) was derived from treatment mean squares, while genotypic variance ($\delta\_g^2$) was calculated by subtracting error mean squares from phenotypic variance. The following formulas were used (Sylvester, 1988; Allard, 1999):

***Heritability (Ho):*** heritability in the broad sense was calculated using this formula

a) Heritability (H0) $= \frac{\delta_g^2}{\delta_{ph}^2} \times 100$

Where: $\delta_g^2$= Genotypic variance $\delta_{ph}^2$= Phenotypic variance

***Genotypic Advance (GA):*** This was calculated using the formula:

(b) GA $= \frac{\delta_g^2}{\delta_{ph}^2} \times K$

where: $\delta_g^2$ = Genotypic Variance, $\sqrt{\delta_{ph}^2}$ = square root of phenotypic variance, K= 2.06 (10% selective index)

***Genetic Gain (GG):*** This was calculated in terms of genetic advance (GA) expressed as a percentage of the population mean as follows:

$(c)$ $GG = \frac{GA}{X} \times 100$

X = Population mean

## RESULTS AND DISCUSSION

At 3 weeks after planting (WAP), Var. Sabdariffa (Indian Sorrel) exhibited significantly greater plant height compared to the other varieties, while *Altisima* Dark Red and White Sorrel also differed significantly from each other. At 6 WAP, White Sorrel was significantly different from all other varieties but did not differ significantly from *Altisima* Dark Red (Table 1). Var. Sabdariffa (Indian Sorrel) and *Altisima* Dark Red showed no significant differences from each other at this stage. By 12 WAP, Var. Sabdariffa (Indian Sorrel) again differed significantly from all other varieties, confirming its distinct growth pattern. According to Kallo et al. (2009), variations in plant height among Roselle varieties are largely attributed to genetic makeup. For the number of leaves per plant, White Sorrel and *Altisima* Wine Red were not significantly different at 3 and 6 WAP, though both differed from the other varieties (Table 2). At 9 WAP, *Altisima* Wine Red and *Altisima* Dark Red were statistically similar but varied significantly from the remaining varieties. By 12 WAP, White Sorrel and *Altisima* Dark Red differed significantly from the other accessions. As noted by Ngwuta et al. (2015), traits primarily governed by genetic factors tend to remain stable and are less influenced by environmental variation, which may explain the observed consistency in certain characters across growth stages.

**Table 1.** Variability of plant height (cm) in Roselle varieties

| Varieties | Weeks after planting | | | |
|---|---|---|---|---|
| | 3 | 6 | 9 | 12 |
| Var. sabdariffa (Indian sorrel) | 12.51c | 23.68c | 43.19c | 70.41c |
| Var. Altisima dark red | 10.19b | 22.63bc | 38.58bc | 55.08ab |
| Var. Altisima wine red | 7.51a | 19.97ab | 36.22ab | 55.49b |
| White sorrel | 8.49ab | 18.36a | 32.14a | 54.49a |
| LSD (p< 0.05) | 2.07 | 3.72 | 4.76 | 7.76 |

Mean values with the same letter(s) in the columns are not significantly different at 5% level of probability; LSD: Least significant difference

**Table 2.** Variability of the number of leaves/plants in Roselle varieties

| Varieties | Weeks after planting | | | |
|---|---|---|---|---|
| | 3 | 6 | 9 | 12 |
| Var. sabdariffa (Indian sorrel) | 11.06c | 24.43c | 56.12c | 73.75c |
| Var. Altisima dark red | 10.56bc | 20.5bc | 51.25ab | 60.56ab |
| Var. Altisima wine red | 8.06ab | 17.18a | 46.18a | 61.87bc |
| White sorrel | 7.62a | 19.06ab | 51.37bc | 58.37a |
| LSD (p< 0.05) | 2.49 | 5.76 | 11.48 | 15.34 |

Mean values with the same letter(s) in the columns are not significantly different at 5% level of probability; LSD: Least significant difference.

**Table 3.** Variability of number of branches/plants in Roselle varieties

| Varieties | Weeks after planting | | | |
|---|---|---|---|---|
| | 3 | 6 | 9 | 12 |
| Var. sabdariffa (Indian sorrel) | 0.00 | 9.5c | 11.5c | 16.5c |
| Var. Altisima dark red | 0.00 | 8.18bc | 10.18bc | 15.18bc |
| Var. Altisima wine red | 0.00 | 7.37a | 9.37a | 14.37 |
| White sorrel | 0.00 | 7.68ab | 9.68ab | 14.68ab |
| LSD (p< 0.05) | 0.00 | 2.53 | 2.53 | 2.53 |

Mean values with the same letter(s) in the columns are not significantly different at 5% level of probability; LSD: Least significant difference.

**Table 4.** Variability of the number of Leaf Area/plant in Roselle varieties

| Varieties | Weeks after planting | | | |
|---|---|---|---|---|
| | 3 | 6 | 9 | 12 |
| Var. sabdariffa (Indian sorrel) | 196.93a | 542.61bc | 843.88bc | 1377.30b |
| Var. Altisima dark red | 275.34b | 608.29c | 926.87c | 1203.25ab |
| Var. Altisima wine red | 217.22ab | 461.49a | 745.06a | 1186.44a |
| White sorrel | 334.93c | 508.42ab | 823.08ab | 1515.02c |
| LSD (p< 0.05) | 101.92 | 149.29 | 186.81 | 158.94 |

Mean values with the same letter(s) in the columns are not significantly different at 5% level of probability; LSD: Least significant different.

**Table 5.** Variability of the Stem Girth (cm) in Roselle varieties

| Varieties | Weeks after planting | | | |
|---|---|---|---|---|
| | 3 | 6 | 9 | 12 |
| Var. sabdariffa (Indian sorrel) | 0.16a | 0.36a | 2.56ab | 2.53b |
| Var. Altisima dark red | 0.20ab | 0.40ab | 2.31a | 2.37ab |
| Var. Altisima wine red | 0.23b | 0.43b | 2.77c | 2.34a |
| White sorrel | 0.29c | 0.49c | 2.59bc | 2.62c |
| LSD (p< 0.05) | 0.00 | 0.04 | 0.54 | 0.15 |

Mean values with the same letter(s) in the columns are not significantly different at 5% level of probability; LSD: Least significant difference

**Table 6.** Variability in days to 50% flowering and maturity, and the yield components of Roselle

| Varieties | Days to 50% flowering | Days to 50% maturity | Weight of dried calyces kg/ha |
|---|---|---|---|
| Var. sabdariffa (Indian sorrel) | 59.25ab | 119.25c | 179.01bc |
| Var. Altisima dark red | 55.5a | 105.00ab | 175.13a |
| Var. Altisima wine red | 61.25bc | 102.5a | 185.55c |
| White sorrel | 65.5c | 114.00bc | 177.71ab |
| LSD (p< 0.05) | 8.83 | 14.01 | 9.10 |

Mean values with the same letter(s) in the columns are not significantly different at 5% level of probability; LSD: Least significant difference

At 3 weeks after planting (WAP), there were no significant differences among the four Roselle varieties for the number of branches (Table 3). However, by 6, 9, and 12 WAP, Altisima Dark Red and Altisima Wine Red were statistically similar but differed significantly from the other varieties. This observation aligns with Singh et al. (2018), who reported substantial variability in branch number among Roselle genotypes. For leaf area per plant, White Sorrel differed significantly from the other varieties at 3 and 12 WAP. At 6 WAP, Altisima Wine Red and White Sorrel were statistically similar but both differed significantly from the remaining varieties, while at 9 WAP, Var. Sabdariffa (Indian Sorrel) and Altisima Dark Red were not significantly different from each other but varied from the others (Table 4). According to Aminu (2016), the genetic constitution of crops remains stable across environments for quantitative traits, which may explain the observed consistency. For stem girth, White Sorrel differed significantly from all other varieties at 3, 6, and 12 WAP, while at 9 WAP, Altisima Dark Red and Var. Sabdariffa were statistically similar but distinct from the others (Table 5). Variation in stem diameter has been attributed to genetic differences among Roselle varieties (Chukwuma et al., 2016).

For days to 50% flowering, White Sorrel differed significantly from Altisima Dark Red and Var. Sabdariffa but was statistically similar to Altisima Wine Red. Altisima Dark Red flowered earlier, whereas Altisima Wine Red matured first, confirming that early flowering does not necessarily correspond to early maturity (Table 6). Altisima Wine Red also differed significantly from Var. Sabdariffa and White Sorrel, while White Sorrel and Altisima Dark Red were statistically similar. Var. Sabdariffa produced the highest calyx yield per hectare, differing significantly from White Sorrel but not from Altisima Dark Red.

**Table 7.** Estimate of genotypic parameters

| Characters | WAP | PCV | GCV | HO (%) | GA | GG |
|---|---|---|---|---|---|---|
| Plant height | 3WAP | 19.16 | 17.47 | 91.17 | 1.87 | 19.33 |
| | 6WAP | 23.67 | 18.23 | 77.01 | 1.58 | 7.46 |
| | 9WAP | 85.26 | 76.38 | 89.58 | 1.84 | 4.90 |
| | 12WAP | 237.6 | 213.95 | 90.04 | 1.85 | 3.14 |
| No. of Leaves | 3WAP | 12.04 | 9.6 | 79.73 | 1.64 | 17.59 |
| | 6WAP | 37.83 | 24.8 | 65.55 | 1.35 | 6.65 |
| | 9WAP | 65.88 | 14.19 | 21.53 | 0.44 | 0.85 |
| | 12WAP | 190.02 | 97.58 | 51.35 | 1.05 | 1.65 |
| No. of Branches | 6WAP | 3.51 | 0.99 | 28.20 | 0.58 | 7.09 |
| | 9WAP | 3.51 | 0.99 | 28.20 | 0.58 | 5.69 |
| | 12WAP | 3.51 | 0.99 | 28.20 | 0.58 | 3.82 |
| Leaf Area | 3WAP | 15463.31 | 11393.75 | 73.68 | 1.51 | 0.58 |
| | 6WAP | 15262.54 | 6532.97 | 42.80 | 0.88 | 0.16 |
| | 9WAP | 22333.81 | 8667.62 | 38.80 | 0.79 | 0.09 |
| | 12WAP | 97049.87 | 87156.71 | 89.80 | 1.85 | 0.14 |
| Stem Girth | 3WAP | 0.01 | 0.01 | 100.00 | 2.06 | 936.36 |
| | 6WAP | 0.01 | 0.009 | 90.00 | 1.85 | 440.47 |
| | 9WAP | 0.14 | 0.02 | 14.28 | 0.29 | 11.34 |
| | 12WAP | 0.07 | 0.06 | 85.71 | 1.76 | 71.54 |
| 50% flowering | | 69.41 | 38.83 | 55.94 | 1.15 | 1.90 |
| 50% maturity | | 243.56 | 166.56 | 68.36 | 1.40 | 1.20 |
| Weight of dried calyces | | 78.8 | 46.28 | 58.73 | 1.20 | 0.66 |

WAP: weeks after planting PCV: Phenotypic coefficient of variation, Ho: Heritability, GCV: Genotypic coefficient of variation, GA: Genetic advance, and GG: Genetic gain

Genetic parameter estimates revealed high heritability and genetic advance for plant height at 9 and 12 WAP (89.58% and 90.04%; GA: 1.84 and 1.85), leaf area at 3 and 12 WAP (73.68% and 89.80%; GA: 1.51 and 1.85), and days to 50% maturity (68.38%; GA: 1.40) (Table 7). These traits, governed largely by additive gene effects, are suitable for selection and genetic improvement. In contrast, number of branches per plant at 3, 6, 9, and 12 WAP (0%, 0; 28.20%, 0.58; 28.20%, 0.58; 28.20%, 0.58) and days to 50% flowering (55.94%; GA: 1.15) exhibited low heritability and genetic advance, suggesting non-additive gene effects and limited potential for improvement through selection. As emphasized by Aristya and Wulandari (2017), high heritability combined with high genetic advance is critical for effective selection, while Kumar et al. (2013) noted that high heritability alone does not guarantee high genetic advance. Thus, understanding the genetic architecture and environmental interactions of agronomic traits is essential for designing effective breeding programs and exploiting the available variability in Roselle.

## CONCLUSION

At 12 weeks after planting (WAP), Var. Sabdariffa (Indian Sorrel) exhibited significantly greater plant height than all other varieties, while White Sorrel and Altisima Dark Red differed significantly in leaf number. Altisima Dark Red flowered earlier, whereas Altisima Wine Red matured earlier, indicating that early flowering does not necessarily correspond to early maturity. For number of branches per plant, Altisima Dark Red and Altisima Wine Red were statistically similar but differed significantly from the other varieties at 6, 9, and 12 WAP. Genetic parameter estimates revealed high heritability and genetic advance for plant height at 9 and 12 WAP (89.58% and 90.04%; GA: 1.84 and 1.85), leaf area at 3 and 12 WAP (73.68% and 89.80%; GA: 1.51 and 1.85), and days to 50% flowering (68.38%; GA: 1.40). These traits, governed largely by additive gene effects, are suitable for selection and can be effectively improved through breeding. In contrast, the number of branches per plant at 6, 9, and 12 WAP (28.20%; GA: 0.58) and days to 50% flowering (55.94%; GA: 1.15) exhibited low heritability and genetic advance, suggesting non-additive gene effects and limited potential for improvement through selection. Among the varieties, Var. Sabdariffa (Indian Sorrel) produced the highest dried calyx yield (kg/ha), underscoring its agronomic superiority and potential as a promising candidate for genetic improvement and large-scale cultivation. The findings highlight that traits such as plant height, leaf area, and days to maturity, characterized by high heritability and genetic advance, are reliable selection indices for Roselle improvement. Breeders can prioritize these traits to develop high-yielding, stable varieties, while farmers may benefit from adopting Var. Sabdariffa (Indian Sorrel), which demonstrated superior calyx yield and strong agronomic potential under local conditions


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Not applicable


## AUTHORS CONTRIBUTIONS

All the authors contributed equally to this work. All authors read and approved the final manuscript.

## CONFLICT OF INTERESTS

The authors declare no conflict of interest.

## ETHICAL APPROVAL

Not applicable.


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## AVAILABILITY OF DATA AND MATERIALS

All datasets analyzed and described during the present study are available from the corresponding author upon reasonable request.

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