Journal of Agriculture, Food, Environment and Animal Sciences
Tarım, Gıda, Çevre ve Hayvancılık Bilimleri Dergisi
http://www.jafeas.com, ISSN: 2757-5659

J. Agric. Food, Environ. Anim. Sci.
6(1): 293-302, 2025

Evaluation of Roselle (*Hibiscus sabdariffa* L.) Accessions for Agronomic and Weed-Suppressive Potentials in the Rainforest-Savannah Transition Agroecology of Nigeria

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Research Article

Article History:
Received:10 January 2025
Accepted:12 May 2025
Published online: 01 June 2025

***Keywords*:**
Rainforest-Savannah Transition Agroecology
Accessions
Roselle Growth
Weed Suppression
Roselle Yield

ABSTRACT

Roselle has rapid broadleaves proliferation potential, dense architecture, and allelopathic attributes which can aid in mitigating weed growth. This study assessed some Roselle accessions for growth, yield, and weed-suppressive traits in Ibadan, Nigeria. The study was conducted using a Randomized Complete Block Design (RCBD) and replicated twice. Data on plant height (cm), number of leaves/plant, leaf area (cm^2), and stem diameter (cm) were collected fortnightly from 4 to 12 weeks after sowing (WAS). Calyx yield (kg), 100-seed weight (g), and weed weights were determined at harvest. All data were subjected to analysis of variance at $\alpha_{0.05}$. The Roselle accessions differed statistically for all traits except dry calyx yield and weights of 100 seeds. The highest and least number of leaves/plant and leaf area was 92.75 leaves/plant ($A_{10}R_2$) and 145.00 leaves/plant ($A_3^2R_2$); 106.91 cm^2 (R_5P_7) and 186.98 cm^2 ($A_3^2R_2$), respectively. Meanwhile, A_6R_2 had the highest values for both dry calyx yield (2.62 t/ ha) and weights of 100 seeds (0.37 kg). The weight of fresh and dry weeds ranged from 116 g/m^2 (A_6R_3) to 572 g/m^2 (A_7R_1) and 64 g/m^2 ($A_{10}R_2$ and A_6R_3) to 284 g/m^2 (A_7R_1), respectively. The yield and weed suppression potential of the accessions were largely dependent on their genetic capacity for the trait. However, accession A_6R_2 is recommended for optimum dry calyx and seed production while cultivation of accessions A_3R_2, $A_3^2R_2$, A_3R_1, and A_6R_3 can effectively mitigate weed growth.

To Cite : Udemba I, Aluko O, Adewumi A, Ayodele O., 2025. Evaluation of Roselle (Hibiscus sabdariffa L.) Accessions for Agronomic and Weed-Suppressive Potentials in the Rainforest-Savannah Transition Agroecology of Nigeria. Agriculture, Food, Environment and Animal Sciences, 6(1): 293-302.

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is an annual, fast-growing, herbaceous shrub within the large *Malvaceae* family (alongside okra, kenaf, and cotton). It is usually cultivated for its stem, fibre, leaves, seeds, and calyces (Satyanarayana et al., 2015). Roselle's height can range between 0.5 and 2 m (El-Naim et al., 2012). The calyces possess a multitude of applications spanning food, feed, beverages, nutraceuticals, cosmeceuticals, and pharmaceuticals (Mohamed et al., 2012; IIyas et al., 2021). Additionally, Roselle presents substantial agronomic and ecological benefits, thriving with minimal management and demonstrating resilience to various environmental conditions, including adverse ones (Ugaoo, 2024). This resilience is possibly attributed to its deep tap root (Ranjan, 2019) which facilitates efficient access to water and nutrients.

Notably, Roselle grows rapidly, producing broad leaves with dense canopy (Yirzagla et al., 2023; Pelczar, 2024). This effectively creates a shading effect, limiting light availability to weed seedlings around the plant and in tandem suppressing their growth (Pelczar, 2024). The ground cover and prolific root system of Roselle (Vasavi et al., 2019) also minimize the space for weeds establishment. Moreover, Roselle exerts an allelopathic effect on surrounding weeds, releasing biochemical (phenolic) compounds that impede weeds' germination and root growth (Pukclai and Kato-Noguchi, 2011). Hence, cultivation of Roselle may limit dependence on herbicides for weed control methods through weed smothering. Thus lowering production costs, and minimizing negative environmental impact. This study therefore aims to evaluate the agronomic traits of some Roselle accessions and their ability to suppress weed in Rainforest-Savannah Transition Agroecology of Nigeria, sequel to paucity of information on this.

MATERIAL and METHOD

The field experiment was conducted at the research field of the Institute of Agricultural

Research and Training, Ibadan during the raining season of 2023. The land was ploughed, harrowed, and partitioned into plots separated by a 1m alley. Subsequently, using a randomized complete block design, seeds of ten (10) Roselle accessions ($A_{10}R_2$, $A_{12}R_3$, A_6R2, A_6R_3, A_3R_1, R_5P_7, A_8R_3, A_7R_1, A_3R_2 and $A_3{}^2R_2$) were sown (1 accession per plot). These were spaced using a dimension of 1 m × 1 m, and replicated twice. From 4 to 12 weeks after sowing (WAS), data were collected on plant height, number and area of leaves; and stem diameter at intervals of two weeks. Leaf area was determined using the leaf area model described by Nnebue et al. (2015).

Leaf area= 5.20 + 0.5179 LW.

Where L and W are leaf length and width, respectively.

At harvest, fresh calyx yield and weight of 100 seeds were determined following manual processing while fresh weight of weeds per plot was assessed using 0.5 m × 0.5 m quadrant, positioned randomly within the plot. Meanwhile, dry weights of calyx and weed samples were determined after drying to constant weight. All data were subjected to analysis of variance using SPSS software and significant means separated using the Duncan multiple range test at a 5% level of probability.

RESULTS and DISCUSSION

Across weeks of evaluation, significant variation was observed among the ten (10) Roselle accessions (RAs) for growth parameters except stem diameter at 4 WAS. Plant height of the RAs at 4 and 6 weeks after sowing (WAS) ranged from 9.17 cm ($A_3{}^2R_2$) to 13.88 cm (A_7R_1) and 19.50 cm ($A_3{}^2R_2$) to 29 cm (A_6R_3), respectively (Table 1). Notably, the tallest RAs at these plant ages had heights that were statistically at par with other RAs except $A_3{}^2R_2$ at both WAS; and $A_{10}R_2$, $A_{12}R_3$, A_6R_2, $R_5P_{7,}$ and A_8R_3 at 6 WAS (Table 1). Moreover, at 8, 10, and 12 WAS, the shortest RAs were A_7R_1 (30.48 cm); and $A_{12}R_3$ (61.75 cm and 81.80 cm), respectively while RAs A_3R_1 (48.95 cm), A_6R_3 (78.5 cm) and A_3R_1 (100.38) had the highest stem elongation at these plant ages, respectively (Table 1).

Table 1. Variation in plant height (cm) of Roselle accessions at specified sampling dates

	Weeks after Sowing				
Accessions	**4**	**6**	**8**	**10**	**12**
$A_{10}R_2$	11.28ab	20.13cd	36.07cde	64.25cd	84.38b
$A_{12}R_3$	10.27ab	20.10cd	34.45ed	61.75d	81.80b
A_6R_2	10.88ab	21.50cd	42.33abcd	72.50ab	88.75ab
A_6R_3	12.50ab	29a	43.83abc	78.75a	87.97ab
A_3R_1	12.92a	27.5a	48.95a	70.70abc	100.38a
R_5P_7	12.62ab	22.25cd	41.67abcd	76.08ab	99.06a
A_8R_3	12.18ab	23.50bc	44.03abc	68.42bcd	84.97b
A_7R_1	13.88a	28.67a	30.48e	64.25cd	82.58b
A_3R_2	12.20ab	26.67ab	47.13ab	78.50a	98.86a
$A_3{}^2R^2$	9.17b	19.50d	39.92bcd	72.00abc	89.90ab

Means with similar letters are not statistically different at 0.05 level of probability

The tallest RAs at the immediate mentioned plant ages differed significantly in height from $A_{10}R_2$, $A_{12}R_{3,}$ and A_7R_1 at the three plant ages; $A_3{}^2R_2$ at 8 WAS; and A_8R_3 at 10 and 12 WAS (Table 1).

The numerical variation in stem diameter of the RAs at 4 WAS was not significant (Table 2).

Table 2. Variation in stem diameter (mm) of Roselle accessions across plant ages

	Weeks after Sowing				
Accessions	**4**	**6**	**8**	**10**	**12**
A10R2	0.20	0.40d	0.82bc	1.10cd	1.38 d
A12R3	0.20	0.43cd	0.75b	1.05d	1.47bcd
A6R2	0.20	0.48bcd	0.77b	1.30a	1.60a
A6R3	0.20	0.53abcd	0.98a	1.28ab	1.54ab
A3R1	0.20	0.52abcd	0.93ab	1.20abc	1.43bcd
R5P7	0.20	0.55abc	0.82bc	1.17abcd	1.43bcd
A8R3	0.20	0.58ab	1.00a	1.23abc	1.50abcd
A7R1	0.20	0.63a	0.99a	1.23abc	1.53abc
A3R2	0.20	0.61ab	0.98a	1.23abc	1.48abcd
A32R2	0.21	0.63a	0.74b	1.13bcd	1.40cd

Means with similar letters are not statistically different at 0.05 level of probability

Howbeit, from 6 to 8 WAS, accessions A_7R_1 (for both WAS) and $A_3{}^2R_2$ (for only 6 WAS) had the widest stems and were significantly different from $A_{10}R_2$, $A_{12}R_3$, and A_6R_2 at both plant ages; and $A_3{}^2R_2$ at 8 WAS. Meanwhile, A_6R_2 had the broadest stem diameter from 10 to 12 WAS and compared statistically with the diameter recorded for all Roselle Accessions (RAs) except $A_{10}R_2$, $A_{12}R_3$, and $A_3{}^2R_2$ at both WAS; A_3R_1 and R_5P_7 at 12 WAS (Table 2).

No accession was consistent in producing the highest quantity of leaves across the weeks of evaluation (Table 3). At 4, 6, 8, 10 and 12 WAS, the number of leaves counted on the RAs ranged from 6.83 ($A_{10}R_2$) to 10.50 (R_5P_7); 13.08 ($A_{10}R_2$) to 24.33 (A_8R_3); 30.25 ($A_{12}R_3$) to 94.67 (A_6R_3); 72.50 ($A_{10}R_2$) to 109.25(R_5P_7) and 92.75 ($A_{12}R_3$) to 145.00 ($A_3{}^2R_2$), respectively (Table 3). The number of leaves on the best foliage-producing RA at each plant age was statistically higher than the number counted from other RAs except $A_{12}R_3$, A_6R_2, A_6R_3, A_3R_1, A_8R_3, A_7R_1, A_3R_2, $A_3{}^2R_2$ at 4 WAS; A_6R_3 and A_7R_1 at 6 WAS; A_7R_1 at 8 WAS, A_6R_3, A_3R_1, and $A_3{}^2R_2$ at 10 WAS and A_6R_2, A_6R_3, A_3R_1, R_5P_7, A_8R_3, A_7R_1 and A_3R_2 at 12 WAS (Table 3). Notably, either $A_{10}R_2$ or $A_{12}R_3$ produced the least quantity of foliage at each plant age of evaluation.

Table 3. Variation in foliage production of Roselle accessions at specified sampling date

	Weeks after Sowing				
Accessions	**4**	**6**	**8**	**10**	**12**
A10R2	6.83b	13.08f	36.17d	72.50d	99.50bc
A12R3	7.25ab	16.50def	30.25d	74.25d	92.75c
A6R2	10.00ab	14.83ef	70.50bc	92.50bc	121.00ab
A6R3	9.42ab	21.50abc	94.67a	108.58a	144.60a
A3R1	8.00ab	14.00f	71.08bc	106.92a	134.50a
R5P7	10.50a	18.50cde	54.50c	109.25a	134.42a
A8R3	9.50ab	24.33a	72.42bc	87.00c	123.00a
A7R1	10.00ab	23.17ab	78.83ab	87.00c	121.25ab
A3R2	9.17ab	15.75def	59.33c	96.00bc	138.75a
A32R2	7.83ab	19.33bcd	61.83bc	100.5ab	145.00a

Means with similar letters are not statistically different at 0.05 level of probability

The maximum leaf area at 4 WAS was recorded from A_7R_1 (29.67 cm^2) and was significantly identical to A_6R_3 for this trait (Table 4). At 6 WAS, 48.62 cm^2, the highest leaf area was obtained from A_6R_3 which differed statistically from only $A_{12}R_3$.

Table 4. Leaf area (cm^2) of Roselle accessions at different plant ages

	Weeks after Sowing				
Accessions	**4**	**6**	**8**	**10**	**12**
A10R2	14.33c	36.28ab	64.08bc	91.99bcd	152.21bc
A12R3	15.16c	28.58b	65.13bc	86.23bcde	143.30bc
A6R2	16.80bc	41.30ab	68.83bc	104.15b	153.34b
A6R3	23.59ab	48.62a	66.95bc	77.57de	121.40cd
A3R1	17.55bc	42.44ab	76.02b	97.41bc	152.21b
R5P7	18.08bc	31.60ab	52.22c	80.09cde	157.14b
A8R3	20.45bc	36.82ab	54.32c	70.65e	106.91d
A7R1	29.67a	37.80ab	66.15bc	98.12bc	119.57cd
A3R2	20.69bc	42.00ab	72.74b	139.12a	183.83a
A32R2	13.53c	44.43ab	98.77a	121.69a	186.78a

Means with similar letters are not statistically different at 0.05 level of probability

Accession $A_3{}^2R_2$ had a significantly higher leaf area than other RAs at 8 and 12 WAS, except A_3R_2 at 12 WAS (Table 4). Meanwhile at 10 WAS, the highest leaf area was obtained from A_3R_2 which varied significantly from other RAs except $A_3{}^2R_2$ (Table 4).

At harvest, fresh calyx yield from A_3R_2 (61.67 t/ha) was highest and statistically different from yield recorded from A_3R_1, R_5V_7, A_8R_3, and $A_{12}R_3$ (Table 5). Conversely, no significant statistical variation was observed among dry calyx yield and weight of 100 seeds from the 10 RAs, but A_6R_2 had the best numerical values for the two traits (Table 5).

Table 5. Calyx yield and weight of 100-seeds of Roselle accessions

Accession	Fresh calyx yield (t/ha)	Dry calyx yield (t/ha)	Weight of 100 seeds (kg)
A10R2	34.17ab	1.27	0.10
A12R3	24.17b	0.89	0.07
A6R2	43.33ab	2.62	0.37
A6R3	32.67ab	1.85	0.05
A3R1	16.67b	0.37	0.07
R5P7	22.50b	1.05	0.07
A8R3	23.34b	1.40	0.05
A7R1	25.84ab	2.55	0.07
A3R2	61.67a	0.90	0.07
A32R2	41.67ab	1.85	0.07

Means with similar letters are not statistically different at 0.05 level of probability

Fresh and dry weight of weeds from plots sown to the 10 RAs ranged from 116 (A_6R_3) to 572 (A_7R_1) and 64 ($A_{10}R_2$ and A_6R_3) to 284 g/ m (A_7R_1), respectively (Table 6). Moreover, the present least weed weights from plots sown to $A_{10}R_2$ and A_6R_3 compared favourably with weights of weed from all plots except where A_7R_1 grew (Table 6). The later mentioned RA was statistically at par with other RAs for these two weed parameters except $A_{10}R_2$ and A_6R_3 (Table 6).

Table 6. Weed weights (g m^{-1}) from plots sown to ten Roselle accessions

Accession	Weed fresh weight (g m-1)	Weed dry weight (g m-1)
A10R2	136b	64b
A12R3	300ab	146ab
A6R2	208ab	106ab
A6R3	116b	64b
A3R1	220ab	112ab
R5P7	352ab	168ab
A8R3	204ab	108ab
A7R1	572a	284a
A3R2	220ab	106ab
A32R2	316ab	158ab

Means with similar letters are not statistically different at 0.05 level of probability

DISCUSSION

Assessment of the present Roselle germplasm for agronomic and weed-suppressive potentials is germane for multiple production and industrial applications including the development of eco-friendly sustainable alternatives to herbicides. Significant variation among the RAs for agronomic and weed-suppressive traits suggests the existence of genotypic variability among the Roselle in the present germplasm. This finding aligns with previous documentation in the literature on Roselle and highlights the need for proper selection before propagation, based on production objectives (Gasim and Khidir, 1998; Atta et al., 2011; Ayipio et al., 2018). Meanwhile, the increase in growth parameters of the RAs with plant age corroborates the earlier report of Norhayati et al. (2019) on Roselle. This might be the tandem effect of continuous division and enlargement of cells in the Roselle plants during the growth period which enhanced their stem elongation and width; as well as leaf quantity and dimension as the plants age increased (Lastdrager et al., 2014). The observed fast growth rate of the RAs as revealed by the growth parameters validates the earlier assertion of Yirzagla et al. (2023) that Roselle grows rapidly. Notably, the plant height and width of the RAs stems at 12 WAS were within the range earlier reported by El-Naim et al. (2012) and Norhayati et al. (2019). The range of quantity and area of leaves produced by the RAs at 12 WAS, 92.75-145.00 and 106.91-186.98 cm^2, respectively affirms the fact that Roselle is a prolific broadleaves producer as reiterated by Yirzagla et al. (2023) and Pelczar (2024).

The consistent lower heights of accessions $A_{10}R_{2}$, $A_{12}R_{3}$, $A_{6}R_{2}$, and $A_{3}{}^{2}R_{2}$ at 4 and 6 WAS relative to other RAs suggests a slower initial growth rate which can be optimized for intercropping, the predominant farming system in Southwestern, Nigeria. This will serve multiple purposes of early weed control, food, and income generation for farmers before the maturity of Roselle. Roselle has been successfully intercropped with various crops ranging from vegetables to maize and legumes (Ayipio et al., 2018; Banjaw et al., 2020). Accessions $A_{6}R_{2}$, $A_{6}R_{3}$, $A_{8}R_{3}$, $A_{7}R_{1}$, and $A_{3}R_{2}$ with broadest stems at 12 WAS can find application for pulp and paper making a sequel to the valuable use of Roselle for this purpose as submitted by Kalita and Boruah (2022). The significant and maximum fresh calyx yield from $A_{3}R_{2}$ highlights its genetic potential for assimilate partitioning to this sink (calyx) of premium economic importance, which could have been enhanced by its supra leaf area. Since the dry yield of produce defines their biological yield and in tandem profitability index, the record of significant similarity in dry calyx yield of the RAs suggests that they accumulated dry matter to the same extent. Similarly, the statistically comparable 100-seed weights highlight similarities in their reproductive potential. However, it is worthy of note that $A_{6}R_{2}$ has numerically better potential for calyx dry matter and seed weight accumulation than the other RAs.

The range of dry calyx yield recorded in this study was higher than the range of 0.19-0.51 t/ ha reported by Yirzagla et al. (2023) from a separate survey of Roselle.

The record of significantly identical weed weights from all plots except where V_7R_1 grew, suggests that the RAs suppressed weed growth to the same extent despite variation in their growth and morphology. Roselle has been reported to contain growth-inhibitory substances and also express allelopathic activity (Pukclai and Kato-Noguchi, 2011). Hence, the present finding might have stemmed from the similarity in their allelopathy effect on surrounding weeds via the possible release of biochemical compounds. It is therefore presumed that the weed-suppressive efficacy of the RAs was not largely dependent on their morphology but on their genetic capacity for this trait.

CONCLUSION

From an overview of this study, it can be concluded that the evaluated Roselle accessions have promising agronomic and weed-suppression potentials. The selection of premium accession is dependent on the farmers' production preference. However, accession A_6R_2 is recommended for propagation due to its high yield of dry calyxes and seed weight, while A_3R_2, $A3^2R_2$, A_3R_1, $V_{10}R_2$, and V_6R_3 with the least and comparable weed weights can be used to check weeds growth either solely or as a companion crop in intercropping system.

Conflict of Interest

The authors have declared that no conflict of interest exist with respect to this paper.

Authors contribution

AOA and UIO conceptualized the research. All the authors executed the experiment and contributed to the writing of the manuscript.

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