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RESEARCH ARTICLE

Genotypic variation in resistance of roselle (*Hibiscus sabdariffa* L.) to the foliar beetle *Monolepta thompsoni* Allard, and its consequences for yield in Nigeria's Southern Guinea Savanna

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ABSTRACT

Monolepta thompsoni Allard is a major foliar beetle that limits roselle (*Hibiscus sabdariffa* L.) production in Nigeria through severe leaf defoliation and yield losses. However, information on genotypic field resistance to this pest remains scarce. This study evaluated the field resistance of eight roselle genotypes under natural *M. thompsoni* infestation at Makurdi (Benue State) and Bali (Taraba State) during the 2023 cropping season. The experiment was laid out in a randomized complete block design with four replications at each location. Beetle population density was assessed at 3, 6, 9, and 12 weeks after sowing (WAS), and leaf defoliation, functional leaf area, yield components, and dry calyx yield were determined. A Composite Field Resistance Index (CFRI) integrating standardized beetle population, leaf defoliation, functional leaf area and dry calyx yield was developed to rank genotypes. Significant genotypic differences ($P < 0.001$) were observed for all measured traits. Beetle populations peaked at 9 WAS, with Jalin-White recording the highest infestation (12.78 insects plant^{-1}), greatest leaf defoliation (57.84%) and lowest dry calyx yield (8.23 g plant^{-1}), whereas Kona White G01 and MKD-Red (Local) exhibited the highest CFRI values (0.907 and 0.854, respectively). Beetle density was strongly correlated with leaf defoliation ($r = 0.94$, $R^2 = 0.88$; $P < 0.001$). The results demonstrate substantial genetic variation in resistance to *M. thompsoni* and identify Kona White G01 and MKD-Red (Local) as promising sources of resistance for breeding and sustainable pest management.

Keywords: genotype susceptibility, *Hibiscus sabdariffa*, host-plant resistance, integrated pest management, leaf defoliation, *Monolepta thompsoni*

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is an important multipurpose crop belonging to the family Malvaceae and is widely cultivated throughout tropical and subtropical regions for its edible calyces, leaves, seeds and fibre (Onyeukwu et al., 2023). The crop serves as a valuable source of food, nutraceuticals, natural colourants and industrial raw materials, while also contributing substantially to household income and rural livelihoods in many developing countries (Simon et al., 2021; Salem et al., 2022). Roselle calyces are particularly valued for their high concentrations of anthocyanins, organic acids, vitamin C and phenolic compounds, which possess strong antioxidant and health-promoting properties. In West Africa, particularly Nigeria, roselle production has expanded considerably because of increasing domestic consumption and growing demand from pharmaceutical, food and beverage industries (Moussa et al., 2024).

Despite its economic importance, roselle productivity in sub-Saharan Africa remains considerably below its genetic potential owing to several biotic constraints, among which insect pests constitute one of the most important yield-limiting factors. Foliar-feeding insects are particularly destructive because they reduce the photosynthetically active leaf area during vegetative growth, resulting in impaired plant development, reduced assimilate production and substantial yield losses (Simon et al., 2021). Defoliation during the early and mid-growth stages has been shown to adversely affect biomass accumulation, reproductive development and harvestable yield in many field crops (Banjaw, 2020; Simon et al., 2021; Nazifi et al., 2024).

Among the major insect pests associated with roselle production in Nigeria, the foliar beetle *Monolepta thompsoni* Allard (Coleoptera: Chrysomelidae) has become increasingly important (Simon et al., 2019; Simon et al., 2021). Both adults and larvae feed on foliage, producing characteristic shot-hole symptoms and extensive defoliation under severe infestations (Simon et al., 2019). Persistent feeding reduces leaf area, limits photosynthetic efficiency and ultimately lowers calyx yield and market quality (Kéllou et al., 2024). The increasing occurrence of *M. thompsoni* in major roselle-growing areas of the Southern Guinea Savanna has heightened concerns regarding sustainable production, particularly among smallholder farmers who depend largely on cultural practices and have limited access to effective pest management options.

Host-plant resistance remains one of the most effective, economical and environmentally sustainable approaches to insect pest management. Resistant cultivars suppress pest establishment or reduce the effects of herbivory through mechanisms such as antixenosis, antibiosis and tolerance, thereby minimizing reliance on synthetic insecticides and supporting integrated pest management (IPM) programmes (Prasanna et al., 2022). Recent advances in crop protection continue to emphasize host-plant resistance as a key strategy for achieving sustainable agricultural production under increasing environmental and economic constraints (Peterson et al., 2017). Although differences in insect resistance among crop genotypes have been extensively reported in several economically important crops, including members of the family Malvaceae, information on resistance of roselle genotypes to *M. thompsoni* remains scarce. Existing studies have largely focused on agronomic performance, nutritional quality and general insect incidence, with limited attention to quantitative evaluation of field resistance under natural infestation. Reliable identification of resistant roselle genotypes is therefore essential for breeding programmes and for developing integrated pest management strategies that reduce production losses while minimizing pesticide dependence. Furthermore, integrating pest abundance, foliar damage, canopy retention and yield performance into a single assessment provides a more comprehensive evaluation of field resistance than reliance on individual traits alone.

Against this background, the present study investigated the field response of selected roselle genotypes to *Monolepta thompsoni* under natural infestation in two Southern Guinea Savanna environments of Nigeria by characterizing beetle population dynamics, quantifying associated leaf damage, functional leaf area retention and yield losses, examining the relationships among these traits, and integrating them into a Composite Field Resistance Index (CFRI) for objective identification and ranking of resistant genotypes suitable for breeding and cultivar recommendation

MATERIALS AND METHODS

Description of the study area

Field experiments were conducted during the 2023 rainy season at two locations within the Southern Guinea Savanna agro-ecological zone of Nigeria. The first site was the Teaching and Research Farm of the Joseph Sarwuan Tarka University, Makurdi, Benue State (7°44′N, 8°32′E; 104 m above sea level). The second site was the Agricultural Development Programme (ADP) Research Farm, Bali, Taraba State (7°51′N, 10°58′E; 170 m above sea level).

Both locations experience a tropical wet-and-dry climate characterized by a unimodal rainfall pattern extending from April to October. Annual rainfall ranges from approximately 1,100 to 1,500 mm, while mean daily temperatures vary between 25 and 35°C. The soils are predominantly sandy loam to loamy sand, conditions considered suitable for roselle cultivation. Conducting the study at two locations enabled assessment of genotype performance and resistance expression under contrasting but representative Southern Guinea Savanna environments.

Plant Materials

Eight roselle (*Hibiscus sabdariffa* L.) genotypes comprising four green-calyx and four red-calyx types were evaluated for their field response to natural infestation by *Monolepta thompsoni* Allard. The green-calyx genotypes were Kona White G01, Jalin-White, NGR-TR-051 and MKD-White (Local), while the red-calyx genotypes consisted of NGR-TR-052, NGR-TR-053, Jalin-Red and MKD-Red (Local). Improved genotypes were obtained from the National Roselle Germplasm Collection, whereas local cultivars were sourced from major roselle-growing communities within Benue and Taraba States. Seeds were manually cleaned, sorted and subjected to a preliminary viability assessment before planting.

Experimental Design and Crop Establishment

The experiment was laid out at each location using a Randomized Complete Block Design (RCBD) with four replications. Each experimental plot measured 3 m × 4 m (12 m^2). Plots were separated by 1.0 m alleys, while blocks were separated by 1.5 m to minimize treatment interference and facilitate field operations. Land preparation involved manual clearing followed by ploughing, harrowing and ridging. Sowing was carried out at the onset of the rainy season. Seeds were planted at a spacing of 75 cm × 50 cm with two to three seeds per hole. Seedlings were thinned to one vigorous plant per stand two weeks after emergence. Each plot contained four rows with approximately 25 plants, while border rows were established around the experimental area to minimize edge effects.

Crop Management

Uniform agronomic practices were maintained across all treatments and locations. Weeding was performed manually at three-week intervals. To permit natural infestation and unrestricted population development of *M. thompsoni*, no insecticide was applied throughout the experimental period. NPK (15:15:15) fertilizer was applied at a rate of 200 kg ha^{-1} in two equal splits, at two and six weeks after sowing (WAS). Routine field sanitation and crop monitoring were maintained throughout the study.

Monitoring of *Monolepta thompsoni* Population

Natural populations of *M. thompsoni* were assessed at 3, 6, 9 and 12 WAS. Five plants were randomly selected and permanently tagged within the two central rows of each plot. To minimize sampling bias associated with beetle movement and border effects, observations were restricted to tagged plants located within the net plot area. Adult beetles present on each tagged plant were visually counted between 0700 and 0900 h when insect activity was relatively low. Counts from the five tagged plants were averaged to obtain the mean number of beetles per plant for each plot.

Assessment of Functional Leaf Area

Functional leaf area was assessed at 9 WAS, corresponding to the period of peak *M. thompsoni* infestation and maximum canopy development. Three fully expanded leaves were randomly selected from each tagged plant. Leaf length (L) and maximum width (W) were measured using a digital Vernier caliper.

Leaf area (LA) was estimated according to Karaca et al. (2020): $LA = L \times W \times K$

where: LA = leaf area (cm^2), L = leaf length (cm), W = maximum leaf width (cm), and K = correction factor for roselle leaf morphology. The average leaf area of sampled leaves was used as the functional leaf area for each experimental unit.

Quantification of Leaf Defoliation

Leaf defoliation caused by *M. thompsoni* feeding was assessed at 9 WAS using the BioLeaf® digital image analysis application developed by Machado Filho and colleagues. Three representative damaged leaves were collected from each tagged plant and photographed under uniform lighting conditions against a contrasting background. Images were processed using BioLeaf®, which automatically distinguishes damaged and healthy tissues and estimates the proportion of leaf area removed by herbivory (Machado et al., 2016). Percentage leaf defoliation was calculated as:

Leaf Defoliation (%) = [(Damaged Leaf Area/Total Leaf Area) × 100]

The mean leaf defoliation for each plot was subsequently computed and used for analysis.

Evaluation of Yield and Yield Components

At physiological maturity (12 WAS), plants within the net plot area were harvested and evaluated. The following parameters were recorded: Number of fruits per plant; Number of damaged fruits per plant; Fresh fruit weight per plot (g); Fresh calyx weight per plant (g); Dry calyx weight per plant (g); Number of surviving stands per plot; and Number of damaged stands per plot. Freshly harvested calyces were air-dried and subsequently oven-dried at 65°C until constant weight was attained before dry weight determination using a precision electronic balance.

Composite Field Resistance Index (CFRI)

To obtain an integrated measure of field resistance, a Composite Field Resistance Index (CFRI) was developed by combining four resistance-related variables: (i) Mean *M. thompsoni* population density; (ii) Mean leaf defoliation (%); (iii) Functional leaf area at 9 WAS; and (iv) Dry calyx yield.

For each genotype, mean beetle population density was calculated by averaging insect counts obtained at 3, 6, 9 and 12 WAS across both locations. Functional leaf area, leaf defoliation and dry calyx yield were pooled across Makurdi and Bali before analysis. Because the variables were measured in different units, values were standardized to a dimensionless scale ranging from 0 to 1 using min–max normalization. The procedure follows established principles for constructing composite indicators based on normalization and aggregation of multiple variables (Pollesch & Dale, 2016), while adapting the approach to quantify field resistance. For variables in which lower values indicated greater resistance (beetle population density and leaf defoliation), standardized scores were calculated as:

$$S = \frac{X_{\max} - X_i}{X_{\max} - X_{\min}}$$

For variables in which higher values indicated greater resistance (functional leaf area and dry calyx yield), standardized scores were calculated as:

$$S = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}$$

where: *S* = standardized score; *Xi* = observed value of genotype *i*; *Xmax* = maximum observed value; and *Xmin* = minimum observed value.

The Composite Field Resistance Index was then computed as:

$$CFRI = \frac{S_P + S_D + S_F + S_Y}{4}$$

where: S_P = standardized score for beetle population density; S_D = standardized score for leaf defoliation; S_F = standardized score for functional leaf area; and S_Y = standardized score for dry calyx yield. CFRI values ranged from 0 (most susceptible) to 1 (most resistant). Genotypes were subsequently ranked according to their CFRI values to facilitate comparison of field resistance under natural infestation.

Statistical Analyses

Data from each location were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS version 9.2) (SAS Institute Inc., 2009). Means were separated using the Student–Newman–Keuls (SNK) test at the 5% probability level. Pearson correlation and simple linear regression analyses were performed to determine relationships between *M. thompsoni* population density and leaf defoliation. The coefficient of determination (R^2) and regression equation were used to describe the strength of association between variables (Montgomery, 2020). All statistical tests were considered significant at P ≤ 0.05. Additionally, CFRI values were calculated using pooled data across locations to provide an integrated assessment of genotypic field resistance to *M. thompsoni*.

RESULTS

Population Dynamics of Monolepta thompsoni on Roselle Genotypes

The abundance of *Monolepta thompsoni* varied significantly among roselle genotypes throughout the cropping season at both Makurdi and Bali (Figure 1). Beetle populations increased progressively from 3 weeks after sowing (WAS), attained peak densities at 9 WAS, and declined thereafter, indicating that the vegetative growth phase between 6 and 9 WAS represented the period of greatest susceptibility to infestation

At Makurdi, genotype effects were highly significant at all sampling periods (F = 7.39–79.20; P ≤ 0.002). Jalin-White consistently supported the highest beetle populations, increasing from 8.75 ± 0.25 insects plant^{-1} at 3 WAS to a peak of 19.25 ± 0.48 insects plant^{-1} at 9 WAS before declining to 12.50 ± 0.65 insects plant^{-1} at 12 WAS. In contrast, NGR-TR-053 and MKD-Red (Local) maintained substantially lower infestations throughout the season and recorded the lowest pest densities at crop maturity (0.50–2.00 insects plant^{-1}).

A similar trend was recorded at Bali, where significant differences among genotypes were observed at all assessment periods (F = 4.53–107.76; P ≤ 0.003). Jalin-White again harboured the highest beetle populations, reaching 16.00 ± 0.71 insects plant^{-1} at 9 WAS, whereas red-calyx genotypes generally maintained significantly lower populations, ranging from 1.50 to 2.75 insects plant^{-1} during the same period. Across locations, Jalin-White was consistently the most susceptible genotype, while MKD-Red (Local), NGR-TR-053 and NGR-TR-052 exhibited comparatively greater field resistance, characterized by reduced beetle colonization and lower pest persistence at later growth stages.

Functional Leaf Area Retention and Leaf Defoliation

Functional leaf area and leaf defoliation differed significantly among roselle genotypes at both locations (Table 1). At Makurdi, functional leaf area at 9 WAS ranged from 38.03 ± 0.47 cm^2 in Jalin-White to 82.03 ± 0.53 cm^2 in Kona White G01 (F = 315.72; P < 0.001). Comparable differences were observed at Bali, where functional leaf area varied between 32.50 ± 0.38 cm^2 and 76.79 ± 0.42 cm^2 among genotypes (F = 258.48; P < 0.001).

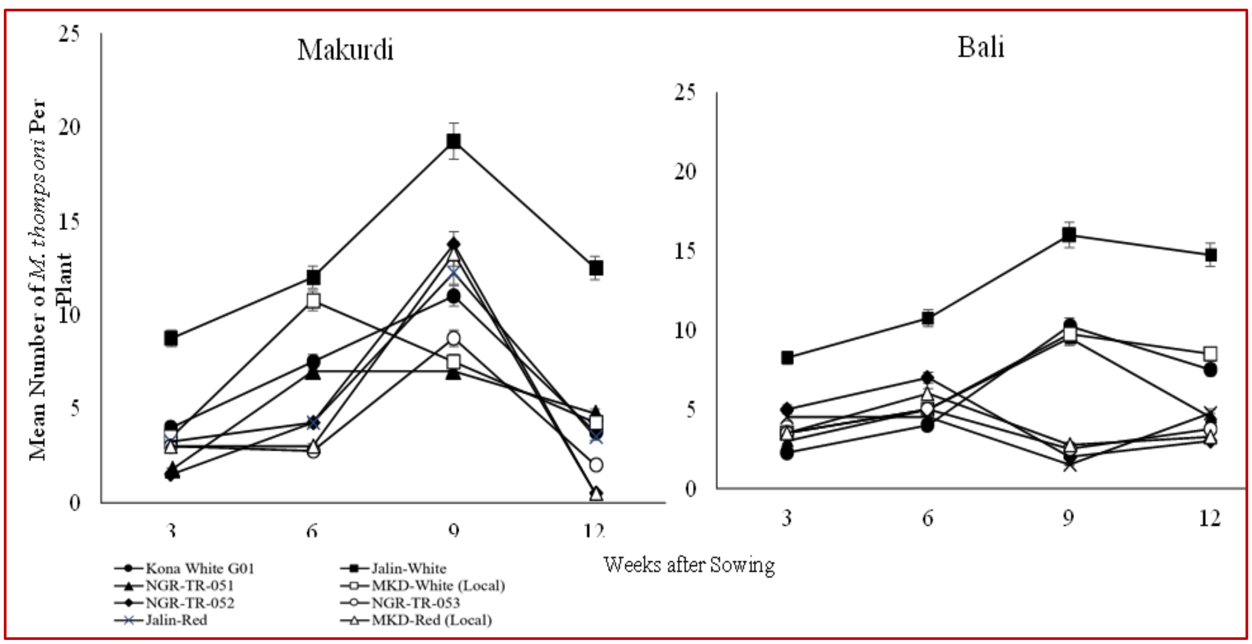

Figure 1. Population Dynamics of *Monolepta thompsoni* on Roselle Genotypes at Makurdi and Bali

Table 1. Effect of Damage Caused by *Monolepta thompsoni* on the Leaf Roselle (*Hibiscus sabdariffa* L.) Genotypes at 9 WAS in Makurdi and Bali

Genotypes	Calyx colour	Functional Leaf Area (cm^2)		% Damaged Leaf Area	
		Makurdi	Bali	Makurdi	Bali
Kona White G01	Green	82.03 ± 0.53[a]	76.79 ± 0.42[a]	23.59 ± 1.10[c]	18.15 ± 1.18[e]
Jalin-White	Green	38.03 ± 0.47[g]	32.50 ± 0.38[g]	60.44 ± 1.17[a]	55.23 ± 1.36[a]
NGR-TR-051	Green	51.10 ± 0.56[d]	46.07 ± 0.58[d]	29.26 ± 0.75[d]	23.97 ± 0.82[d]
MKD-White (Local)	Green	41.65 ± 0.54[f]	35.40 ± 1.42[f]	33.94 ± 1.18[c]	28.67 ± 1.30[c]
NGR-TR-052	Red	55.25 ± 0.61[d]	47.02 ± 0.84[d]	31.79 ± 0.31[cd]	24.87 ± 0.38[d]
NGR-TR-053	Red	55.20 ± 1.75[c]	52.15 ± 1.50[c]	26.33 ± 0.85[e]	20.77 ± 0.88[d]
Jalin-Red	Red	47.55 ± 0.92[e]	42.48 ± 1.03[e]	39.18 ± 1.21[b]	32.19 ± 1.34[b]
MKD-Red (Local)	Red	65.65 ±0.35[b]	60.45 ± 0.23[b]	18.88 ± 0.86[f]	14.11 ± 0.92[e]
F-value		315.72	258.48	184.85	153.04
P-value		<0.001	<0.001	<0.001	<0.001
C.V (%)		2.92	3.61	5.70	7.51

Mean (±SEM) values followed by the same letter in a column are not significantly different from one another (Student Newman Keuls, $P > 0.05$), SE = Standard error of mean, C.V. = Coefficient of variation.

d-calyx genotypes generally retained a larger photosynthetically active leaf area than green-calyx genotypes. MKD-Red (Local) retained 65.65 ± 0.35 cm^2 and 60.45 ± 0.23 cm^2 of functional leaf area at Makurdi and Bali, respectively, despite sustained exposure to natural infestation. Among the green-calyx genotypes, Kona White G01 maintained the largest functional leaf area at both locations, suggesting a greater capacity to tolerate foliar injury.

Leaf defoliation differed significantly among genotypes at Makurdi ($F = 184.85$; $P < 0.001$) and Bali ($F = 153.04$; $P < 0.001$). Jalin-White consistently experienced the greatest foliage loss, with defoliation of 60.44 ± 1.17% and 55.23 ± 1.36% at Makurdi and Bali, respectively. In contrast, MKD-Red (Local) sustained significantly lower damage, with a mean leaf defoliation of only 18.88 ± 0.86% at Makurdi and 14.11 ± 0.92% at Bali. Kona White G01 also exhibited relatively low levels of foliage damage, particularly during peak beetle infestation. Generally, the genotypes that retained larger functional leaf areas consistently experienced lower levels of leaf defoliation, indicating that reduced feeding damage contributed to improved canopy persistence during crop development.

Relationship Between Beetle Population Density and Leaf Defoliation

Across the eight roselle genotypes, mean leaf defoliation increased significantly with increasing *M. thompsoni* population density (Figure 2). Regression analysis revealed a strong positive linear relationship between beetle abundance and percentage leaf defoliation ($Y = 3.21x + 5.72$). The regression model explained 88% of the observed variation in leaf defoliation ($R^2 = 0.88$), indicating that beetle density was a strong predictor of foliage damage across roselle genotypes. Pearson's correlation analysis further demonstrated a very strong positive association between both variables ($r = 0.94$, $P < 0.001$).

The scatter plot clearly separated resistant and susceptible genotypes. MKD-Red (Local), NGR-TR-053 and NGR-TR-052 clustered in the lower-left quadrant of the regression plot, reflecting low beetle abundance and reduced leaf injury. Conversely, Jalin-White occupied the upper-right extreme of the plot, exhibiting the highest beetle population density and the greatest leaf defoliation. Intermediate genotypes, including Kona White G01, NGR-TR-051 and Jalin-Red, occupied intermediate positions along the regression line. These findings demonstrate that increasing beetle infestation was closely associated with increased foliage damage across roselle genotypes.

Effect of *Monolepta thompsoni* Infestation on Yield Components and Productivity

Significant genotypic differences were observed for all measured yield attributes at harvest in both environments (Tables 2 and 3). Genotype exerted a highly significant effect on fruit production, fresh fruit weight, fresh calyx weight and dry calyx yield (P < 0.001), indicating that differences in field resistance influenced reproductive performance.

At Makurdi, Kona White G01 produced the highest number of fruits (40.25 ± 0.63 fruits plant^{-1}), fresh fruit weight (323.90 ± 0.87 g plot^{-1}), fresh calyx weight (216.20 ± 0.31 g plant^{-1}) and dry calyx yield (37.17 ± 0.74 g plant^{-1}). MKD-Red (Local) ranked second, producing 35.75 ± 0.75 fruits plant^{-1} and 33.02 ± 0.74 g dry calyx plant^{-1}. In contrast, Jalin-White produced only 17.75 ± 0.48 fruits plant^{-1} and recorded the lowest dry calyx yield (10.73 ± 0.18 g plant^{-1}), representing approximately a 71% reduction relative to Kona White G01.

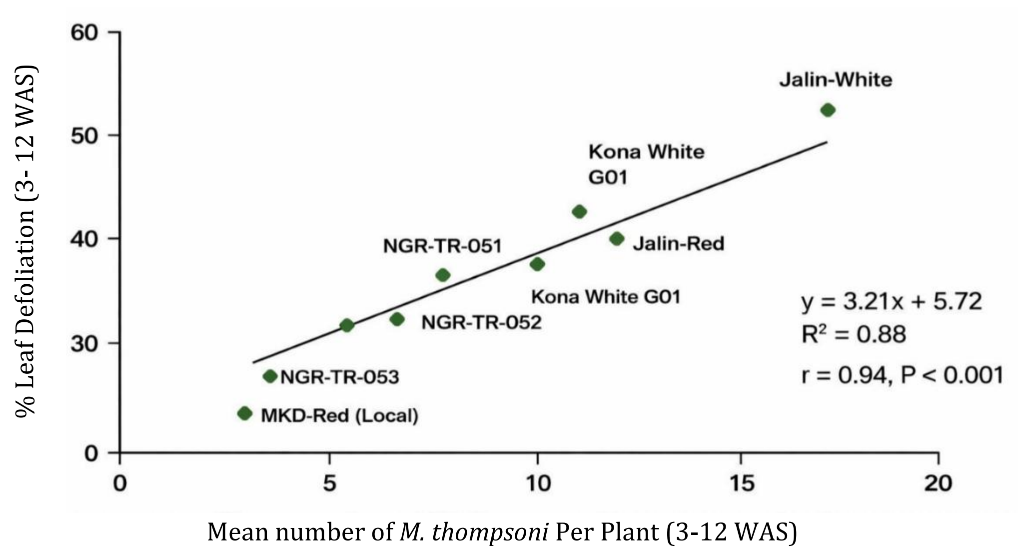

Figure 2. Relationship between mean population density of *M. thompsoni* (3–12 WAS) and mean leaf defoliation (%) across roselle genotypes (pooled across locations)

Table 2. Effect of *Monolepta thompsoni* Infestation on Yield Components and Productivity of Roselle (*Hibiscus sabdariffa* L.) Genotypes at Harvest (12 Weeks After Sowing) in Makurdi, Benue State, Nigeria

Genotypes	Number of Fruits /Plant	Number of fruits damaged /Plant (g)	Fresh Fruit Weight/Plot (g)	Fresh Calyx Weight /Plant (g)	Dry Calyx Weight /Plant (g)	Number of Damaged Stands/Plot	Number of Survived Stands/Plot
Kona White G01	40.25 ± 0.63a	11.00 ± 0.41^{c}	323.90 ± 0.87^{a}	216.20 ± 0.31^{a}	37.17 ± 0.74^{a}	3.50 ± 1.94^{c}	23.50 ± 1.94^{a}
Jalin-White	17.75 ± 0.48f	16.75 ± 0.75^{a}	154.73 ± 0.32^{e}	148.95 ± 0.19^{d}	10.73 ± 0.18^{e}	8.50 ± 0.29^{a}	18.50 ± 0.29^{c}
NGR-TR-051	29.00 ± 0.41c	12.75 ± 1.49^{bc}	233.00 ± 1.67^{c}	151.28 ± 0.45^{c}	15.75 ± 0.29^{d}	5.50 ± 0.29^{abc}	21.50 ± 0.29^{abc}
MKD-White (Local)	22.00 ± 0.58e	15.75 ± 0.48^{ab}	180.75 ± 0.29^{d}	111.55 ± 0.30^{e}	30.45 ± 0.18^{b}	7.25 ± 0.48^{ab}	19.75 ± 0.48^{bc}
NGR-TR-052	30.25 ± 0.48c	13.25 ± 0.25^{bc}	144.40 ± 22.57^{e}	75.75 ± 0.32^{h}	18.48 ±0.22^{c}	7.00 ± 0.71^{c}	20.00 ± 0.71^{bc}
NGR-TR-053	31.00 ± 2.16c	13.50 ± 0.29^{bc}	148.60 ± 0.27^{e}	78.13 ± 0.24^{g}	19.93 ± 1.34^{c}	4.75 ± 0.48^{bc}	22.25 ± 0.48^{ab}
Jalin-Red	24.75 ± 0.63^{d}	14.00 ± 0.41^{bc}	221.13 ±0.51^{c}	96.00 ± 0.^{17f}	22.25 ± 2.25^{c}	8.50 ± 0.29^{c}	18.50 ± 0.29^{c}
MKD-Red (Local)	35.75 ± 0.75^{b}	12.00 ± 0.41^{c}	271.50 ± 0.25^{b}	174.70 ± 0.30^{b}	33.02 ± 0.74^{b}	4.25 ± 0.85^{c}	22.75 ± 0.85^{ab}
F-value	66.31	6.82	63.95	28478.39	71.81	5.60	5.60
P-value	<0.001	<0.003	<0.001	<0.001	<0.001	<0.001	<0.001
C.V (%)	6.19	10.59	7.70	0.45	9.22	26.44	7.81

Note: Mean (±SEM) values followed by the same letter in a column are not significantly different from one another (Student Newman Keuls, P > 0.05), SE = Standard error of mean, C.V. = Coefficient of variation, GV1-3 (Genotypes of green roselle), GVL (Green Control); RV1-3 (Genotypes of red roselle), RVL (Red Control).

Table 3. Effect of *Monolepta thompsoni* Infestation on Yield Components and Productivity of Roselle (*Hibiscus sabdariffa* L.) Genotypes at Harvest (12 Weeks After Sowing) in Bali, Taraba State, Nigeria

Genotypes	Number of Fruits/Plant	Number of Fruit Damaged /Plant	Fresh Fruit Weight/Plot (g)	Fresh Calyx Weight /Plant (g)	Dry Calyx weight (g)	Number of Damaged Stands/Plot	Number of Survived Stands/Plot
Kona White G01	35.25 ± 0.63^{a}	6.00 ± 0.41^{b}	318.00 ± 0.87^{a}	211.20 ± 0.31^{a}	32.17 ± 0.72^{a}	3.50 ± 1.94^{c}	23.50 ± 1.94^{a}
Jalin-White	12.75 ± 0.48^{f}	10.75 ± 0.48^{a}	139.40 ± 22.57^{e}	106.60 ± 0.30^{e}	5.73 ± 0.18^{e}	8.50 ± 0.29^{a}	18.50 ± 0.29^{c}
NGR-TR-051	24.00 ± 0.41^{c}	9.25 ± 1.75^{ab}	228.00 ± 1.67^{c}	144.00 ± 0.19^{d}	10.75 ± 0.48^{d}	5.50 ± 0.29^{abc}	21.50 ± 0.29^{abc}
MKD-White (Local)	17.00 ± 0.58^{e}	8.50 ± 0.29^{ab}	216.10 ± 0.51^{c}	146.30 ± 0.43^{c}	25.45 ± 0.18^{b}	7.25 ± 0.48^{ab}	22.25 ± 0.48^{ab}
NGR-TR-052	25.25 ± 0.48^{c}	8.25 ± 0.25^{ab}	175.80 ± 0.29^{d}	70.80 ± 0.32^{h}	13.48 ± 0.22^{cd}	7.00 ± 0.71^{ab}	20.00 ± 0.71^{bc}
NGR-TR-053	26.00 ± 2.16^{c}	7.75 ± 1.49^{ab}	143.60 ± 0.27^{e}	73.10 ± 0.24^{g}	14.93 ± 1.34^{c}	4.75 ± 0.48^{bc}	19.75 ± 0.48^{bc}
Jalin-Red	19.75 ± 0.63^{d}	9.00 ± 0.41^{ab}	149.70 ± 0.32^{e}	91.20 ± 0.29^{f}	17.25 ± 2.25^{c}	8.50 ± 0.29^{a}	18.50 ± 0.29^{c}
MKD-Red (Local)	30.75 ± 0.75^{b}	6.75 ± 0.63^{ab}	266.50 ± 0.25^{b}	169.70 ± 0.30^{b}	28.02 ± 0.74^{b}	4.25 ± 0.85^{bc}	22.75 ± 0.85^{ab}
F-value	66.31	2.64	63.95	28659.22	71.81	5.60	5.60
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
C.V (%)	7.49	22.07	7.89	0.46	11.71	26.44	7.81

Mean (±SEM) values followed by the same letter in a column are not significantly different from one another (Student Newman Keuls, P > 0.05), SE = Standard error of mean, C.V. = Coefficient of variation, GV1-3 (Genotypes of green roselle), GVL (Green Control); RV1-3 (Genotypes of red roselle), RVL (Red Control).

Table 4. Integrated resistance index of roselle (*Hibiscus sabdariffa* L.) genotypes to *Monolepta thompsoni* based on pooled pest, damage and yield parameters

Genotype	Calyx colour	Mean beetle population (insects plant^{-1})	Mean leaf defoliation (%)	Functional leaf area (cm^2)	Mean dry calyx yield (g plant^{-1})	Resistance Index (RI)	Resistance category
Kona White G01	Green	6.28	20.87	79.41	34.67	0.907	Highly Resistant
MKD-Red (Local)	Red	4.41	16.50	63.05	30.52	0.854	Highly Resistant
NGR-TR-053	Red	3.91	23.55	53.68	17.43	0.649	Resistant
NGR-TR-052	Red	4.63	28.33	51.14	15.98	0.571	Moderately Resistant
MKD-White (Local)	Green	6.59	31.31	38.53	27.95	0.540	Moderately Resistant
Jalin-Red	Red	4.81	35.69	45.02	19.75	0.523	Intermediate
NGR-TR-051	Green	5.31	26.62	48.59	13.25	0.522	Intermediate
Jalin-White	Green	12.78	57.84	35.27	8.23	0.000	Highly Susceptible

CFRI = Composite Field Resistance Index calculated from pooled data across Makurdi and Bali using four standardized variables: mean *Monolepta* thompsoni population density (3, 6, 9 and 12 WAS), mean leaf defoliation at 9 WAS, functional leaf area at 9 WAS, and dry calyx yield per plant. Beetle population density and leaf defoliation were inversely standardized because lower values indicate greater resistance, whereas functional leaf area and dry calyx yield were positively standardized because higher values indicate greater resistance. Standardized scores ranged from 0 to 1, and the CFRI was computed as the arithmetic mean of the four standardized scores. Higher CFRI values indicate greater field resistance. Genotypes were classified as Highly Resistant (≥0.80), Resistant (0.60–0.79), Moderately Resistant (0.40–0.59), Intermediate (0.20–0.39), Moderately Susceptible (0.10–0.19), and Highly Susceptible (<0.10). See Materials and Methods for details of the CFRI calculation.

DISCUSSION

Substantial genotypic variation in field resistance of roselle (*Hibiscus sabdariffa* L.) to *Monolepta thompsoni* under natural infestation across the two Southern Guinea Savanna environments was observed in this study. Beetle populations increased progressively after crop establishment, peaked around 9 weeks after sowing (WAS), and subsequently declined toward crop maturity. This pattern suggests that the vegetative growth phase of roselle provides favourable conditions for beetle colonization and feeding, after which changes in plant phenology may reduce host suitability.

Genotypes differed markedly in their ability to limit beetle infestation and leaf injury. Jalin-White consistently harboured the highest beetle populations and suffered the greatest defoliation, whereas MKD-Red (Local) and Kona White G01 maintained lower infestation levels and reduced foliage damage. The strong positive relationship between beetle population density and leaf defoliation ($r = 0.94$, $P < 0.001$) indicates that increased beetle abundance translated directly into greater feeding injury. Similar relationships between foliar beetle density and leaf area loss have been reported in other crop systems, where defoliating chrysomelid beetles substantially reduce photosynthetic capacity and plant productivity (Zhang et al., 2022).

The superior performance of MKD-Red (Local) and Kona White G01 suggests the presence of field resistance and/or tolerance mechanisms that limited the impact of *M. thompsoni*. Although the present study did not investigate resistance mechanisms directly, differences in canopy retention and yield among genotypes imply that both reduced beetle colonization and the ability to maintain productivity under pest pressure contributed to the observed responses. Host-plant resistance is widely recognized as a cornerstone of integrated pest management because resistant cultivars provide season-long pest suppression, reduce insecticide requirements, lower production costs, and contribute to environmentally sustainable crop protection (Trapero et al., 2016; Prasanna et al., 2022).

Red-calyx genotypes generally exhibited lower beetle infestation and reduced defoliation than most green-calyx genotypes. This trend may reflect differences in morphological or biochemical traits associated with calyx colour groups, although such mechanisms require further investigation. In related Malvaceae crops such as okra (*Abelmoschus esculentus* L. Moench), genotypic differences in susceptibility to flea beetles and other foliar-feeding insects have been associated with morphological and biochemical traits, including trichome density, leaf structural characteristics, and the composition of secondary metabolites (Ounis et al., 2024). Because roselle and okra belong to the same family, similar defensive traits may contribute to differential beetle responses, but this inference should be interpreted cautiously until confirmed experimentally.

Yield responses closely mirrored the resistance pattern observed during vegetative growth. Kona White G01 and MKD-Red (Local) produced substantially higher dry calyx yields than the susceptible genotype Jalin-White, demonstrating the agronomic importance of resistance to *M. thompsoni*. The Composite Field Resistance Index (CFRI) further integrated pest abundance, leaf damage, canopy retention, and yield into a single metric, clearly distinguishing highly resistant from highly susceptible genotypes. Such composite indices are increasingly useful in breeding programs because they capture multiple dimensions of plant response under field conditions rather than relying on a single trait.

Some limitations should be considered when interpreting the findings of this study. First, resistance was evaluated under natural infestation at only two locations during a single cropping season. Although these environments represent important roselle-producing areas within the Southern Guinea Savanna, broader multi-location and multi-season evaluations would be required to fully characterize the stability of resistance across diverse agro-ecological conditions and pest populations. Second, the study assessed field resistance based on infestation, damage, and yield responses but did not investigate the underlying resistance mechanisms (e.g., antixenosis, antibiosis, or biochemical defenses). Finally, environmental factors influencing beetle abundance were not modelled explicitly. Consequently, the identified resistant genotypes should be regarded as promising candidates for further validation and breeding rather than definitive sources of stable resistance across all production environments.

CONCLUSION

The study demonstrated significant genotypic variation in field resistance of roselle to *Monolepta thompsoni* in the Southern Guinea Savanna of Nigeria. Increased beetle abundance was strongly associated with greater leaf defoliation, reduced functional leaf area, and lower calyx yield. Among the evaluated genotypes, MKD-Red (Local) and Kona White G01 consistently exhibited superior field resistance and productivity, whereas Jalin-White was highly susceptible across both locations. The Composite Field Resistance Index effectively integrated multiple resistance-related traits and provided a practical framework for ranking genotypes under natural infestation. These findings identify MKD-Red (Local) and Kona White G01 as promising parental materials for resistance breeding and as potential cultivar options for farmers seeking to reduce yield losses caused by *M. thompsoni*. Future research should validate these responses across additional environments and seasons and investigate the morphological and biochemical mechanisms underlying resistance.

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AUTHOR CONTRIBUTION STATEMENT

All authors contributed to the conception and design of the study, conducted the field experiments, collected and analyzed the data, interpreted the results, and prepared the manuscript. Both authors read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL

Not applicable.

CONSENT FOR PUBLICATION

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

REFERENCES

Banjaw, D. T. (2020). Growth and yield performances of roselle (Hibiscus sabdariffa L.) to intercropping practices: A review. *Advances in Life Science and Technology*, *84,* 1–10. https://doi.org/10.7176/ALST/84-01

Karaca, C., Büyüktaş, D., & Şehir, S. (2020). Determination of leaf area of some vegetable plants grown under greenhouse conditions by non-destructive methods. *Horticultural Studies, 38*(1), 23–28. https://doi.org/10.16882/HortiS.841745

Kéllou, K. K. B., Abdourazak, M. A., Boukar, M. C. M., Saley, M. D., Sanoussi, A., & Yacoubou, B. (2024). Roselle (*Hibiscus sabdariffa* L.): Overview of its biology, ecology, socio-economic importance and cultivation constraints in West Africa. *World Journal of Pharmaceutical and Life Sciences, 10*(3), 47–56.

Machado, B. B., Orue, J. P. M., Arruda, M. S., Santos, C. V., Sarath, D. S., Gonçalves, W. N., Silva, G. G., & Pistori, H. (2016). BioLeaf: A professional mobile application to measure foliar damage caused by insect herbivory. *Computers and Electronics in Agriculture*, 129, 44–55. https://doi.org/10.1016/j.compag.2016.09.009

Montgomery, D. C. (2020). Design and analysis of experiments (10th ed.). John Wiley & Sons. pp. 77–78

Moussa, A. A., Boucar, M. C. M., & Kellou, K. K. B. (2024). Roselle (*Hibiscus sabdariffa* L.): Overview of its biology, ecology, socio-economic importance and cultivation constraints in West Africa. *World Journal of Advanced Pharmaceutical and Life Sciences*, *10*(3), 47–56.

Nazifi, M. I., Madina, P., & Imrana, B. Z. (2024). Production of Roselle (Hibiscus sabdariffa L.) as influenced by density and fertilizer rate in Kano State, Nigeria. International *Journal of Agriculture and Earth Science, 10*(3), 37–53. https://doi.org/10.56201/ijaes.v10.no3.2024.pg37.53

Onyeukwu, O. B., Dibie, D. C., and Njideaka, O. T. (2023). Hibiscus sabdariffa - uses, nutritional and therapeutic benefits - A review. *Journal of Bioscience and Biotechnology Discovery*, 8(2), 18–23. https://doi.org/10.31248/JBBD2023.178

Peterson, R. K. D., Varella, A. C., & Higley, L. G. (2017). Tolerance: The forgotten child of plant resistance. *PeerJ,* 5, e3934. https://doi.org/10.7717/peerj.3934

Pollesch, N. L., & Dale, V. H. (2016). Normalization in sustainability assessment: Methods and implications. *Ecological Economics,* 130, 195–208. https://doi.org/10.1016/j.ecolecon.2016.06.018

Prasanna, B. M., Bruce, A., Beyene, Y., Makumbi, D., Gowda, M., Asim, M., Martinelli, S., Head, G. P., & Parimi, S. (2022). Host plant resistance for fall armyworm management in maize: Relevance, status and prospects in Africa and Asia. *Theoretical and Applied Genetics*, 135, 3897–3916. https://doi.org/10.1007/s00122-022-04073-4

Salem, M. A., Zayed, A., Beshay, M. E., Abdel Mesih, M. M., Ben Khayal, R. F., George, F. A., & Ezzat, S. M. (2022). Hibiscus sabdariffa L.: Phytoconstituents, nutritive, and pharmacological applications. *Advances in Traditional Medicine*, 22, 497–507. https://doi.org/10.1007/s13596-020-00542-7

SAS Institute Inc. (2009). *SAS/STAT® 9.2 User's Guide* (2nd ed.). Cary, NC: SAS Institute Inc.

Simon L.D., Ogunwolu E.O., Okoroafor E., and Ekoja E.E (2021). Density, relative abundance and temporal spread of insects associated with Roselle (*Hibiscus sabdariffa* L.) at Makurdi, Nigeria. *Annals of Tropical Research* 43(1), 1-15

Simon, L. D., E. O. Ogunwolu, and E. Okoroafor. 2019. Impact of Insect Infestation on Plant Damage and Yield of Roselle [*Hibiscus sabdariffa* L.] in Benue State, Nigeria. *International Journal of Plant & Soil Science* 26 (1), 1-10. https://doi.org/10.9734/IJPSS/2018/45446.

Trapero, C., Wilson, I. W., Stiller, W. N., & Wilson, L. J. (2016). Enhancing integrated pest management in GM cotton systems using host plant resistance. *Frontiers in Plant Science*, 7, 500. https://doi.org/10.3389/fpls.2016.00500

Zhang, B., Zhou, L., Zhou, X., Bai, Y., Zhan, M., Chen, J., & Xu, C. (2022). Differential responses of leaf photosynthesis to insect and pathogen outbreaks: A global synthesis. *Science of the Total Environment*, 832, 155052. https://doi.org/10.1016/j.scitotenv.2022.155052