



## Research Article

# Effects of Different Soil Types on the Growth, Phytochemical and Physiochemical Properties of *Solanum Aethiopicum*

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### ABSTRACT

Soil properties are critical determinants of crop performance and phytochemical expression, yet their influence on indigenous vegetables such as *Solanum aethiopicum* (African eggplant) in Nigeria remains underexplored. This study evaluates the effects of five soil types, loamy, sandy, clay, red earth, and garden topsoil (control), on growth parameters and phytochemical composition of *S. aethiopicum* under greenhouse conditions. Seeds were cultivated for 12 weeks in a randomized design with 3 replicates per soil type in each five soil treatments resulting to 75 planting bags. Growth metrics (plant height, leaf area, shoot/root fresh and dry weight) and soil physiochemical properties (pH, moisture, texture) were assessed, alongside qualitative and quantitative phytochemical analyses (phenols, flavonoids, saponins, tannins). Results revealed significant variation among soil treatments (ANOVA,  $p \leq 0.05$ ). Loamy soil supported superior vegetative growth, with the highest plant height ( $41.00 \pm 3.21$  cm), mean leaf area ( $51.82 \pm 20.51$  cm<sup>2</sup>), and shoot fresh weight ( $9.05 \pm 2.15$  g). Phytochemical concentrations were also greatest in loamy soil, with phenols, flavonoids, saponins, and tannins significantly exceeding other treatments. Sandy and garden topsoil exhibited the poorest growth and metabolite profiles, while clay and red earth were intermediate. These findings show the role of soil type in optimizing both yield and nutraceutical quality of *S. aethiopicum*, providing a basis for soil management strategies to enhance food and nutritional security in sub-Saharan Africa.

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## INTRODUCTION

The provision of safe, high-quality, and nutritionally adequate food remains a central goal of plant biology, agronomy, and food science. This goal has become increasingly urgent due to escalating food insecurity driven by climate variability, land degradation, the proliferation of pests and diseases, and suboptimal agricultural management practices. Plants synthesize a wide array of primary and secondary metabolites that are essential for human health and therapeutic applications. Many of these metabolites exhibit important biological and pharmacological activities, including hypoglycemic, anti-inflammatory, antioxidant, antibacterial, and anticancer effects, thereby contributing to the mitigation of oxidative cellular damage (Katalinic *et al.* 2006, Junsathian *et al.* 2018, Sattar 2021). In plants, these compounds are equally critical, serving as regulators of growth, development, and defense against biotic and abiotic stressors. Their biosynthesis is highly responsive to environmental conditions, which simultaneously influence plant growth and productivity.

Among abiotic factors, soil represents a fundamental determinant of plant performance and metabolic expression. Soil texture is a fundamental determinant of plant growth because it regulates water retention capacity, aeration status, nutrient diffusion rates, cation exchange capacity, and root penetrability (Brady & Weil, 2016; Hillel, 2004). Variations in sand, silt, and clay proportions influence rhizosphere oxygen availability and nutrient mobility, thereby modulating physiological processes such as photosynthesis, transpiration efficiency, and root system architecture. Although agronomic manuals report that *S. aethiopicum* performs optimally in moderately acidic to near-neutral soils (pH 5.5–6.8), cultivation practices across Nigeria are largely based on empirical soil preferences rather than experimentally validated comparisons of defined soil textural classes. Consequently, soil pH is a key factor in agricultural productivity, with optimal crop growth for most species occurring within a pH range of 5.5–7.5 (Oshunsanya 2019).

*Solanum aethiopicum* L. (African eggplant), also known as Ethiopian or scarlet eggplant, is an important traditional vegetable crop widely cultivated and consumed across sub-Saharan Africa particularly Nigeria, where it serves

both dietary and medicinal functions (Grubben & Denton, 2004; Schippers, 2000). The species is nutritionally rich, providing carbohydrates, proteins, fats, dietary fibre, essential vitamins (B2, B3, and C), and important minerals such as potassium, magnesium, iron, calcium, phosphorus, and zinc (Choi and Choi 2024). This nutritional profile highlights its potential contribution to food and nutritional security. In addition to its dietary value, *S. aethiopicum* is extensively used in traditional medicine for the management of hypertension, diabetes, cholera, uterine disorders, skin infections, constipation, weight control, and rheumatic diseases (Han *et al.* 2021). Till date, despite its nutritional and medicinal importance, no controlled greenhouse study has compared soil textural classes with quantitative assessment of their effects on growth kinetics alongside secondary metabolite production of this plant. Consequently, the mechanistic relationship between soil texture and nutraceutical quality in *S. aethiopicum* remains unresolved.

Current literature indicates that the crop is adaptable to a range of well-drained soils and performs optimally within a soil pH of 5.5–6.8 (Myungi *et al.*, 2025). However, these general recommendations fail to account for the influence of specific soil types and their inherent properties, such as texture, organic matter content, nutrient availability, and subtle pH variations within the optimal range. Despite growing recognition that soil physicochemical properties influence both biomass production and phytochemical accumulation, existing studies on *S. aethiopicum* have primarily focused on morphological characterization, genetic diversity, or qualitative phytochemical profiling without systematically linking metabolite variation to defined soil parameters (Adeniji *et al.*, 2013; Grubben & Denton, 2004).

The biochemical process in an edaphic conditions are known to alter carbon allocation patterns and activate stress-responsive metabolic pathways that govern secondary metabolite biosynthesis (Marschner, 2012; Treutter, 2010). For instance, nutrient limitation and mild abiotic stress can stimulate phenylpropanoid pathway activity, leading to enhanced accumulation of phenolics and flavonoids. Another related studies support this relationship; for example, soil type

influences soluble phenols and tannins in woody plants (Mudau *et al.* 2022), while soil texture has been shown to affect soil composition and antioxidant activity in *Solanum nigrum* (Ogundola *et al.* 2022a, 2022b). Although phytochemical profiles of *S. aethiopicum* have been reported (Eze and Kanu 2014), these studies do not establish direct links between phytochemical variation and specific soil types or soil physiochemical properties. This represents a critical knowledge gap in understanding how environmental inputs are translated into biochemical outputs in this species.

In light of these gaps, the present study aims to systematically evaluate the effects of different soil types on the growth performance and phytochemical composition of *Solanum aethiopicum*. By elucidating the relationship between soil type and phytochemical expression in *S. aethiopicum*, this work seeks to provide a mechanistic basis for optimizing soil selection and management strategies that enhance both yield and nutritional quality. The findings are expected to contribute to sustainable cultivation practices and support the valorization of *S. aethiopicum* as a

nutritionally and medicinally important crop in sub-Saharan Africa, especially Nigeria.

#### METHODOLOGY

The experiment was carried out in the greenhouse at the Botanical Garden of the University of Lagos from December, 2024 to March, 2025 (12 weeks). The seeds of *S. aethiopicum* were purchased from Oyingbo market, Lagos State and sown in different soil types (red earth, sandy, loamy, clay) including the garden top soil for reference (control) (Table 1). The study was conducted in a completely randomized design, with five soil treatments. Each treatment consisted of three independent replicates in five plants per replicate. Each replicate comprised five individual plants grown in separate planting bags, resulting to 75 planting bags (5 soil types × 3 replicates × 5 plants). Each bag contained 1kg of the designated soil. Day/night temperature regime in the green house was 35/28°C with 14 h photoperiod. Relative humidity during the experiment varied between 50-65%. For statistical analysis, replicate means were treated as the experimental unit (n = 3 per treatment).

**Table 1:** Locations where soil types were collected

Soil type	Location collected
Red earth	Ikorodu
Clay	Termite mound at the Biological Garden, University of Lagos, Akoka
Loamy	University of Lagos, Lagoon front
Sandy	Field pitch behind the Faculty of Education, University of Lagos, Akoka
Garden Topsoil	Biological Garden, University of Lagos, Akoka

#### *Planting procedure and growth parameters measured*

The seeds were planted in the nursery by means of broadcasting in a shallow filled basins containing the different soil types approximately 40cm in diameter for 4 weeks. After which they were transplanted into the perforated planting bags containing each of the five soil types. The plants were kept in ascreenhouse, watered adequately on the average of 2-3 days depending on the soil types and weeded when necessary. At the 6<sup>th</sup> and 12<sup>th</sup> week of sowing, the plants were harvested and growth parameters measured include: plant height, stem girth, number of leaves, leaf area, shoot fresh weight, shoot dry weight, root dry weight (procedures and

formulas are available on the supplementary note).

#### *Soil analysis*

The following soil analysis were conducted for the purpose of this study:

##### **i. Soil moisture content**

About 200 g of each of the soil sample were placed in the electric oven at 100°C for 24 hours. Thereafter, the dry soil weight was taken and the percentage moisture content was calculated (Black, *et al* 1965).

##### **ii. Soil salinity**

Briefly, 10 ml of distilled water was added to 5g of the soil samples in different test tubes. After vigorous shaking, a small amount of the solvents was taken with a dropper and placed on the prism of the refractometer. Salinity was

recorded from the calibrated viewing chamber (Black et al 1965).

### iii. Soil pH

Solvents gotten from the mixture of distilled water and soil samples were subjected to pH testing using a digital pH meter.

### iv. Soil sedimentation

Here, 140 g of each of the five soil samples collected from the locations and 200ml distilled water were poured into each 250ml glass jar, covered and sealed with foil paper. Samples were shaken vigorously (to homogenize the particle sizes) for five minutes and left for 24 hours to settle. Thereafter, the volumes of the soil types were recorded (Black et al., 1965).

### v. Soil texture sampling

Soil texture was determined using the hydrometer method to estimate the proportions of sand, silt, and clay. The resulting percentages were classified according to the US Soil Texture Triangle (Saxton et al. 1986).

### *Plant sample preparation for phytochemistry*

Plant samples collected were cut into smaller sizes, air-dried at room temperature, and ground into fine, uniform powder using an electric milling machine. The aqueous extract of each sample was prepared by soaking 1g of the dried powdered samples in 15 mL of distilled water and boiling for 5 minutes, after which it was filtered and collected. The extract was filtered and collected. The methanolic extraction of each sample was prepared by soaking 2g of the dried powdered sample in 20 ml of methanol, and it was left to macerate for 3 days. The macerated contents were filtered

and poured into evaporating dishes and left to dry in an oven at 50°C for 24 hours (Sofowora 1996). Qualitative analysis was conducted for the presence of phenolics, flavonoids, tannins, cardiac glycosides, triterpenoids (Evans 2009), alkaloids, saponins, reducing sugars, anthraquinones, terpenoids, steroids (Sofowora 1996). Quantitative analysis was conducted for estimating total phenolic content (Singleton and Rossi 1965), total flavonoid content (Kumaran and Joel Karunakaran 2007), total saponin content, and total tannin content (Stanković 2011).

### *Statistical analysis*

All experimental data were analysed using a one-way Analysis of Variance (ANOVA). Level of significant differences among treatments were separated using the Tukey-Kramer Honest and post hoc test ( $p < 0.05$ ).

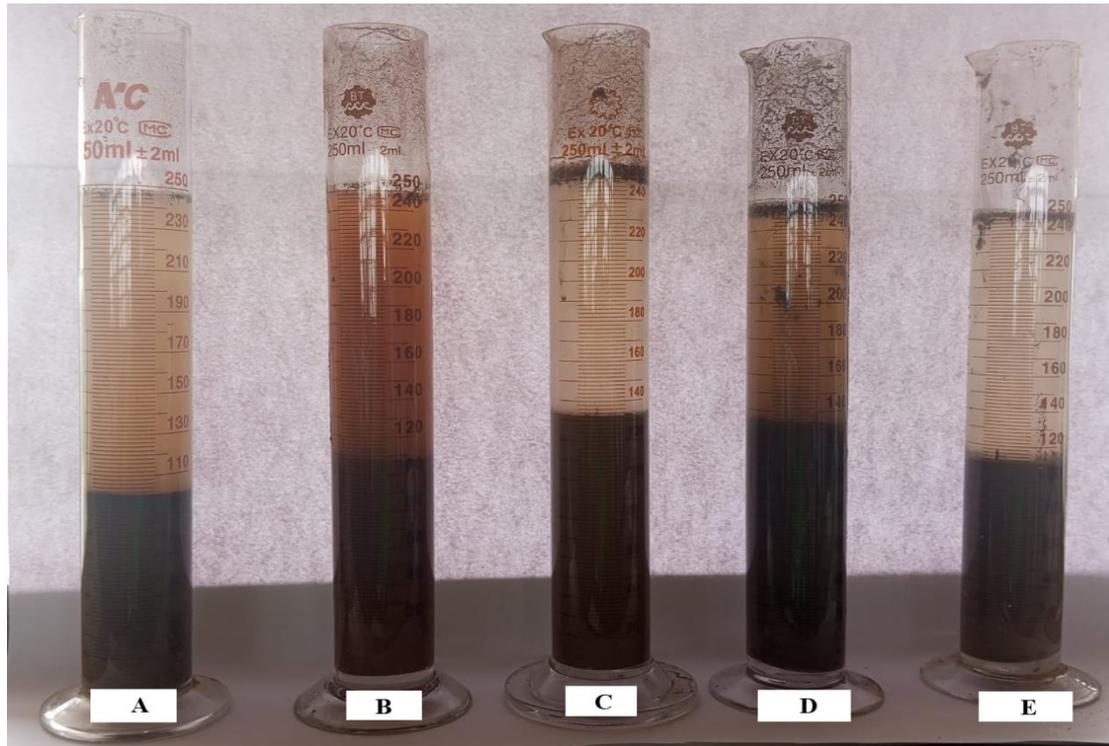
## RESULTS

### *Soil characterization*

Textural, chemical, and physical properties differed among the five soils (Table 2). Clay soil had the highest moisture content (14.89%), an acidic pH (5.13), and a clay-loam texture; sandy soil had the lowest moisture content (0.41%), an alkaline pH (8.55), and a sand texture; loamy soil exhibited relatively high moisture (14.56%), slightly alkaline pH (7.87), and was classified as loamy sand. Red earth and garden top soils were also loamy sands with pH 6.98 and 5.99, respectively. The sedimentation profiles of the different soil samples are shown in Plate 1, illustrating the relative proportions of sand, silt, and clay fractions.

**Table 2:** Soil Profile

Soil Type	Salinity Content (DS m <sup>-1</sup> )	Moisture Content (%)	Soil pH	Silt (%)	Clay (%)	Sand (%)
Clay	5.5	14.89 %	5.13	35.39 %	38.05 %	26.54 %
Red Earth	5.5	2.91 %	6.98	13.73 %	2.94 %	83.30 %
Loamy	5.0	14.56 %	7.87	18.33 %	4.17 %	51.17 %
Sandy	5.1	0.41 %	8.55	7.78 %	1.11 %	91.10 %
Garden top (control)	5.3	5.41 %	5.99	23.00 %	2.00 %	75.00 %



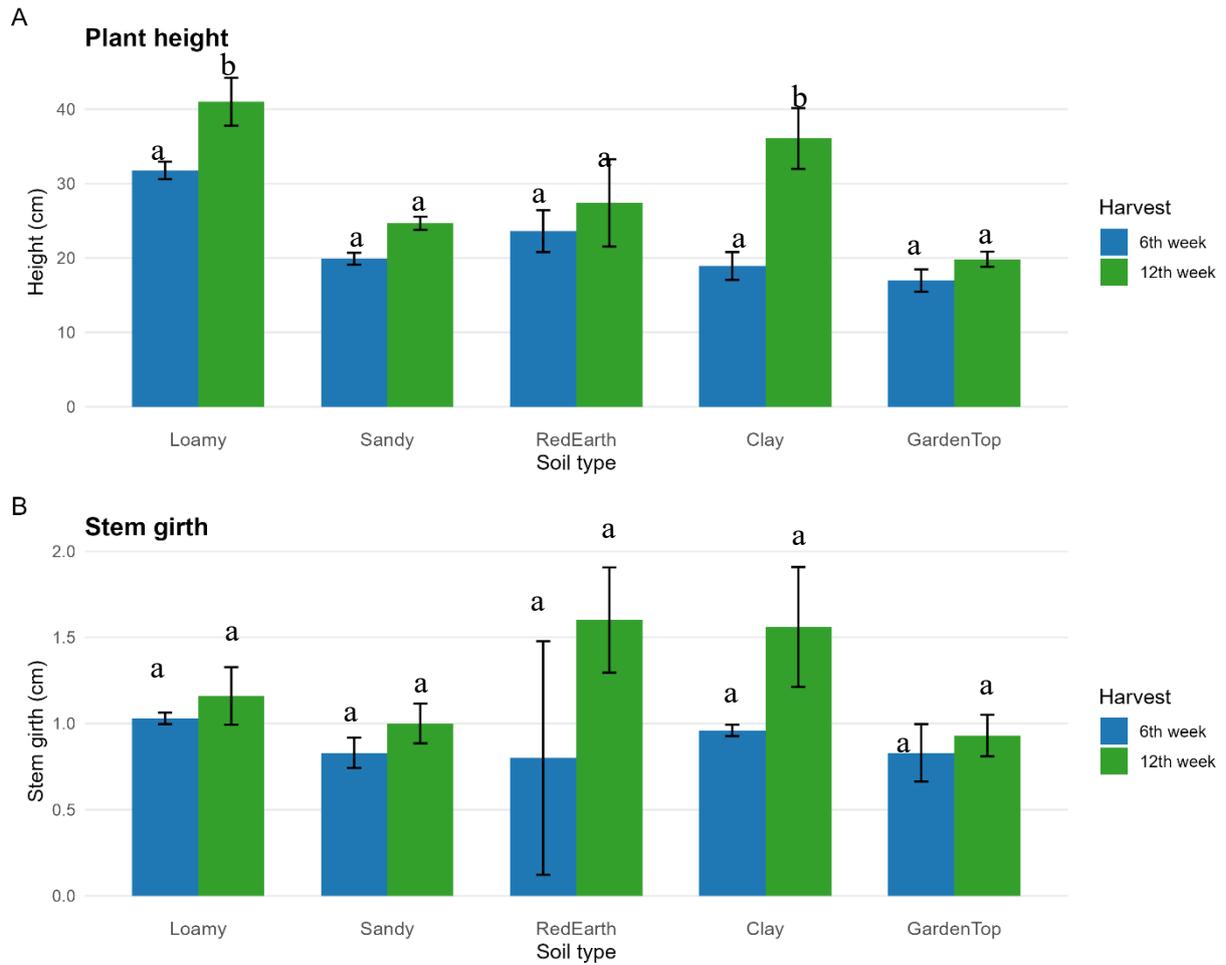
**Figure 1:** Sedimentation of the different soil samples.

a: sandy soil b: red earth soil c: clay soil d: loamy soil e: garden top soil

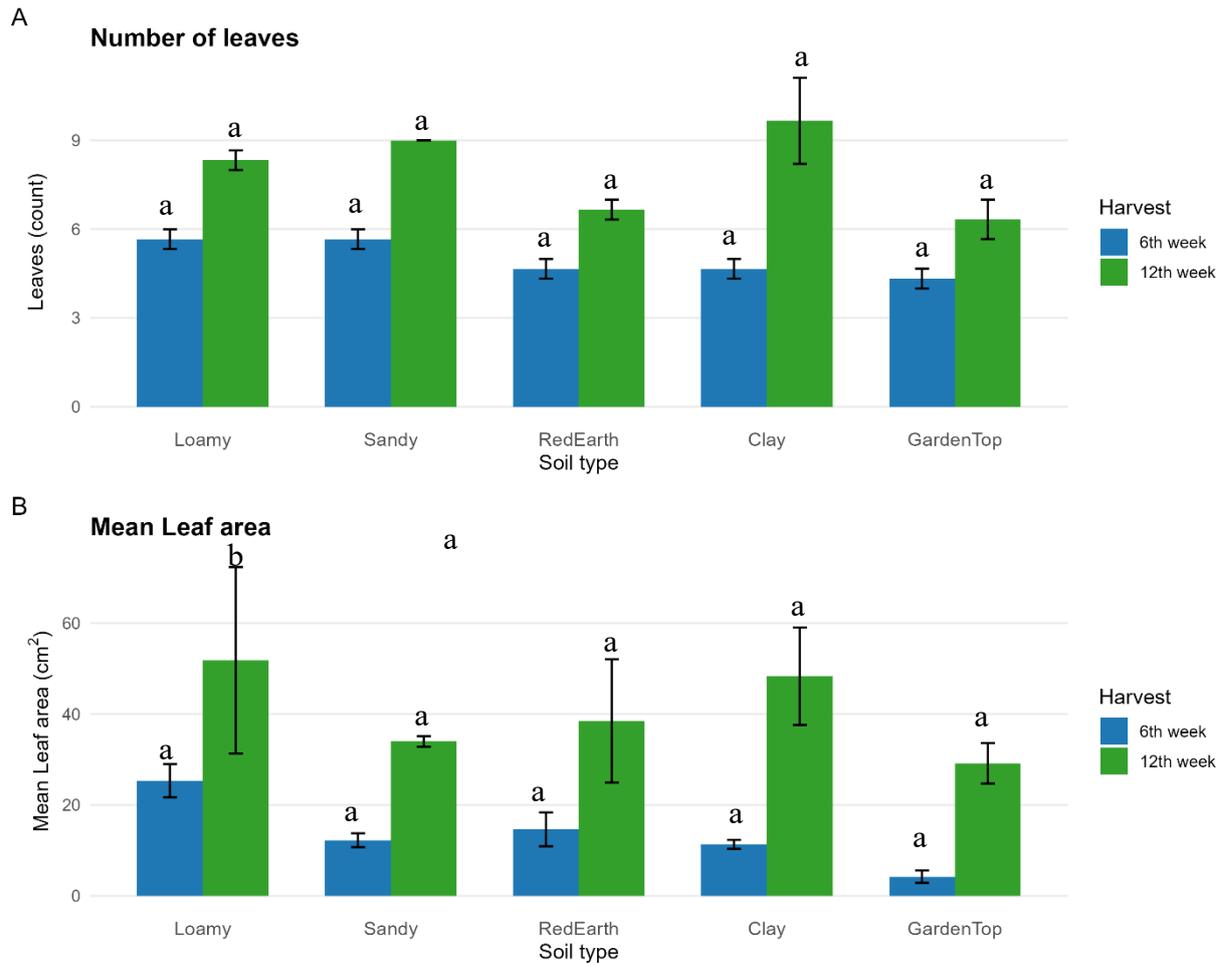
#### ***Plant growth performance at 6<sup>th</sup> and 12<sup>th</sup> week***

The loamy soil displayed the tallest plant height at both week 6 ( $31.76 \pm 1.178$ ) and week 12 ( $41.00 \pm 3.21\text{cm}$ ), followed by red earth at week 6 ( $23.60 \pm 2.8095$ ) and clay at week 12 ( $36.07 \pm 4.09\text{cm}$ ). There is no significance differences in all the plant height at week 6 while loamy and clay soils at week 12 are statistically significant ( $P > 0.05$ ) as compared to other different soil types (Figure 2A). At week 12, mean stem girth ranged from  $0.93 \pm 0.12\text{cm}$  (garden top soil) to  $1.60 \pm 0.53\text{cm}$  (red earth), but differences among soils were not significant ( $P = 0.202$ ). (Figure 2B). At week 6 and 12, leaf number differed among soils ranging from  $4.33 \pm 0.3333$  (control=garden top soil) to  $5.66 \pm 0.3333$

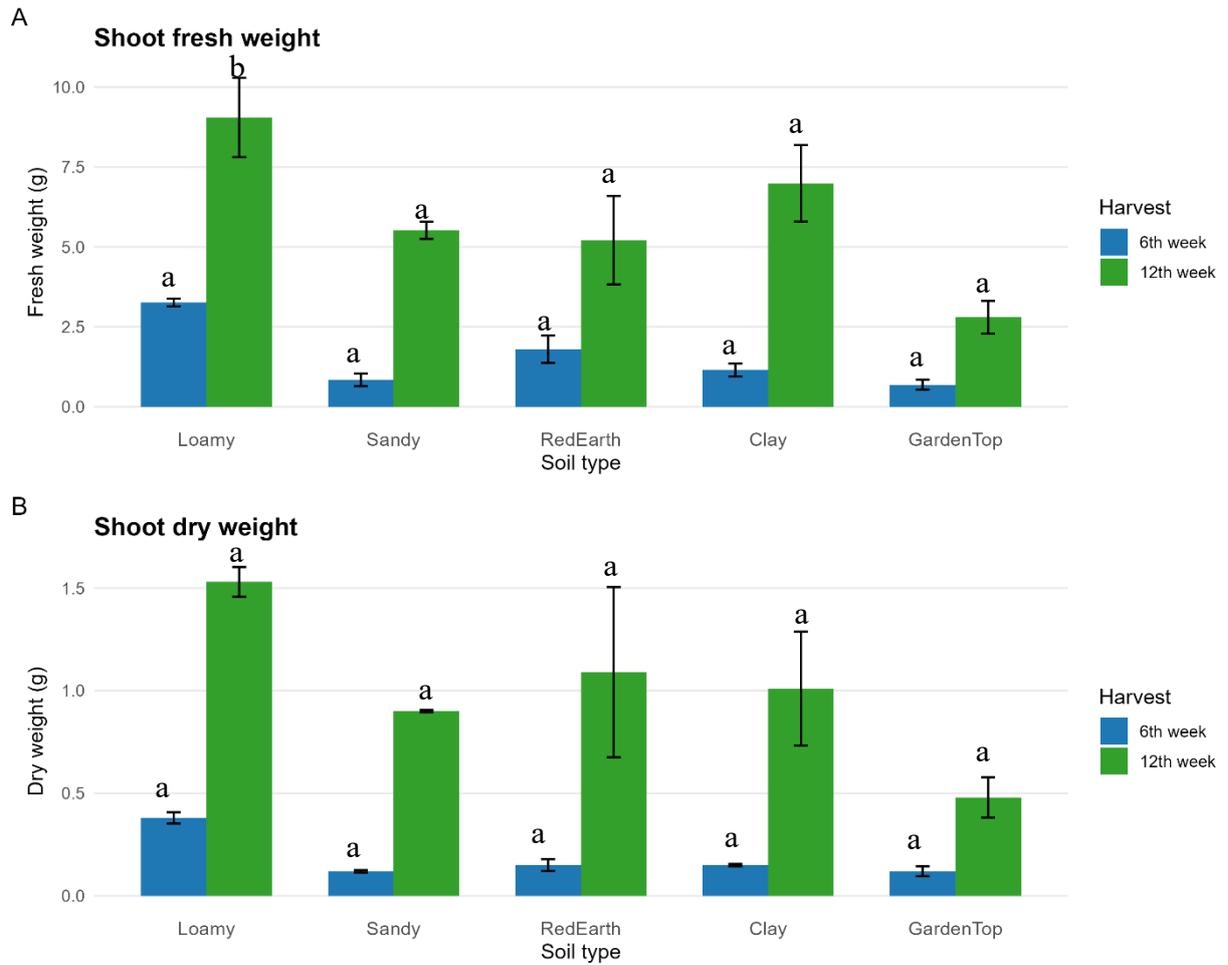
(loamy and sandy soils) and  $6.33 \pm 0.6666$  (control=garden top soil) to  $9.66 \pm 1.4529$  (clay soil) respectively (Figure 3A). However, there was no statistical differences in all the treatments. This result was also applicable to mean leaf area as it was not statistically significant ( $P > 0.05$ ) (Figure 3B). The fresh shoot weight (Figure 4A) and dry shoot weight (Figure 4B) at week 6 and 12 showed no significance difference at  $P < 0.05$  in all the different soil types except for fresh shoot weight of the loamy soil at week 12 that had  $9.05 \pm 1.2417$  which was statistically significant. The sandy soils ( $0.48 \pm 0.0580$ ;  $0.21 \pm 0.0512$ ) and red earth soils ( $0.42 \pm 0.0881$ ;  $0.24 \pm 0.0512$ ) of the fresh (Figure 5A) and dry root weight (Figure 5B) respectively at week 12 were statistically significant.



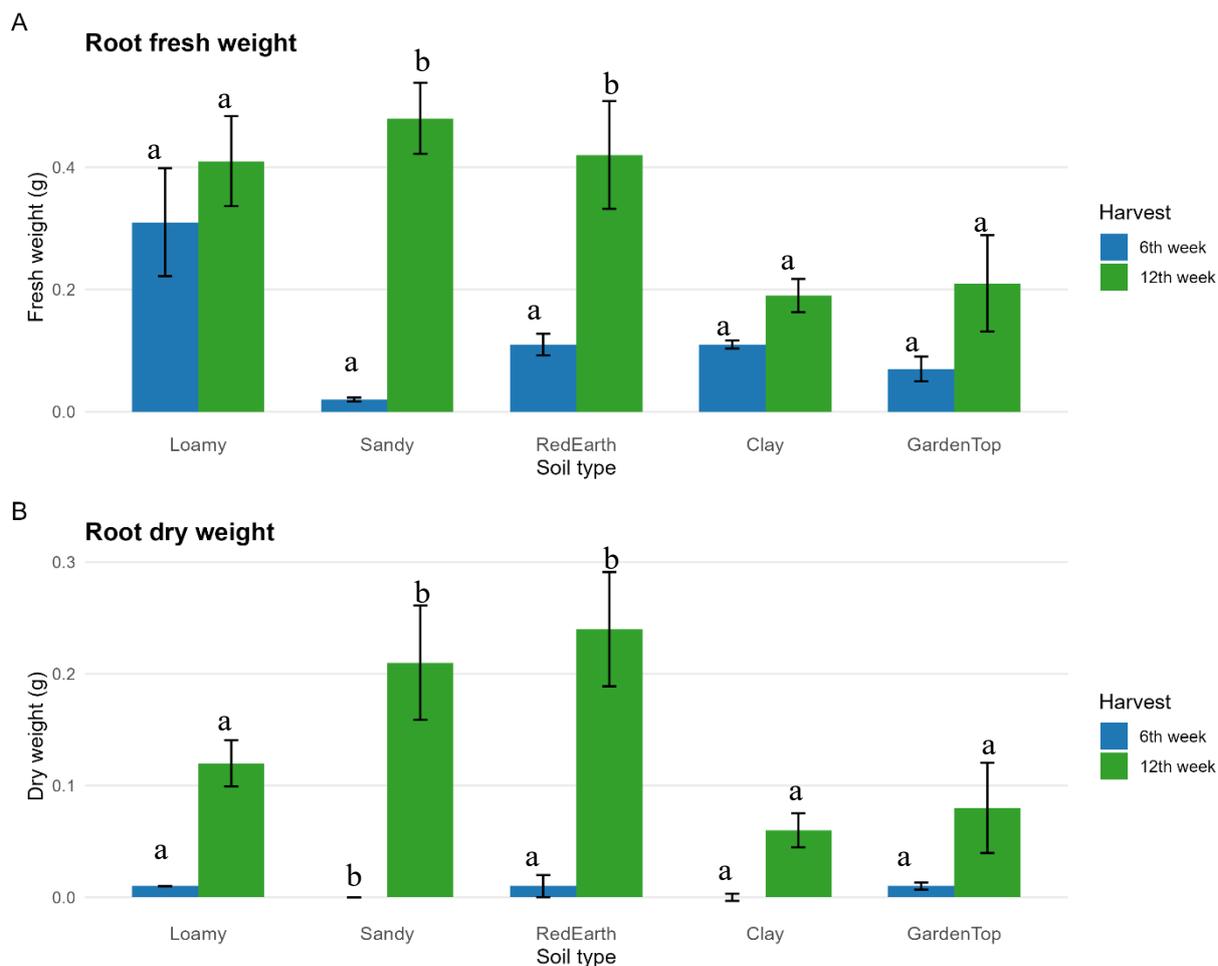
**Figure 2:** Effects of soil type on growth parameters of *Solanum aethiopicum* at 6th and 12th weeks after planting. (A) Plant height and (B) stem girth of plants grown in different soil types. Bars represent mean  $\pm$  SE. Bars with similar letters in each group are not significantly different at  $p \leq 0.05$  using Tukey's post hoc test



**Figure 3:** Effects of soil type on growth parameters of *Solanum aethiopicum* at 6th and 12th weeks after planting. (A) Number of leaves and (B) Mean Leaf area of plants grown in different soil types. Bars represent mean  $\pm$  SE. Bars with similar letters in each group are not significantly different at  $p \leq 0.05$  using Tukey's post hoc test



**Figure 4:** Effects of soil type on growth parameters of *Solanum aethiopicum* at 6th and 12th weeks after planting. (A) Shoot fresh weight and (B) Shoot dry weight of plants grown in different soil types. Bars represent mean  $\pm$  SE. Bars with similar letters in each group are not significantly different at  $p \leq 0.05$  using Tukey's post hoc test



**Figure 5:** Effects of soil type on growth parameters of *Solanum aethiopicum* at 6th and 12th weeks after planting. (A) Root fresh weight and (B) Root dry weight of plants grown in different soil types. Bars represent mean  $\pm$  SE. Bars with similar letters in each group are not significantly different at  $p \leq 0.05$  using Tukey's post hoc test

#### Growth Kinetics (6-12 weeks)

Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) were computed from shoot and leaf area measurements. Shoot RGR ranged 0.231-

0.335  $\text{g g}^{-1} \text{ week}^{-1}$  across soils; root RGR ranged 0.621- 0.710  $\text{g g}^{-1} \text{ week}^{-1}$ , NAR ranged 0.0046 - 0.0063  $\text{g m}^{-2} \text{ day}^{-1}$ ; LAR ranged 0.64-0.96  $\text{cm}^2 \text{ g}^{-1}$  (Table 3).

**Table 3:** Growth Kinetics

Soil Type	Shoot RGR ( $\text{g g}^{-1} \text{ week}^{-1}$ )	Root RGR ( $\text{g g}^{-1} \text{ week}^{-1}$ )	NAR ( $\text{g m}^{-2} \text{ day}^{-1}$ )	LAR ( $\text{cm}^2 \text{ g}^{-1}$ )
Clay Soil	0.317	0.694	0.0056	0.88
Loamy Soil	0.232	0.621	0.0051	0.72
Sandy Soil	0.335	0.372	0.0059	0.82
Red Earth	0.330	0.625	0.0063	0.96
Garden Top Soil (Control)	0.231	0.710	0.0046	0.64

## Phytochemical Profiles

### Qualitative screening

Methanolic extracts were present for saponins, phenols, tannins, flavonoids, reducing sugars, steroids, alkaloids, cardiac glycosides, and triterpenoids, while anthraquinones were absent across soils. (Table 4).

**Table 4:** Qualitative Profile of Phytochemicals of *Solanum aethiopicum* L. grown in different soil types

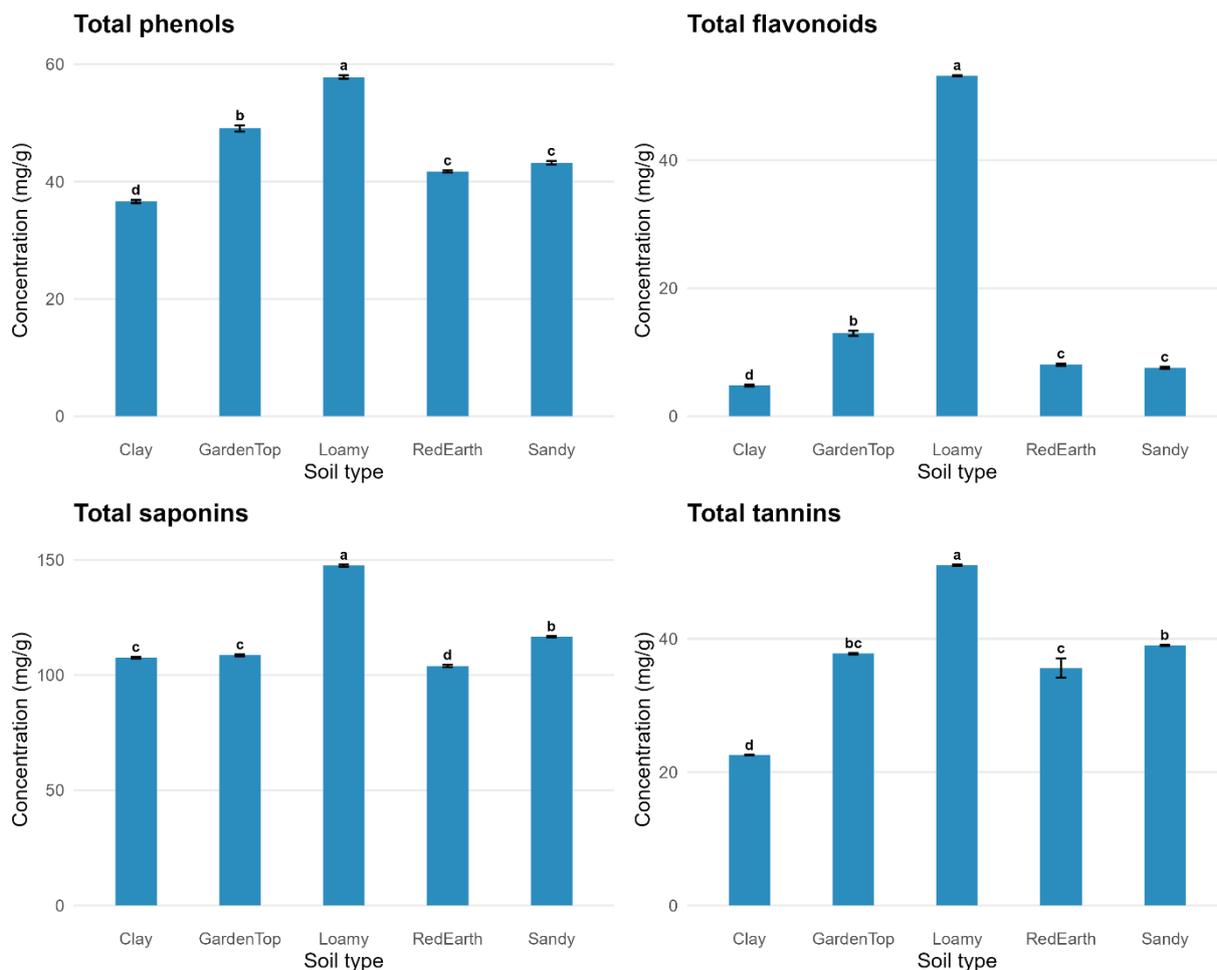
PHYTOCHEMICALS	STATUS					
	CLAY SOIL	LOAMY SOIL	RED SOIL	EARTH	SANDY SOIL	GARDEN SOIL(CONTROL) TOP
Saponins	+++	+++	++		+++	+
Phenols	+++	+++	+++		+++	+++
Tannins	+++	+++	++		+++	+++
Flavonoids	+++	+++	++		++	++
Reducing Sugars	+++	+++	++		+++	+
Steroids	++	+	++		+++	+++
Alkaloids	+	+	+		+	+++
Cardiac Glycosides	++	++	++		+++	+++
Triterpenoids	++	++	++		+++	++
Anthraquinone	-	-	-		-	-

**Key:** - = Not present  
 + = Slightly present  
 ++ = Moderately present  
 +++ = Heavily present

### Quantitative concentrations

Triplicate measurements were analyzed using one-way ANOVA, and significant differences among soil treatments were determined by Tukey's Honest Significant Difference (HSD) test at  $\alpha=0.05$ . Loamy soil consistently exhibited the highest concentrations across all four quantified phytochemical classes (phenols, flavonoids, saponins, and tannins).

Figure 11 present the mean $\pm$ standard deviation ( $\text{mg g}^{-1}$ ) for each compound, with Tukey grouping indicating statistical similarity. Corresponding ANOVA results were highly significant for all parameters: phenols ( $F=572.56$ ,  $p < 1 \times 10^{-11}$ ), flavonoids ( $F=8333.15$ ,  $p < 2 \times 10^{-17}$ ), saponins ( $F=1830.58$ ,  $p < 3 \times 10^{-14}$ ), and tannins ( $F=241.44$ ,  $p < 7 \times 10^{-10}$ ).



**Figure 11:** Effect of soil type on the quantitative phytochemical composition of *Solanum aethiopicum*, showing total phenols, flavonoids, saponins, and tannins across five soil treatments. Across all phytochemical classes, soil type exerted.

## DISCUSSION AND CONCLUSION

The present study provides clear evidence that soil type is a critical determinant of both growth performance and phytochemical accumulation in *Solanum aethiopicum*, a crop of major nutritional and medicinal importance in sub-Saharan Africa. *S. aethiopicum* has been widely documented as an indigenous African vegetable especially in Nigeria with substantial phytochemical and nutraceutical properties, including phenolics, flavonoids, and antioxidants that contribute to health benefits including anti-inflammatory and antidiabetic effects (Choi and Choi 2024).

Plants grown in loamy soil consistently exhibited superior vegetative performance, as reflected by greater plant height, leaf area, and shoot fresh weight at 12 weeks. Loamy soils, sand, silt, and clay, support optimal nutrient

and moisture retention, which aligns with recommendations that loamy to sandy-loam soil maximize vegetable production in Nigeria and West Africa (Dada et al. 2019). Similar responses have been reported in greenhouse and field studies where well-structured soils enhanced growth and nutrient uptake in crops like *Moringa oleifera*, with loamy sand outperforming clay and sand in early growth parameters (Ewetola 2019). Additionally, studies on *Senna obtusifolia* seedlings in Northern Nigeria found that loamy soil supported greater vegetative and root growth compared with clay and sandy soils under greenhouse conditions, echoing our findings of soil physicochemical differences influence on plant performance (Abubakar 2017).

Poor growth in garden topsoil and sandy soils in this study likely reflects lower moisture

retention and nutrient availability typical of these soils, which is consistent with studies showing that coarser soils in Nigerian farmlands have lower water-holding capacity and organic matter content, thereby limiting crop performance (Yusuf *et al.* 2024). Clay soil supported intermediate growth, which may be attributed to higher water retention but restricted aeration and root penetration, a balance shown in other tropical cropping systems where clay-rich soils require management for optimal yields (Abdulkadir, *et al.* 2025).

Differences in relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) among soil types reflect the importance of soil properties in plant physiological responses. Higher assimilation rates under stress often do not translate to greater biomass accumulation, a pattern observed across various vegetable crops on marginal soils where compensatory physiological responses are insufficient to overcome sustained resource limitations (Mahmoud *et al.*, 2000).

While nutrient profiling was not performed in this study, both qualitative and quantitative analyses revealed that soil type significantly influenced the phytochemical profile of *S. aethiopicum*. Loamy soils supported the highest concentrations of total phenols, flavonoids, saponins, and tannins. These secondary metabolites are known to be abundant in *S. aethiopicum*, where phenolics and flavonoids contribute to antioxidant activity and potential health benefits (Eze and Kanu 2014). Other studies, particularly on *Solanum nigrum*, show that phytochemical constituents and antioxidant properties vary with soil conditions, reinforcing that soil environment affects biochemical expression in indigenous vegetables (Ogundola *et al.* 2022). Lower phytochemical concentrations in sandy and clay treatments may reflect suboptimal nutrient availability or restricted root development affecting biosynthetic pathways. While some stress conditions can enhance specific metabolites, this study suggests optimal conditions favor higher overall accumulation, consistent with broader observations in African leaf vegetables that good fertility conditions enhance nutraceutical quality.

The findings from this study have important agronomic implications for sustainable cultivation of *S. aethiopicum* in Nigeria and

across Africa. Many Nigeria soils are sandy or acidic with low organic matter, which can constrain vegetable production without targeted soil management practices (Yusuf *et al.* 2024). Soil amendments such as organic matter incorporation, mulching, and liming have been shown to improve soil structure, fertility, and crop yield in Nigerian vegetable systems (Yusuf *et al.* 2024). By demonstrating that loamy or loamy-sandy soils with near-neutral pH optimize both growth and phytochemical content, this study supports soil-based recommendations to improve food and nutritional security among smallholder farmers. Indigenous vegetables like *S. aethiopicum* play a vital role in diet quality and traditional healthcare systems, making soil management crucial for maximizing their agronomic and nutraceutical potentials (Mungofa *et al.* 2022).

While the greenhouse-based design allowed controlled comparison of soil types, field validation across diverse Nigerian and African agroecological zones is needed. Future research should integrate detailed soil nutrient profiling, targeted metabolomics, and rhizosphere microbial assessments to understand soil-plant-microbe interactions influencing phytochemical synthesis more comprehensively.

#### **Conflict of interest**

The authors declare that they have no competing interests.

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