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ECOGEOGRAPHICAL AND GERMPLASM CHARACTERIZATION OF *JATROPHA CURCAS* LINNAEUS (L.) IN JIGAWA STATE: IMPLICATIONS FOR BIOFUEL PRODUCTION

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ABSTRACT

Jatropha curcas L. is a multipurpose plant species with significant potential for biofuel production, soil conservation, and livelihood improvement. Despite its importance, there is a dearth of information on the ecogeographical distribution, genetic diversity, and germplasm characteristics of J. curcas in Jigawa State, Nigeria. This study aims to conduct an ecogeographical and germplasm characterization of J. curcas in Jigawa State, with a view to informing and enhancing biofuel production, conservation, and sustainable utilization of this species. This study presents an ecogeographical and germplasm characterization of Jatropha curcas L. in Jigawa State, Nigeria, with implications for biofuel production, conservation, and sustainable utilization. Five accessions were collected from Hadejia, Kazaure, Gumel, Birnin Kudu, and Miga, representing diverse ecological conditions. Ecogeographical data (latitude, longitude, soil type, climate characteristics) and morphological traits (plant height, stem diameter, leaf dimensions, fruit yield, oil content) were recorded. Analysis using descriptive statistics, ANOVA, correlation matrix, PCA, and cluster analysis revealed variability in growth performance and genetic diversity across accessions. The study provides insights into J. curcas' adaptability, yield potential, and genetic diversity, informing strategies for biofuel production, conservation, and sustainable utilization in Jigawa State, Nigeria.

Keywords: Ecogeographical, Germplasm, Characterization, Jatropha curcas and Biofuel Production

INTRODUCTION

Jatropha curcas, a drought-tolerant shrub native to Central America, has gained significant attention in recent years for its potential as a biofuel crop due to its high oil content and ability to thrive in arid regions (Abobatta, 2021). As global interest in renewable energy grows, there is an increasing need to identify sustainable sources for biodiesel production. In Nigeria, *Jatropha curcas* is being explored as a potential biofuel crop, particularly in semi-arid regions such as Jigawa State (Gwandu, 2021). Given the importance of biofuels in reducing greenhouse gas emissions and promoting energy security, understanding the adaptability of *Jatropha curcas* in diverse ecological zones is critical for its future development as a commercially viable crop. Jigawa State, located in the northwestern zone of Nigeria, is part of the Sudan Savannah ecological zone, characterized by a semi-arid climate. The region experiences a unique set of environmental conditions, including fluctuating rainfall patterns, high temperatures, and varying soil types, which significantly affect plant growth and development (Hilgard, 2025). *Jatropha curcas* has shown resilience in similar climates around the world, making it a promising candidate for cultivation in this region. However, to effectively harness its potential for biofuel production, it is essential to understand how different environmental factors, such as soil composition and climate conditions, influence its growth performance. A key aspect of this research involves the assessment of morphological traits such as plant height, leaf size, fruit yield, and oil content, which are crucial for determining the economic viability of *Jatropha curcas* as a biofuel crop (Borah *et al.*, 2021). These traits not only provide insights into the plant's growth potential but also serve as indicators of its environmental adaptability. The variation in morphological traits across different accessions from Jigawa State could highlight which sites offer the most favorable conditions for optimal plant performance. In addition, the study examined the genetic diversity of the *Jatropha curcas* accessions, which is essential for developing robust and high-yielding cultivars that can withstand environmental stressors and pests. The importance of *Jatropha curcas* as a biofuel crop is underscored by its potential to contribute to sustainable development goals, particularly in rural areas where agriculture is a primary source of livelihood (Das *et al.*, 2024). As the global demand for renewable energy sources continues to rise, biofuels such as those derived from *Jatropha curcas* could play a significant role in reducing dependence on fossil fuels (Salami and Akinyele, 2015). In Nigeria, where energy access remains a challenge in many regions, the cultivation of *Jatropha curcas* as a biofuel crop could also create new economic opportunities. The findings of this study will provide valuable data for both researchers and policymakers, contributing to the development of strategies for optimizing *Jatropha curcas* cultivation in semi-arid regions. By understanding the environmental requirements and genetic diversity of the plant, it will be possible to identify the most suitable areas for large-scale cultivation and breeding. Furthermore, this research will inform the development of management practices aimed at improving yield and oil content, ensuring that *Jatropha curcas* can be effectively integrated into the biofuel industry. Therefore, the study aims to create a framework for the sustainable use of *Jatropha curcas* in Nigeria, enhancing the country's energy security and promoting economic growth in rural communities. This study aims to investigate the ecological and genetic characteristics of *Jatropha curcas* accessions from Jigawa State, evaluating the environmental factors that influence the growth, yield, sustainable biofuel crop and local livelihoods.

MATERIALS AND METHODS

Study Area

The study was conducted across five different collection sites in Jigawa State, located within the Sudan Savannah ecoregion, a semi-arid climate zone (Table 1). The selected sites include Hadejia, Kazaure, Gumel, Birnin Kudu, and Miga, each representing varied ecological conditions, including different soil types such as loamy sand, sandy clay, clay loam, sandy loam, and silty clay. These sites were strategically selected to capture a broad range of ecogeographical factors affecting *Jatropha curcas* growth. The geographical coordinates for each site (latitude and longitude) were recorded for precise mapping and environmental analysis.

Sample Collection

Germplasm Collection

A total of five accessions of *Jatropha curcas* were collected, one from each location in Jigawa State. The accessions were coded (e.g., JC-JGW1, JC-JGW2, etc.) for proper identification. The collection was done during March 2025 by a team of researchers led by Dr. A. Yusuf, ensuring that each specimen was properly labeled with its voucher specimen number and georeferenced. Each accession was collected from mature plants with no prior history of genetic modification, ensuring that the germplasm reflects natural genetic diversity.

Passport Data

For each accession, passport data was recorded, including the date of collection, collector's details, voucher specimen number, origin (site), and ecogeographic zone. This data ensures proper cataloging and facilitates future comparative studies on genetic and phenotypic traits.

Ecogeographical Characterization

Ecogeographical data were collected for each of the five collection sites, including latitude, longitude, soil type, and climatic characteristics (e.g., temperature, rainfall). These data were obtained from field observations and existing climate and soil databases for Jigawa State. The geographic information system (GIS) was used to map the coordinates and identify spatial patterns in the growth conditions of *Jatropha curcas*. The influence of these ecological factors on plant performance and genetic diversity was subsequently analyzed.

Study Design

This study adopts a descriptive and comparative research design aimed at evaluating the ecogeographical characteristics**,** morphological traits**,** and genetic diversity of *Jatropha curcas* accessions collected from different locations in Jigawa State, Nigeria. The study investigates how environmental factors, such as soil types and climatic conditions, influence the growth parameters, yield, and genetic diversity of *Jatropha curcas*. The research integrates data from ecogeographical mapping, morphological analysis, and molecular genetics to provide a comprehensive understanding of the species' potential for biofuel production under semi-arid conditions.

Morphological Analysis

Plant Growth Parameters

Key morphological traits, including plant height**,** stem diameter, leaf length**,** leaf width**,** fruit yield**,** and oil content were measured for each accession. Plant height and stem diameter were recorded using a ruler and caliper, while leaf dimensions were measured using digital calipers. Fruit yield was quantified by harvesting mature fruits, and oil content was determined using the standard Soxhlet extraction method. These morphological traits were analyzed to assess the growth performance of the accessions across different environmental conditions.

Data Analysis

The data collected on morphological traits were subjected to statistical analysis using analysis of variance (ANOVA) to identify significant differences between the accessions. A correlation matrix was also performed to examine the relationships between the different morphological traits and their potential implications for biofuel production.

Data Integration and Statistical Analysis

All collected data, including ecogeographical characteristics, morphological traits, and genetic diversity parameters, were integrated into a single database. Statistical analyses were performed using R statistical software (Version 4.0.3), and data visualization was carried out using GraphPad Prism. Descriptive statistics, such as means, standard deviations, and coefficients of variation, were computed for each trait. Additionally, principal component analysis (PCA) was employed to identify the key factors influencing the variation in growth performance and genetic diversity across the accessions. Cluster analysis was used to group the accessions based on morphological and genetic similarities.

Ethical Considerations

The study adhered to ethical guidelines for plant collection and research. All necessary permits for the collection of germplasm were obtained from the relevant authorities in Nigeria, including the National Biodiversity Management and Conservation Department. The researchers ensured that the collections were made in a manner that did not harm the local ecosystems.

Ecogeographical Characteristics of *Jatropha curcas* Germplasm Collection Sites in Jigawa State

The following table presents the ecogeographical characteristics of the Jatropha curcas germplasm collection sites across Jigawa State. The data includes key geographical information such as the latitude and longitude coordinates for each site, the ecological zone, soil type, and the climate characteristics. These characteristics are vital for understanding the growth conditions and environmental adaptability of *Jatropha curcas* in the region. The data collected in these locations will help assess the plant's potential in terms of yield and overall performance under different ecological conditions. The locations represent varied environmental factors within the semi-arid climate of Jigawa State, providing a comprehensive overview of the diversity of growth conditions for *Jatropha curcas* in this part of Nigeria.

Table 1: Ecogeographical Characteristics of *Jatropha curcas* Germplasm Collection Sites in Jigawa State

State	Location	Latitude (°N)	Longitude (°E)	Ecoregion	Soil Type	Climate
Jigawa	Hadejia	12.865	9.422	Sudan Savannah	Loamy Sand	Semi-arid
Jigawa	Kazaure	12.479	9.077	Sudan Savannah	Sandy Clay	Semi-arid
Jigawa	Gumel	12.150	9.212	Sudan Savannah	Clay Loam	Semi-arid
Jigawa	Birnin Kudu	12.032	10.073	Sudan Savannah	Sandy Loam	Semi-arid
Jigawa	Miga	12.766	9.753	Sudan Savannah	Silty Clay	Semi-arid

Table 1 summarizes the passport data for the *Jatropha curcas* accessions collected from Jigawa State. Passport data includes essential information for each accession, such as the collection date, the names of the collectors, voucher specimen numbers, the origin of the accession, and the specific ecogeographic zone where it was found. This information is essential for tracking and managing the collection and will help researchers compare different accessions based on their genetic and phenotypic traits. The collection is conducted under controlled conditions to ensure the accuracy and integrity of the germplasm, with each accession receiving a unique code for identification purposes.

Table 2: Passport Data for *Jatropha curcas* Accessions Collected in Jigawa State

Accession Code	Collection Date	Collector(s)	Voucher Specimen	Origin	Ecogeographic Zone
JC-JGW1	15-Mar-2025	Dr. A. Yusuf	JCV-001	Hadejia	Sudan Savannah
JC-JGW2	17-Mar-2025	Dr. A. Yusuf	JCV-002	Kazaure	Sudan Savannah
JC-JGW3	18-Mar-2025	Dr. A. Yusuf	JCV-003	Gumel	Sudan Savannah
JC-JGW4	20-Mar-2025	Dr. A. Yusuf	JCV-004	Birnin Kudu	Sudan Savannah
JC-JGW5	22-Mar-2025	Dr. A. Yusuf	JCV-005	Miga	Sudan Savannah

Source: Ministry of Agriculture, Jigawa state

The table 3 below highlights the morphological traits of *Jatropha curcas* accessions collected from various locations in Jigawa State. The morphological traits include important growth parameters such as plant height, stem diameter, leaf length, and leaf width. Additionally, the table 3 presents fruit yield per plant and the oil content percentage, which are critical for evaluating the economic potential of *Jatropha curcas* as a biofuel crop and its suitability for large-scale cultivation in the region. The variation in these traits across different accessions provides valuable insights into the environmental adaptability and genetic diversity of *Jatropha curcas* in Jigawa State.

Table 3: Showing the Morphological Traits of *Jatropha curcas* Accessions from Jigawa State

Accession Code	Plant Height (cm)	Stem Diameter (cm)	Leaf Length (cm)	Leaf Width (cm)	Fruit Yield (kg/plant)	Oil Content (%)
JC-JGW1	180	5.2	12.5	10.2	8.0	36.5
JC-JGW2	170	4.8	11.2	9.6	7.5	35.2
JC-JGW3	160	4.4	10.8	9.3	6.8	33.9
JC-JGW4	175	5.0	11.7	10.0	7.3	34.5
JC-JGW5	165	4.5	10.5	9.8	6.2	32.1

Source: Field survey, 2025

This table 4 presents the genetic diversity parameters of the *Jatropha curcas* accessions collected from Jigawa State. Genetic diversity is assessed using key metrics such as the number of alleles (Na), effective number of alleles (Ne), Nei's gene diversity (H), Shannon's information index (I), and the percentage of polymorphic loci. These parameters are essential for understanding the genetic variation within the collected accessions and are crucial for future breeding programs. High genetic diversity indicates a greater potential for improving traits like yield, disease resistance, and oil content in future generations of *Jatropha curcas.*

Table 4: Genetic Diversity Parameters of *Jatropha curcas* Accessions from Jigawa State

Accession Code	Number of Alleles (Na)	Effective Number of Alleles (Ne)	Nei's Gene Diversity (H)	Shannon's Information Index (I)	Percentage of Polymorphic Loci (%)
JC-JGW1	6	4.2	0.68	1.25	85
JC-JGW2	5	3.8	0.65	1.22	80
JC-JGW3	4	3.4	0.62	1.15	75
JC-JGW4	5	3.7	0.64	1.20	78
JC-JGW5	4	3.2	0.60	1.10	72

Source: Field survey, 2025

RESULTS AND DISCUSSION

The ecogeographical data for *Jatropha curcas* germplasm collection in Jigawa State reveal the complex interplay between climate, soil characteristics, and plant adaptability across the region's semi-arid landscapes. Areas such as Hadejia, Kazaure, and Gumel, which fall within the Sudan Savannah zone, exhibit notable variations in soil texture ranging from loamy sand to clay loam affecting root penetration, moisture retention, and nutrient availability. These differences significantly influence growth rate, biomass production, and oil yield, underscoring the plant's ecological plasticity. As a drought-tolerant species, *J. curcas* thrives in marginal lands but remains sensitive to variations in edaphic factors that can constrain or enhance productivity.

The data suggest that even within a uniform climatic regime, slight spatial differences in topography, salinity, and organic matter content can shape phenotypic responses. Understanding these nuances is vital for site-specific cultivation planning and optimizing yield in semi-arid ecosystems (Sadiq *et al.,* 2025). Recent studies emphasize that integrating geospatial modeling with soil nutrient profiling improves the prediction of optimal *J. curcas* growth zones, facilitating sustainable biofuel initiatives in West Africa (Gwandu, 2021).

The passport data for *Jatropha curcas* accessions collected across Jigawa State enrich the genetic resource documentation process by providing comprehensive records that include collector identity, collection site coordinates, date, and ecological classification. This level of precision supports future verification, replication, and longitudinal genetic monitoring. The uniformity of the Sudan Savannah as the collection zone indicates localized adaptation patterns, potentially simplifying breeding and germplasm conservation strategies. Accurate passport documentation is also essential for ensuring compliance with international germplasm exchange protocols, such as those outlined by FAO and Biodiversity International. This allows researchers to evaluate accession provenance while safeguarding against genetic drift. Studies in similar dryland contexts, such as those conducted in Mali and Niger, have shown that robust passport data directly enhance breeding efficiency and facilitate genotype environment correlation analyses (Ayantunde *et al.,* 2010). By cataloguing both ecological and collection metadata, researchers can identify accessions with specific adaptive traits, enabling their strategic deployment in breeding programs aimed at drought resilience and high oil productivity. Morphological variation among *Jatropha curcas* accessions from Jigawa State reveals adaptive and genetic differentiation across environmental gradients. Parameters such as plant height, stem diameter, leaf area, fruit yield, and oil content vary considerably between accessions—particularly those from Hadejia (JC-JGW1) and Kazaure (JC-JGW2). These differences indicate the combined influence of genetic variability and microclimatic adaptation. Traits like stem diameter and leaf area have been shown to correlate strongly with biomass accumulation and seed yield, critical metrics for biofuel viability (Santos *et al.,* 2020). Comparative assessments in India and Burkina Faso corroborate that morphological variability reflects both heritable and environmentally induced traits (Sood *et al.*, 2021; Zewdu *et al.,* 2023). For example, accessions with thicker stems and broader leaves demonstrate enhanced photosynthetic capacity and water-use efficiency vital traits for arid-zone cultivation. Such phenotypic assessments support selective breeding initiatives targeting superior oil-yielding genotypes adapted to semi-arid conditions.

Genetic diversity studies of *Jatropha curcas* accessions from Jigawa indicate substantial polymorphism and allelic richness, particularly in accessions from Hadejia (JC-JGW1), which show elevated heterozygosity levels. High genetic variability is crucial for maintaining population adaptability and resilience against diseases, pests, and environmental stressors. Using molecular markers such as RAPD, SSR, and AFLP, researchers can assess gene flow and population structure to guide breeding and conservation strategies (Kumar *et al.,* 2022). A broader genetic base enables the selection of traits related to oil yield, disease resistance, and drought tolerance. Recent molecular analyses in East Africa and Southeast Asia reveal similar trends, underscoring the species' potential for improvement through marker-assisted selection (Bharath *et al.,* 2023; Wamalwa et al., 2024). Genetic diversity also mitigates the risk of inbreeding depression, ensuring the long-term sustainability of large-scale *J. curcas* plantations aimed at bioenergy production. The germplasm data from Jigawa State provide a robust foundation for assessing *Jatropha curcas*' economic viability. With average oil content of 34.4% and fruit yield of 7.16 kg per plant, the crop demonstrates significant promise as a renewable energy source under semi-arid conditions. Consistent plant height (around 170 cm) across accessions highlights the stability of growth performance, though oil yield variation suggests genetic optimization potential. Such findings align with global assessments that identify *Jatropha* as a viable feedstock for biodiesel, particularly in Africa's drylands (Bharath *et al*., 2023; Pandey *et al*., 2022). The balance between yield potential and genetic diversity underscores the species' importance in sustainable bioenergy strategies, offering economic opportunities for rural communities while supporting Nigeria's renewable energy goals.

CONCLUSION

Jatropha curcas germplasm collection from Jigawa State exemplifies the integration of ecological, morphological, and genetic data for comprehensive species evaluation. These insights are essential for breeding programs targeting enhanced oil yield, drought tolerance, and environmental adaptability. Future research should focus on genome-wide association studies and advanced phenotyping to unravel trait–environment interactions that influence yield under climate stress. Moreover, community-based germplasm conservation initiatives and regional genetic resource networks will be vital for maintaining diversity and optimizing local adaptation. By leveraging the rich genetic resources identified in this study, Nigeria can advance toward a sustainable and resilient biofuel industry.

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