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*Research Article*

# Agrophysiological Characterization of Okra Ecotypes Under the Conditions of the Cool Dry Season in the Sudanian Zone of Burkina Faso

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We conducted an experiment at INERA Farako-Bâ (Bobo-Dioulasso) to identify okra (*Abelmoschus esculentus* [L.] Moench) ecotypes adapted to Burkina Faso's cool, dry season. The experiment used 38 ecotypes collected in Togo and Burkina Faso. Analysis of variance revealed highly significant differences ($p = 0.0001$) among ecotypes for most agronomic and physiological traits, particularly the wet and dry weight per plant, and leaf area index (LAI). In contrast, no significant differences were observed for leaf chlorophyll content (LCC%) and leaf water content (LWC%), suggesting a homogenization of responses for these traits under low-temperature conditions. Hierarchical ascending classification grouped the ecotypes into three classes, clearly highlighting distinct growth and yield strategies. Within this framework, ecotypes TGO-031, TGO-029, TGO-014, and TGO-034 clearly demonstrated superior agronomic performance. The study also revealed key correlations, notably a strong negative relationship between thousand-seed weight and specific leaf area, pointing to a specific adaptive strategy. These high-performing ecotypes are a vital source of genetic material for breeding programs that target enhancing okra's resilience to low temperatures.

**Keywords:** *Abelmoschus esculentus*; agrophysiological performance; Burkina Faso; cool; dry season; hierarchical classification

## 1. Introduction

Okra (*Abelmoschus esculentus* [L.] Moench) is a key horticultural crop in Burkina Faso, prized for its nutritional value and long-standing traditional applications. It is a key component in everyday cooking, especially in sauces served with tô, the country's iconic national dish. In urban areas, okra marketing is a major source of income for market gardeners, especially around Ouagadougou [1]. In this region, several varieties are cultivated, including local varieties prized for their mucilage, low seed content and flavor, as well as the hybrid variety "Indiana," selected for its earliness and high yield [2]. Despite this diversity, local varieties are characterized by longer growth cycles and often insufficient yields, which limit their adoption and the optimization of production [3]. Okra cultivation in Burkina Faso faces several major challenges. The cool, dry season (November–February) is marked by lower temperatures and low relative humidity. This slows growth, disrupts flowering, and reduces yields [4]. Farmers also have limited access to improved seeds, and the narrow genetic diversity available hinders varietal improvement efforts [5]. Exploring local ecotypes is undoubtedly a promising avenue. These ecotypes are full of genes that make them tolerant to abiotic stresses, such as drought or low temperatures. This makes them a valuable resource for breeding resilient varieties [6]. The

use of phenotypic evaluation and molecular tools is key to identifying high-performing genotypes and strengthening breeding programs. This will stabilize production and improve food security in the Sahelian region. The present study definitively identifies okra ecotypes with superior agro-physiological performance for cultivation during the cool, dry season in Burkina Faso. The identification of these ecotypes will provide a strong genetic foundation for future breeding programs, contributing to the development of more adapted, resilient, and productive varieties.

## 2. Materials and Methods

*2.1. Study Area.* The study was conducted at the Farako-Bâ research station (11°11′ N, 4°17′ W), located in Bobo-Dioulasso, within the Sudanian zone of southwestern Burkina Faso (Figure 1). The soil at the site is clay–loam and well-drained. The trial took place during the cool, dry season. This was from November 2023 to February 2024. During the experimental period, minimum temperatures gradually decreased from 19.7°C in November to 12.5°C in January, before rising again to 16.8°C in February. Maximum temperatures remained stable, ranging between 34.7°C and 38.0°C. The relative humidity dropped sharply from 63.8% in November to 35.8% in February. The supplementary materials clearly show the variation in temperature and humidity.

*2.2. Plant Material.* Thirty-eight okra ecotypes, including 27 from Togo and 11 from Burkina Faso, were evaluated (Table 1).

*2.3. Experimental Design and Crop Management.* The experiment was conducted using a completely randomized Fisher block design, with four replications. Each ecotype was grown on an elementary plot of $2\,m^2$, consisting of five plants spaced at $0.5\,m \times 0.5\,m$. Sowing was carried out on November 15, 2023. Irrigation was provided daily at a rate of 10 L per bed. A fertilizer application of NPK (15–15–15) at 100 kg/ha was applied three times during the trial. Weeding was performed manually as needed, and phytosanitary treatments (fungicide COGA 80WP and insecticide PACHA) were applied twice during the experiment. Fruit harvest began 45 days after sowing (DAS) and was carried out every 3 days.

*2.4. Data Collection.* Physiological, climatic, and agronomic data were collected from central plants in each elementary plot.

*2.4.1. Physiological and Climatic Traits.* Leaf chlorophyll content (LCC) (SPAD-502 Plus), leaf water content (LWC) [7], leaf area index (LAI), and specific leaf area (SLA) [8]. Climatic conditions (temperature and relative humidity) were recorded using a thermohygrometer (Elitech GSP-6).

*2.4.2. Agronomic Traits.* Plant height at flowering and at maturity (PHF and HTP), stem diameter at flowering and at maturity (DTI and DTF), dates of occurrence of phenological stages (number of days to flower bud initiation [NDB], number of days to flowering [NDF], and NDF), number and weight of fruits (number of fruits harvested per plant [NFP], fruit's wet weight per plant [FW], and dry weight per plant [DW]), fruit length (FL) and diameter (DTI and DTF), number of seeds per fruit (NS/F), and thousand-seed weight (WTS).

*2.5. Statistical Analysis.* Data were subjected to analysis of variance (ANOVA) using the Kruskal–Wallis test at the 5% significance level. A hierarchical ascending classification (HAC) was performed, along with Pearson correlations to evaluate relationships among measured traits. All analyses were conducted using R software (Version 2024.12.1).

## 3. Results

*3.1. Performance of the Physiological Parameters of Okra Ecotypes.* Descriptive statistics and the results of the ANOVA for the physiological parameters measured on the okra ecotypes are presented in Table 2. The coefficients of variation (CVs) ranged from 5.1% for LWC% to 73.1% for SLA, indicating greater variability for SLA and LAI (CV = 44.2%). In contrast, LCC% (CV = 13.6%) and LWC% showed lower variability among ecotypes. ANOVA revealed highly significant differences only for LAI ($p = 0.0001$), while no significant differences were observed for LCC, LWC, and SLA.

*3.2. Agronomic Performances of the Studied Okra Ecotypes.* The results of variance analysis and descriptive statistics for the agronomic parameters measured are presented in Table 3. Variance analysis performed with 38 degrees of freedom (DOFs) and a mean square of 837.1 revealed highly significant differences ($p = 0.0001$) among ecotypes for several parameters. CVs for these parameters showed a wide range, from 48% (for the NDB) to 96% (for fruit's DW). Parameters displaying the highest variability among ecotypes (CV > 50%) were fruit's DW (CV = 96%), FW (CV = 95.8%), NFP (CV = 57.5%), total biomass (TB) (CV = 55.5%), and NS/F (CV = 55.3%). Conversely, parameters showing low variability (CV < 15%) were the NDB (CV = 4.8%), NDF (CV = 9.4%), and number of days to fruit set (NDFr) (CV = 10.1%). For these cycle-related parameters (NDB, NDF, and NDFr), NDB ranged from 40 to 53 DAS, with a mean of 45.23 ± 2.17 DAS. ANOVA revealed highly significant differences among ecotypes ($p = 0.0001$). NDF varied between 47 and 80 DAS, with a mean of 57.17 ± 5.36 DAS. NDFr ranged from 52 to 84 DAS, with a mean of 59.9 ± 6.08 DAS.

*3.3. Relationships Among Traits of the Studied Okra Ecotypes*

*3.3.1. Relationships Among Agronomic Parameters.* The correlation matrix (Figure 2) revealed significant

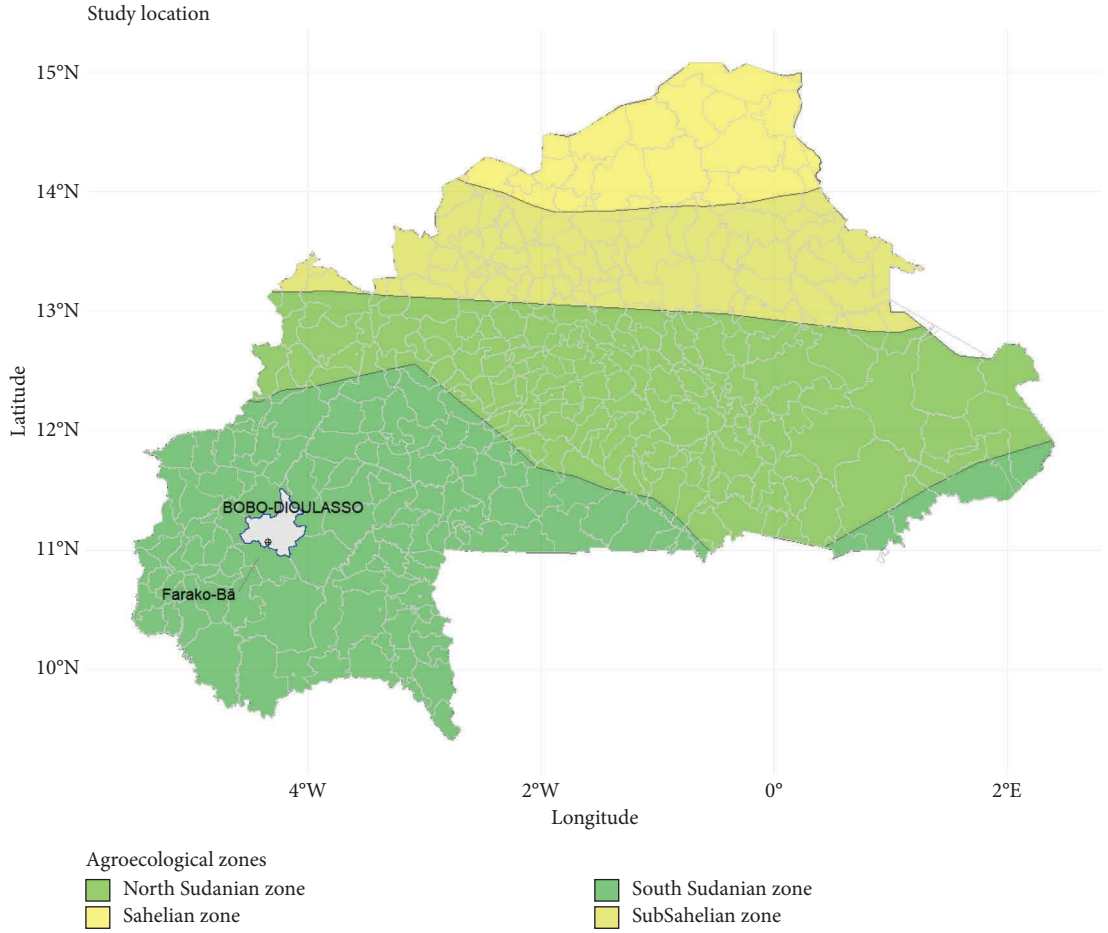



Figure 1: Location of the Farako-Bâ research station in the municipality of Bobo-Dioulasso, Burkina Faso (INERA/Farako-Bâ).

relationships among agronomic parameters. A very strong association was observed between the NDF and the NDFr ($r = 0.96$). In addition, a strong positive correlation was found among yield-related parameters, with FW and fruit's DW being strongly correlated with TB ($r = 0.72$). The NS/F was also positively correlated with TB ($r = 0.55$).

*3.3.2. Relationships Between Physiological and Agronomic Parameters.* Regarding the relationships between physiological and agronomic parameters, important associations were noted (Figure 3). A strong negative correlation was observed between WTS and SLA ($r = -0.77$). Furthermore, a negative correlation was identified between FL and the NDF ($r = -0.49$), as well as the NDFr($r = -0.48$).

*3.4. Performance of Okra Ecotypes Based on HAC.* HAC grouped the 39 ecotypes into three distinct clusters, reflecting varied growth and production strategies (Figure 4 and Table 4).

Group 1, consisting of 22 ecotypes, included early-developing ecotypes (NDB, NDF, and NDFr). They were characterized by substantial vegetative growth (high plant height and stem diameter) and moderate yields, with fruits of average size and seed weight. Physiologically, they exhibited high LAI and SLA. Group 2 comprised 14 ecotypes, predominantly originating from the Sahelian zone. Their development cycle was intermediate. These ecotypes displayed high production potential, with a large number of fruits, considerable fruit dimensions, and high leaf chlorophyll and water content. Group 3 included three ecotypes, distinguished by a late development cycle and overall low performance. These ecotypes exhibited limited vegetative growth and very low, or even null, yield, with small fruit size and low seed weight. Physiologically, they showed low chlorophyll and LWC.

## 4. Discussion

The analysis of physiological trait variability highlighted specific adaptation features of okra ecotypes to the conditions of the cool, dry season. While numerous studies have reported significant differences in biomass or chlorophyll content among genotypes, such as those by [9], our results reveal a distinct pattern in the context of this study. Under the influence of the cool, dry season, only LAI showed significant differences among groups identified by HAC ($p < 0.0001$). Other physiological traits, including LCC%, LWC%, and SLA, remained nonsignificantly different among groups ($p > 0.05$). This suggests a homogenization of trait expression, likely due to dominant environmental

Table 1: Okra ecotypes from Burkina Faso and Togo.

| Order number | Ecotypes | Countries | Villages | Climate zones |
|---|---|---|---|---|
| 1 | BF-11G1-1 | Burkina Faso | Bilanga | Sudan–Sahel |
| 2 | BF-11G1-2 | Burkina Faso | Bilanga | Sudan–Sahel |
| 3 | BF-11G1-6 | Burkina Faso | Bogande | Sudan–Sahel |
| 4 | BF-12G1-2 | Burkina Faso | Dendé | Sudanese |
| 5 | BF-13G1-2 | Burkina Faso | Lophing | Sudanese |
| 6 | BF-1G1 | Burkina Faso | Oulo | Sudan–Sahel |
| 7 | BF-1G1-2 | Burkina Faso | Oulo | Sudan–Sahel |
| 8 | BF-1G1-3 | Burkina Faso | Oulo | Sudan–Sahel |
| 9 | BF-1G1-6 | Burkina Faso | Oulo | Sudan–Sahel |
| 10 | BF-24G1-1 | Burkina Faso | Souri | Sudan–Sahel |
| 11 | UAE22 | Burkina Faso | UJKZ | Sudan–Sahel |
| 12 | TGO-002 | Togo | Yaloumbe | Sudanese–Guinean |
| 13 | TGO-006 | Togo | Kpotome | Guinean |
| 14 | TGO-007 | Togo | Kpime Tomegbe | Guinean |
| 15 | TGO-009 | Togo | Boade | Sahel |
| 16 | TGO-013 | Togo | Bagre | Sahel |
| 17 | TGO-014 | Togo | Bagre | Sahel |
| 18 | TGO-015 | Togo | Bagre | Sahel |
| 19 | TGO-016 | Togo | Bagre | Sahel |
| 20 | TGO-020 | Togo | Kolo | Sahel |
| 21 | TGO-021 | Togo | Kolo | Sahel |
| 22 | TGO-022 | Togo | Natchamba | Sahel |
| 23 | TGO-024 | Togo | Kpankpandja | Sahel |
| 24 | TGO-025 | Togo | Kpankpandja | Sahel |
| 25 | TGO-026 | Togo | Tambigou | Sahel |
| 26 | TGO-027 | Togo | Tambigou | Sahel |
| 27 | TGO-029 | Togo | Tambiegou | Sahel |
| 28 | TGO-030 | Togo | Mono Nassiegou | Sahel |
| 29 | TGO-031 | Togo | Mono Nassiegou | Sahel |
| 30 | TGO-032 | Togo | Mono Nassiegou | Sahel |
| 31 | TGO-033 | Togo | Boade | Sahel |
| 32 | TGO-034 | Togo | Boade | Sahel |
| 33 | TGO-037 | Togo | Sagbiebou | Sahel |
| 34 | TGO-038 | Togo | Sagbiebou | Sahel |
| 35 | TGO-040 | Togo | Sagbiebou | Sahel |
| 36 | TGO-041 | Togo | Namon | Sahel |
| 37 | TGO-042 | Togo | Namon | Sahel |
| 38 | TGO-046 | Togo | Doufoulli | Sahel |
| 39 | TGO-047 | Togo | Gbadjahé | Sudanese–Guinean |

Table 2: Analysis of variance of the physiological parameters of okra ecotypes.

| Variables | Min | Max | Avg | CV% | Pr > F |
|---|---|---|---|---|---|
| LCC% | 41.40 | 91.800 | 55.548 ± 7.5 | 13.6 | 0.735 |
| LWC% | 63.75 | 91.67 | 81.19 ± 4.19 | 5.1 | 0.323 |
| SLA | 0.51 | 17.84 | 3.39 ± 2.49 | 73.1 | 0.837 |
| LAI | 2.085 | 25.22 | 8.210 ± 8.89 | 44.2 | 0.0001 |

Abbreviations: Avg, average; LAI, leaf area index; LCC, leaf chlorophyll content; LWC%, leaf water content; Max, maximum; Min, minimum; SLA, specific leaf area.

factors of the dry season, particularly low temperatures and photoperiod, as noted by the authors in [10, 11] in studies on horticultural species under dry conditions. Group 1 was characterized by a high LAI (8.95), indicating superior capacity to intercept light and, consequently, support photosynthesis, which aligns with observations by the authors in [12, 13]. In contrast, Group 3 (LAI = 4.86) exhibited a low LAI, reflecting a typical adaptation strategy to constraining environments, characterized by rapid but limited growth [14, 15]. Therefore, LAI emerges as a major discriminating trait, capable of reflecting different ecotype responses to environmental constraints.

Alongside these physiological observations, ANOVA revealed highly significant differences ($p < 0.0001$) among ecotypes for cycle traits (NDB, NDF, and NDFr) and yield traits (FL, FD, NS/F, and WTS), corroborating the

Table 3: Descriptive and variance analysis of measured agronomic parameters.

| Variables | Min | Max | Avg | CV | Pr > F |
|---|---|---|---|---|---|
| NDB | 40 | 53 | 45.23 ± 2.17 | 4.8 | 0.0001 |
| NDF | 47 | 80 | 57.17 ± 5.36 | 9.4 | 0.0001 |
| NDFr | 52 | 84 | 59.9 ± 6.08 | 10.1 | 0.0001 |
| FW | 0.00 | 127.000 | 19.816 ± 19.05 | 95.8 | 0.0002 |
| DW | 0.00 | 16.833 | 2.815 ± 2.71 | 96 | 0.0001 |
| TB | 0.00 | 165.000 | 54.164 ± 30.14 | 55.5 | 0.593 |
| PHF (cm) | 9.26 | 117.5 | 22.92 ± 11.72 | 51 | 0.422 |
| HTP (cm) | 7.43 | 52.33 | 29.25 ± 8.48 | 28.9 | 0.025 |
| DTI (mm) | 2.82 | 24 | 7.96 ± 2.32 | 29 | 0.328 |
| DTF (mm) | 4,33 | 16,33 | 10.41 ± 2.02 | 19.3 | 0.025 |
| NFP | 0 | 12 | 4.05 ± 2.30 | 57.5 | 0.316 |
| FD (mm) | 0 | 28,33 | 15.07 ± 4.38 | 29 | 0.0001 |
| FL (cm) | 0 | 13,19 | 6.41 ± 2.37 | 37 | 0.0001 |
| NS/F | 0 | 81 | 35.82 ± 20.14 | 55.3 | 0.0001 |
| WTS (g) | 0 | 41,31 | 25.61 ± 12.53 | 47.9 | 0.0001 |

Abbreviations: Avg, average; CV, coefficient of variation; DTF, final stem diameter; DTI, initial stem diameter; DW, dry weight; FD, fruit diameter; FL, fruit length; FW, fresh weight; HTP, total plant height.; Max, maximum; Min, minimum; NDB, number of days to budding; NDF, number of days to flowering; NDFr, number of days to fruiting; NFP, total number of fruits per plant; NS/F, number of seeds per fruit; PHF, plant height at flowering; SD, standard deviation; TB, total biomass; WTS, thousand-seed weight.

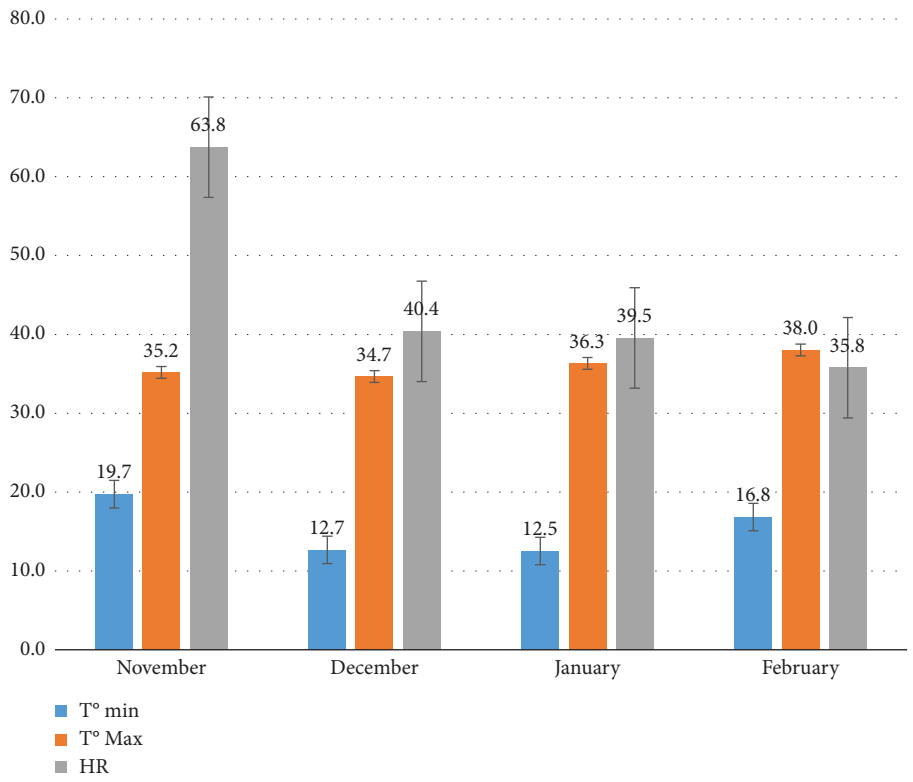



Figure 2: Air temperature and humidity recorded during the study Legend: Min T: minimum temperature; Max T: maximum temperature; HR: relative humidity of the air.

intraspecific diversity of okra [10, 16]. The three groups resulting from classification correspond to distinct developmental strategies. Group 1 comprised ecotypes with a very early cycle, a stress-avoidance strategy often observed in constraining environments [17]. Group 2, with a short cycle, demonstrated high yield potential under irrigation, an ideal profile for off-season crops. Group 3 included late-cycle ecotypes with low performance, reflecting a typical survival strategy in marginal environments [18].

Furthermore, correlation matrix analysis highlighted key relationships explaining these performances. The strong positive correlation between days to flowering and fruit set confirms the consistency of the phenological cycle. The negative correlation between FL and NDF and

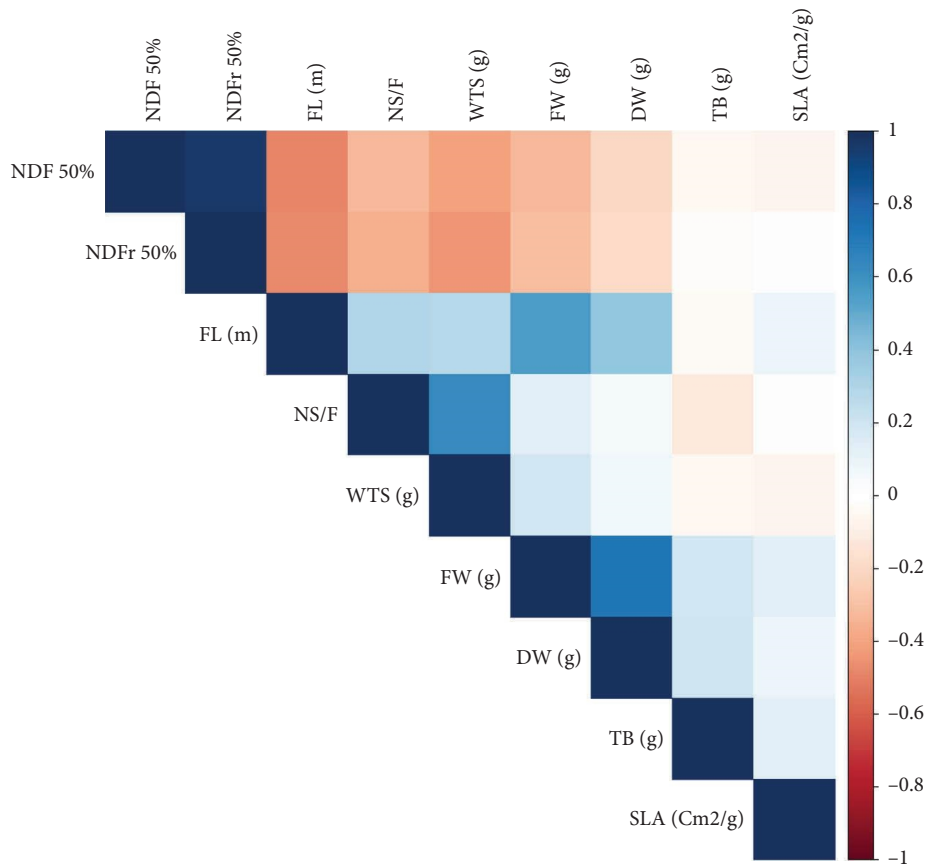



Figure 3: Correlation matrix between agronomic and physiological parameters. **Legend 1**: The blue color indicates a positive correlation, while the red indicates a negative correlation. The intensity of the color is proportional to the strength of the correlation (the darker the color, the stronger the correlation). The statistical significance of the correlations is described in the results section. **Legend 2:** Number of days to budding (NDB), number of days to flowering (NDF), number of days to fruiting (NDFr), fresh weight (FW), dry weight (DW), total biomass (TB), plant height at flowering (PHF), total plant height (HTP), initial stem diameter (DTI), final stem diameter (DTF), total number of fruits per plant (NFP), fruit diameter (FD), fruit length (FL), number of seeds per fruit (NS/F) thousand-seed weight (WTS), leaf chlorophyll content (LCC), leaf water content (LWC%) specific leaf area (SLA), and leaf index (LAI).

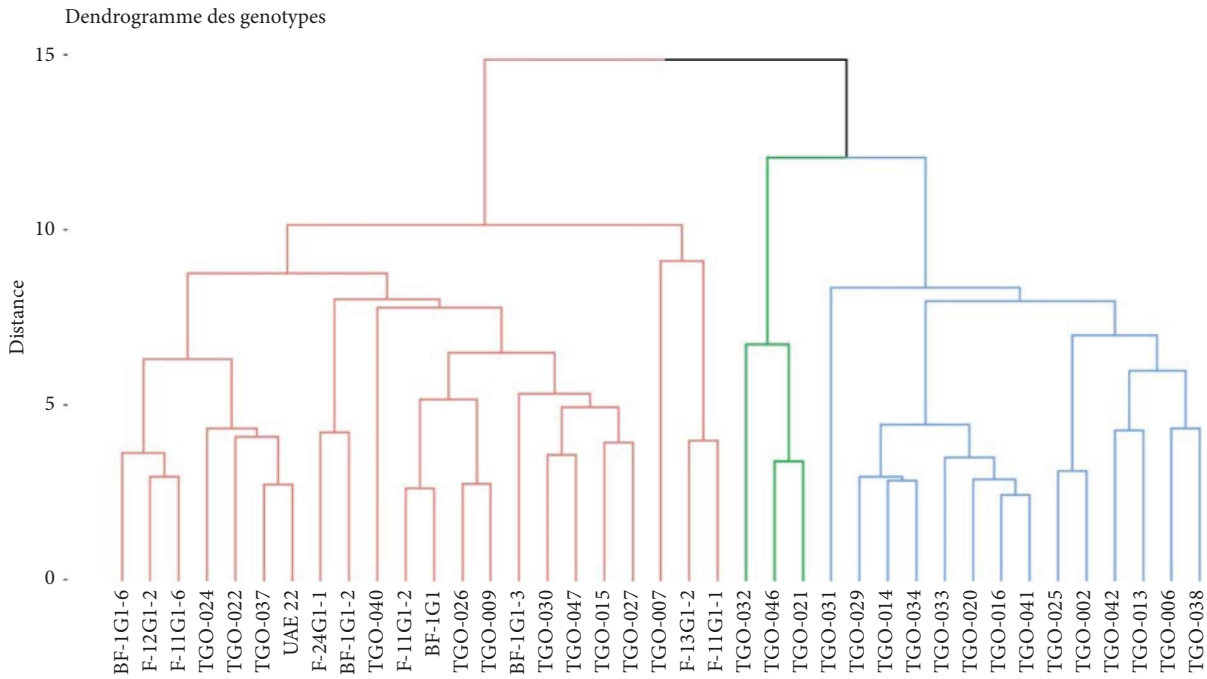



Figure 4: Different classes of variables by hierarchical ascending classification analysis.

Table 4: Characteristics of the groups resulting from hierarchical ascending classification (HAC).

| Parameters | Class 1 ($n = 22$) | Class 2 ($n = 14$) | Class 3 ($n = 3$) |
|---|---|---|---|
| NDB (JAS) | 44 | 46 | 47 |
| NDF (JAS) | 54 | 60 | 64 |
| NDFr (JAS) | 56 | 63 | 69 |
| FW (g) | 23.12 | 17.26 | 7.47 |
| DW (g) | 2.96 | 3 | 0.83 |
| TB (g) | 51.77 | 59.89 | 44.93 |
| PHF (cm) | 24.78 | 21.25 | 17.1 |
| HTP (cm) | 30.89 | 28.71 | 19.77 |
| DTI (mm) | 8.16 | 7.92 | 6.69 |
| DTF (mm) | 10.19 | 10.8 | 10.22 |
| NFP | 4.28 | 3.89 | 3.16 |
| FD (mm) | 15.04 | 16.9 | 6.76 |
| FL (cm) | 7.43 | 5.46 | 3.33 |
| NS/F | 42.81 | 31.87 | 2.98 |
| WTS (g) | 31.16 | 21.92 | 2.13 |
| TC% | 54.21 | 58.14 | 53.2 |
| TE% | 81.19 | 81.4 | 80.14 |
| SFS | 3.59 | 3.25 | 2.55 |
| IF | 8.95 | 7.76 | 4.86 |

Abbreviations: DTF, final stem diameter; DTI, initial stem diameter; DW, dry weight; FD, fruit diameter; FL, fruit length; FW, fresh weight; HTP, total plant height; LAI, leaf are index; LCC, leaf chlorophyll content; LW%, leaf water content; NDB, number of days to budding; NDF, number of days to flowering; NDFr, number of days to fruiting; NS/F, number of seeds per fruit; NFP, total number of fruits per plant; PHF, plant height at flowering; SLA, specific leaf area; TB, total biomass; WTS, thousand-seed weight.

NDFr delays ($r = -0.49$ and $r = -0.48$, respectively) suggests a trade-off between earliness and fruit development, consistent with previous findings [19]. In addition, the strong positive correlation between the NS/F and WTS ($r = 0.77$) indicates a reproductive strategy focused on producing high-quality seeds, particularly among Group 2 ecotypes. A novel finding of this study is the negative correlation between WTS and SLA ($r = -0.77$). This relationship, rarely documented in okra, may indicate a leaf-thickening strategy for water conservation associated with better seed quality [12, 15].

HAC revealed a partial structuring of ecotypes according to geographic origin. Group 2, predominantly Sahelian and high-yielding, represents a strategic genetic resource for breeding programs, aiming at intensive production under irrigation [20]. These ecotypes, adapted to arid conditions, maintain high LAI while developing significant biomass, suggesting favorable physiological adaptation. Groups 1 and 3, being more heterogeneous, demonstrate interesting plasticity [21]. Group 1 could provide genes for tolerance across a wide range of environments. Group 3, although low-yielding, represents a resource-conserving strategy that may be useful in targeted breeding programs for adaptation to severe stress [22].

## 5. Conclusion

This study identified ecotypes, notably TGO-020, TGO-025, TGO-031, and TGO-033, which stood out for their superior agronomic performance, high productivity, and substantial LAI under cool dry season conditions. These results underscore the central role of genetic diversity in adapting okra cultivation to the cool season. The identified correlations between agronomic and physiological traits, particularly the importance of LAI, highlight key adaptation mechanisms in response to low-temperature conditions. The highlighted genetic material constitutes a valuable resource for breeding programs, whether for direct adoption of high-performing ecotypes or for use in crosses aimed at introducing cold tolerance. Ultimately, these findings provide a solid foundation for developing resilient okra varieties adapted to dry-season production systems in Burkina Faso and the subregion, thereby contributing to the sustainable enhancement of food security.

## Data Availability Statement

The data supporting the findings of this study are sensitive because they are part of an ongoing doctoral thesis that has not yet been defended. Therefore, the dataset cannot be made publicly available at this time. However, the data may be provided by the corresponding author upon reasonable request and for justified academic purposes.

## Conflicts of Interest

The authors declare no conflicts of interest.

## Author Contributions

All authors contributed equally to this work.

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## References

[1] F. Hama-Ba, C. Parkouda, R. Kamga, A. Tenkouano, and S. Diawara, "Disponibilité, Modes Et Fréquence De Consommation Des Légumes Traditionnels Africains Dans Quatre Localités Du Burkina Faso a Diverses Activités De Maraichage: Ouagadougou, Koubri, Loumbila, Kongoussi,"

*African Journal of Food, Agriculture, Nutrition and Development* 17, no. 2 (2017): 11552–11570, https://doi.org/10.18697/ajfand.77.15960.

[2] M. Ouedraogo, L. Bougma, N. Sawadogo, O. Adjima, R. Ouedraogo, and M. Sawadogo, "Phenotypic Variation of Okra (*Abelmoschus esculentus* L.) Genotypes Cultivated in Burkina Faso Based on Qualitative Traits," *Journal of Animal and Plant Sciences* 55, no. 1 (2023): 10032–10042, https://doi.org/10.35759/JAnmPlSci.v55-1.3.

[3] M. Sawadogo and D. Balma, "Etude De La Variabilité Agromorphologique De Quelques Écotypes Locaux De Gombo Cultivés Au Burkina Faso," *Sciences Naturelles Et Appliquées* 27, no. 1 et 2 (2021): 99–117, https://www.revue sciences-techniquesburkina.org/index.php/sciences_nature lles_et_appliquee/article/view/142.

[4] S. S. Mkhabela, H. Shimelis, A. S. Gerrano, and J. Mashilo, "Drought Tolerance Assessment of Okra (*Abelmoschus esculentus* [L.] Moench) Accessions Based on Leaf Gas Exchange and Chlorophyll Fluorescence," *Life* 13, no. 3 (2023): 682, https://doi.org/10.3390/life13030682.

[5] D. Tiama, B. Sakandé, I. Sougué, and R. E. Traoré, "Evaluation of the Agronomic Performance of Twelve Okra Accessions (*Abelmoschus esculentus* (L.) Moench) in the Sudano-Sahelian Climate of Burkina Faso," *International Journal of Biosciences* 26, no. 2 (2025): 92–105.

[6] S. S. Mkhabela, H. Shimelis, A. S. Gerrano, J. Mashilo, and A. Shayanowako, "Characterization of Okra (*Abelmoschus esculentus* L.) Accessions with Variable Drought Tolerance Through Simple Sequence Repeat Markers and Phenotypic Traits," *Diversity* 14, no. 9 (2022): 747, https://doi.org/10.3390/d14090747.

[7] A. Clément, *Dosages De Différents Constituants De La Plante Et De Marqueurs Biochimiques De Stress* (CERAAS: Formation ECOBIO, 2003).

[8] L. Fondio, *Contribution À La Connaissance Du Développement Du Gombo Tomi: Abelmoschus Caillei (A. Chev.) Stevels (Malvaceae), Dans Le Centre De La Côte D'Ivoire. Influence De L'Apport D'Eau Et D'* (Thèse de doctorat, Université de Cocody-Abidjan, 2005).

[9] R. Kumar, P. Karmakar, A. Bahadur, D. Sreekanth, R. Kumar Verma, and H. Krishna, "Exploring Drought Tolerance in Okra Through Morpho-Physiological, Biochemical Characteristics and Yield Based Indices," *Journal of Crop Health* 77, no. 3 (2025): 91–23, https://doi.org/10.1007/s10343-025-01155-3.

[10] J. L. Hatfield and J. H. Prueger, "Temperature Extremes: Effect on Plant Growth and Development," *Weather and Climate Extremes* 10, no. Part A (2015): 4–10, https://doi.org/10.1016/j.wace.2015.08.001.

[11] J. H. Cornelissen, S. Lavorel, E. Garnier, et al., "A Handbook of Protocols for Standardised and Easy Measurement of Plant Functional Traits Worldwide," *Australian Journal of Botany* 51, no. 4 (2003): 335–380, https://doi.org/10.1071/BT02124.

[12] S. P. Long, E. A. Ainsworth, A. Rogers, and D. R. Ort, "Rising Atmospheric Carbon Dioxide: Plants FACE the Future," *Annual Review of Plant Biology* 55, no. 1 (2004): 591–628, https://doi.org/10.1146/annurev.arplant.55.031903.141610.

[13] J. Monteith and M. Unsworth, *Principles of Environmental Physics: Plants, Animals, and the Atmosphere* (Academic Press, 2013).

[14] J. P. Grime, *Plant Strategies, Vegetation Processes, and Ecosystem Properties* (Blackwell Science, 2001).

[15] M. M. Chaves, J. Flexas, and C. Pinheiro, "Photosynthesis Under Drought and Salt Stress: Regulation Mechanisms from Whole Plant to Cell," *Annals of Botany* 103, no. 4 (2009): 551–560, https://doi.org/10.1093/aob/mcn125.

[16] C. C. Nwangburuka, O. A. Denton, O. B. Kehinde, D. K. Ojo, and A. R. Popoola, "Genetic Variability and Heritability in Cultivated Okra [*Abelmoschus Esculentus* (L.) Moench]," *Spanish Journal of Agricultural Research* 10, no. 1 (2012): 123–129, https://doi.org/10.5424/sjar/2012101-021-11.

[17] F. Tardieu, "Plant Response to Environmental Conditions: Assessing Potential Production, Water Demand, and Negative Effects of Water Deficit," *Frontiers in Physiology* 4 (2013): 17, https://doi.org/10.3389/fphys.2013.00017.

[18] J. E. Specht, D. J. Hume, and S. V. Kumudini, "Soybean Yield Potential a Genetic and Physiological Perspective," *Crop Science* 39, no. 6 (1999): 1560–1570, https://doi.org/10.2135/cropsci1999.3961560x.

[19] I. J. Wright, P. B. Reich, M. Westoby, et al., "The Worldwide Leaf Economics Spectrum," *Nature* 428, no. 6985 (2004): 821–827, https://doi.org/10.1038/nature02403.

[20] A. Bationo, S. Kimani, and K. L. Sahrawat, "Soil Fertility Management for Sustainable Land Use in the West African Sudano-Sahelian Zone," *Advances in Agronomy* 78 (2003): 1–137.

[21] S. J. Franks, J. J. Weber, and S. N. Aitken, "Evolutionary and Plastic Responses to Climate Change in Terrestrial Plant Populations," *Evolutionary Applications* 7, no. 1 (2014): 123–139, https://doi.org/10.1111/eva.12112.

[22] H. Lambers, F. S. Chapin III, and T. L. Pons, *Plant Physiological Ecology* (Springer Science & Business Media, 2008).