Research Article

Varietal Diversity Analysis of Date Palm and Identification of High Agro-Economic Genotypes in Middle Draa

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Abstract | The date palm (*Phoenix dactylifera L.*) is the cornerstone of the oasis agro-systems of the middle Draa, home to Morocco's largest traditional palm grove. The ecosystem extends over nearly 200 km and covers 25,620 ha, supporting more than 2.5 million palm trees. The study was conducted between 2023 and 2024 during the date ripening period. Varietal diversity was assessed across 264 hectares using random sampling of date growers in the six main oases: Mezguita, Tinzoline, Ternata, Fezouata, Ktaoua, and Mhamid. The results revealed an exceptional varietal richness with 60 varieties identified, but a highly uneven distribution. Seed-origin date palms (*Khalts*) largely dominate the composition with 48.7% of the total population, followed by *Jihel* (22.5%) and *Black Bousthammi* (19.8%). The other 57 varieties make up most of the varietal diversity but represent only 9% of the population. Analysis of ecological indices shows contrasting profiles between the oases: Fezouata has the most balanced diversity (Shannon Index = 2.41; Equitability = 0.78), while Ktaoua, despite having the highest richness (28 varieties), shows moderate equitability (0.57). This study underscores the dual conservation challenge: safeguarding the exceptional genetic richness of this reservoir while ensuring a balanced varietal distribution despite pressures toward standardization. The traditional palm grove of the Middle Draa thus constitutes a crucial genetic heritage for adaptation to future environmental changes.

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Introduction

The (*Phoenix dactylifera L.*) commonly known as the date palm is one of the oldest plants species domesticated by humans. Its domestication dates back more than 5,000 years (Chao and Krueger, 2007). This longevity testifies to its economic, nutritional, and cultural importance in arid and semi-arid regions (Bouaziz *et al.*, 2018). The Middle East and North Africa constitute the most favorable biotope for

its cultivation, home to approximately 90% of the world's date palm population (Khardi *et al.*, 2024). The ancient establishment of the date palm in vast regions and the long history of its domestication make it difficult to determine its precise center of origin (Gros-Balthazard *et al.*, 2023; Krueger, 2021).

The varietal diversity of the date palm is very high, due to its dioeciously nature and number of chromosomes (2n = 36) (Krueger, 2021). Propagation by seed generates highly varied heterogeneous populations, locally known as *Khalts* or *Sairs* (Krueger, 2021; Sedra, 2015). This heterogeneity has enabled date growers to select *Khalts* of high agronomic quality to create new varieties, giving them names related to the shape of the date or its origin (Gros-Balthazard *et al.*, 2023). As a result, traditional palm groves are home to an extremely rich genetic heritage of date palms, with an estimated 5,000 cultivars (Abul-Soad *et al.*, 2017).

In Morocco, the date palm (*Phoenix dactylifera L.*) plays a central role in agriculture in arid regions (Mahjoubi *et al.*, 2025; Zein Taleb *et al.*, 2024), particularly in the palm oases of the south (Outghouliast *et al.*, 2020, 2021). The national palm tree population is estimated at 6.9 million (Meziani, 2023) with annual production varying between 100,000 and 120,000 tons. The main areas of cultivation are: Draa-Tafilalet: 77%, Sous Massa: 15%, Oriental: 5%, and Guelmim Oued Noun: 4%. It plays a key role in agronomic, ecological, and economic terms, protecting underlying crops and providing an essential source of income for palm growers and local traders (Sedra, 2015; Soomro *et al.*, 2023).

The Moroccan date palm gene pool is particularly diverse, with around 453 varieties recorded, representing 52.3% of the national total, while *Khalts* account for 47.7% (Sedra, 2015). The oases of the Middle Draa, located in southeastern Morocco, fall administratively under the province of Zagora. They cover an area of approximately 25 620 hectares and constitute the country's main traditional palm grove, with a length of 200 km (Meskour *et al.*, 2025) and a population of over 2.5 million palm trees (Mrabet *et al.*, 2018). The oases of the middle Draa are distinguished by a wide variety of date palms, such as *Jihel, Black Boustahmmi, Boufeggous, Iklane, Tadmante, Bouzeggar, Bouskri, Ahardane, Aguellid, Mekt*, and others. There are also thousands of different *Khalts*, which constitute an essential gene bank for research and selection of new varieties with important characteristics in terms of date quality and resistance to bayoud disease (Altaf *et al.*, 2025), such as the *Najda* variety selected by INRA Morocco (Essarioui *et al.*, 2018; Harrak, 2022).

This study aims to conduct an inventory of the phoenicicultural genetic resources of the Middle Draa palm groves, with the goal of documenting their varietal richness and identifying *Khalts* of agro-economic interest. The study focused on female date palms, without neglecting the importance of male palms for reproduction and the maintenance of genetic diversity (Maryam *et al.*, 2025). Phoenicicultural biodiversity contributes to the resilience of the oases against biotic and abiotic stresses. The results will allow the development of a varietal map and highlight high-quality *Khalts*, thereby contributing to the conservation of genetic resources and the sustainable preservation of biodiversity.

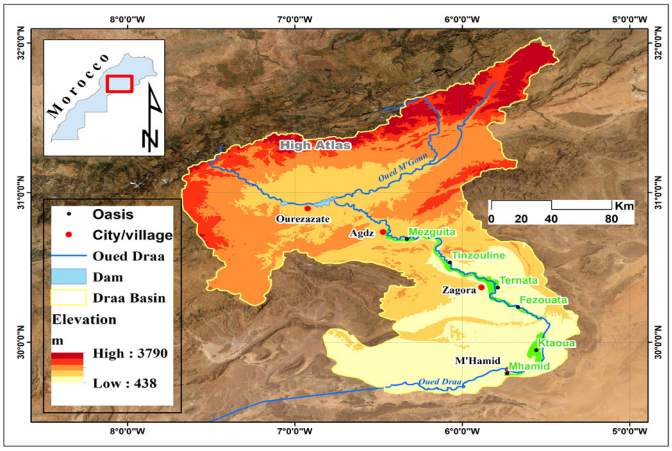

Figure 1: *Location of the study area in the draa basin, morocco.*

Materials and Methods

Study area

The Middle Draa palm grove is located in southeastern Morocco (Figure 1), near the 30th parallel and intersected by the 6° West meridian. Administratively, it belongs to Zagora Province, which includes two urban communes and 18 rural communes, with a total population of 283,363, 81% of whom live in rural areas (Haut Commissariat au Plan, 2024). The grove forms a 200 km long green belt composed of six oases (Mezguita, Tinzouline, Ternata, Fezouata, Ktaoua, and M'hamid) fed by the El Mansour Eddahbi dam via the Draa wadi, a temporary river (Ait Youssef *et al.*, 2025; Karmaoui *et al.*, 2014; Lamqadem *et al.*, 2017). Covering 25,620 ha and hosting over 2.5 million palm

trees, Ternata is the largest oasis with more than 7,000 ha and 38% of the total palms, while M'hamid is the smallest with 670 ha and 191,000 palms (Mrabet *et al.*, 2018). The region is hot and arid, with an average aridity index of 0.03, annual precipitation of 54–108 mm, evaporation up to 3,000 mm, and temperatures ranging from -1°C in winter to 48°C in summer (Ait Lamqadem *et al.*, 2018; Trabucco *et al.*, 2008).

Sampling method

A random survey method was used to assess and inventory the varietal diversity of the oases in the Middle Draa. Sample sizes were determined based on the surface area of each oasis (Table 1). The study focused exclusively on palm trees in authentic oases.

Data collection was undertaken in 2023 and 2024 during the date ripening period that runs from mid-July to mid-October. Date palm growers were the target of this survey, as the growers have knowledge about the date palm varieties and date palm cultivation heritage of their *ksours* (also known as *douars*, a term referring to a village). A participatory approach to administering the questionnaires was favored. At each collection site, a brief presentation in Arabic or in Berber was given to explain the study objectives. The elderly residents present were then invited to answer the questionnaire.

The survey was designed to collect: (i) general data on the respondents, (ii) information on the farms, including ownership status, size, main occupation, irrigation water sources, and (iii) data acquired regarding date palm varietal diversity, including variety names, number of individuals, proportion of *Khalts*, as well as rare varieties recently propagated through vegetative means by exchanging offshoots, these varieties often being named after specific characteristics of the palm tree or its dates. The survey also aimed to identify date palm *Khalts* with significant morphological and physiological traits.

To determine the sample size n, we applied the following formula, assuming a normal distribution of the surface area (Cochran, 1977):

$$n = \frac{N.z^2.p(1-p)}{(N.\varepsilon^2 + z^2.p(1-p)).}$$

n: Sample size (area)
N: Total area of the palm grove
z: Set at 1.96 for a 95% confidence interval
p: Proportion of high-abundance varieties, estimated at 50%
ε: Margin of error, set at 6%

Table 1: *Data on the studied palm groves in the middle draa.*

Palm grove	Total number of palm trees	Total area (ha)	Surveyed area (ha)	Percentage of total area (%)	Names of sampled villages
Mezguita	385203	3012	31	12%	Afella ndra
					Tisergat
					Afra
Tinzoline	345952	5895	61	23%	Tanssiktht
					Ait hammou
					Oulad yahya
					Tinzoline
					Tizguine
Ternata	983149	7053	73	28%	Lamkatra
					Beni zoli
					Kasbat nchachda
					Asrir ilamchane
					Ouald elhaj
Fezouata	404162	6860	71	27%	Timtig
					Tamegroute
					Tinfou
					Askejjour
					Beni ali
Ktaoua	249501	2130	22	8%	Ksar ignaoun ait ali
					Zaouite moulay chrif
					Ksar Hnit
Mhamid	191236	670	7	3%	Bounou
					Oulad driss
					Zaouite lahnae
Total	2559203	25620	264	100%	

Morphometric characterization of dates from selected Khalts

For each date palm, based on fruit quality, as complete a dataset as possible was collected, including GPS coordinates, plot history, and other contextual information. A one kg date sample was collected from each individual tree, and a subsample of ten representative fruits was measured using a caliper.

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Their individual weights were determined using a precision scale. Fruit color and shape were assessed visually, while texture was evaluated by tactile examination.

The pulp-to-pit ratio is an essential indicator for assessing the commercial quality of dates, as it reflects fruit yield. A high pulp percentage is generally associated with greater commercial and industrial value for the variety (Chafi *et al.*, 2015). This parameter was calculated using the following formula:

Pulp percentage = (Pulp weight × 100) / Whole date weight

This approach enables detailed characterization of fruit phenotypes and helps identify *Khalts* with high agronomic and economic potential.

Data processing and analysis

The collected data were compiled and organized in an Excel spreadsheet. Data processing was performed using Microsoft Office Excel 2016 and IBM SPSS Statistics version 20. To assess diversity, three types of indicators were employed: (i) Species richness, corresponding to the total number of date palm varieties identified within each palm grove, and (ii) the Shannon-Weaver index (H') (Ortiz-Burgos, 2016; Shannon, 1948), which evaluates both the number of varieties and their distribution within the palm groves. Higher index values indicate greater diversity. This index typically ranges from 0 to 5, and is calculated using the following formula:

$$H' = -\sum_{i=1}^{s} (pi \times log^2(pi))$$

S is the total number of species (or varieties/cultivars)
p^i is the proportion of species *i* relative to the total number of species present

log_2 is the base-2 logarithm.

(iii) Pielou's evenness index (E′) (Pielou, 1966) was calculated using the formula E′ = H′ / log(S), where H′ is the Shannon-Wiener diversity index and S represents the number of varieties identified in a palm grove. The index ranges from 0 to 1 and evaluates the relative distribution of cultivars and varieties independently of species richness (Aouissi *et al.*, 2021). It is particularly useful for comparing samples with varying richness levels or for comparing different ecosystem types (Houssni *et al.*, 2022).

Table 2: *Survey of date palm varieties and their abundance in the Middle Draa*

Category	Varieties
Very frequent	*Black Bousthammi, Jihel, Iklane, Boufeggous, Bourar, Bouzeggar, Najda, Tadmante, Majhoul, Bouskri.*
Frequent	*Sbaa Sultane, Jaafari, Flika, Raslatmer, Mest -Ali, Omnhal, Ahardane, Mekt, Aguellid.*
Infrequent	*El Khaddoury, Mah-elbid, Aceddame, Sair-lay-alate, Bouhafs, Tighmi Nidodane, Mekkour Yahya, Tfoulkamte, Akaadi, Konssa, Admou, Belmakhtar, El Hmouri, Assensif, Am-dmoj, El Handia, Sair-lahmer, Lambirrem, Ellokma, Temgarte, Tazagzoute, Akourar, Lahwimid, Tabounafert, Tamaassalt.*
Very rare	*Lakhder, Labkiri, Rtab, Krrabi, Amoutri, Chatouiyya, Bou-slikha, Tikoubbadine, Timachiwine, Mezmlal, Bouyblouh, Talmoutarte, Tislikha, Bazzolt -El-Ouda, Am-Jihel*

Data visualization

Data visualization was performed using Python 3.10.12 in the Google Colaboratory environment. The analysis utilized the Pandas library for data manipulation and Matplotlib/Seaborn for creating visualizations. All graphs were generated in high resolution (300 dpi) and exported to Google Drive in JPG format.

Results and Discussion

Varietal diversity in the palm groves

This study identified 60 date palm varieties across all Middle Draa groves (Table 2), including Khalts, with "variety" encompassing both cataloged types and all locally recognized genotypes propagated via offshoots (Houssni *et al.*, 2022). Varietal diversity in Morocco is highly heterogeneous: the Draa Valley hosts 80 varieties, followed by Ziz–Tafilalet (71), Bani (57), and the Eastern region (26), whereas the Anti-Atlas (33), Saghro, and Saghro–High Atlas (17 each) show lower richness, reflecting clear regional structuring (Sedra, 2015). Local studies further illustrate this variation; El Bakouri *et al.* (2025) recorded 46 varieties in Tafilalet, while Houssni *et al.* (2018) documented 31 varieties across Rich, Aoufouss, Alnif, and Zagora oases, highlighting the role of these areas in conserving national diversity. At the national level, the Draa basin remains the main reservoir, hosting 170 varieties, approximately 38% of Morocco's 453

varieties, underscoring its central role in the country's date palm heritage (INRA, 2011).

The variation in the number of varieties, from 80 to 60, can be explained by several factors. Nearly a decade separates this study from previous ones, during which the oases experienced severe droughts and a decline in groundwater levels (Meskour *et al*., 2025). Differences in survey methodologies and the loss of a significant number of experienced phoeniciculturists, custodians of extensive local knowledge, due to aging and socio-demographic changes, have also likely contributed to this variation (Santoro, 2023). This situation reflects a broader issue of genetic erosion in date palm cultivation, evident in the gradual decline of local varieties and the loss of disease-susceptible genotypes, particularly those affected by Bayoud disease (Figure 2). Varietal choices during new plantings, favoring high-yielding or high-value cultivars over less competitive local genetic resources, along with the expansion of monoculture systems and market-driven pressures, have further accelerated this process.

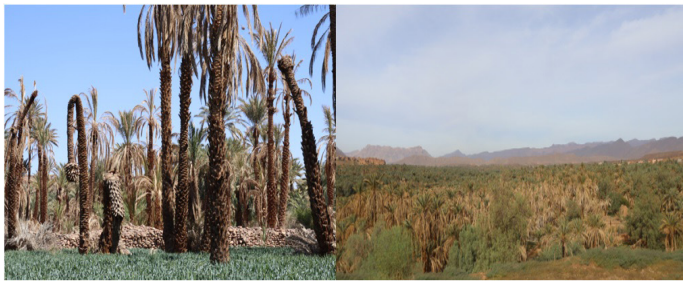

Figure 2: *Effects of drought and Bayoud disease on date palm trees (Ternata oasis).*

Within the framework of the Green Morocco Plan, the State provides subsidies for the acquisition of vitroplants and promotes both the rehabilitation of traditional oases and the establishment of new plantations. To support this policy, large-scale propagation has focused on a limited number of varieties, *Boufeggouss*, *Majhoul*, and *Najda* selected primarily for their commercial value (Chaabi, 2022). *Boufeggouss* and *Majhoul*, which are highly susceptible to Bayoud disease, are mainly planted in expansion areas, whereas *Najda*, a resistant variety, is preferentially used in authentic oases. More recently, the Green Generation strategy has shifted toward large-scale propagation of all local varieties characteristic of each oasis (for example, in the Draa Valley: *Jihel, Black Bousthammi, Iklane, Bourar, Aguelid, Tadmante, Omnhal* and others). This integrated approach contributes to the conservation of date palm biodiversity by promoting varietal traits such as resistance to Bayoud disease, fruit storage capacity, earliness, and adaptation to water and salinity stress, while enhancing the resilience of oasis agro-ecosystems to climate change and supporting the economic potential of high-quality local dates (Ali *et al*., 2024). In this context, in-depth assessments of genetic diversity, particularly through the use of genetic markers, are essential for designing improvement programs that reconcile productivity, fruit quality, and the long-term sustainability of oasis agroecosystems, while ensuring the conservation of local biodiversity (Ahmad *et al*., 2023; Jamil *et al*., 2022; Yalinkiliç *et al*., 2024).

Varietal distribution by palm grove

Our results reveal that *Khalts* largely dominate the varietal profile of the Middle Draa, accounting for nearly 49% of the recorded population. This trend aligns with that reported by (Sedra, 2015), who estimated their share at 48.2% nationally and 44.56% in the Draa Valley. However, a significant divergence emerges when comparing our data with the study by the Centre de Ressources Pilier 2 (2012), where *Khalts* represent only 31% of the total population. This notable difference could be explained by methodological discrepancies in census campaigns, recent changes in planting dynamics, or the geographical specificity of the surveyed areas.

The *Jihel* (22.5%) and *Black Bousthammi* (19.8%) varieties rank second and third, respectively, in our study, compared with 26.5% and 10.1% reported by the Centre de Ressources Pilier 2 (2012). Together with *Khalts*, these two varieties account for more than 90% of the inventoried palm trees, indicating low effective diversity in current plantations. In contrast, the same study reported a more balanced varietal composition, with notable representation of varieties such as *Boufeggous* (9.9%), *Aguellid* (2.3%), and *Bouskri* and *Iklane* (1.7% each), whereas these varieties remain marginal in this sbbbmxrurvey.

This decline in the number of individuals can be explained by both biotic and abiotic pressures. It should be emphasized that most high-quality varieties exhibit high susceptibility to Bayoud disease (Essarioui *et al*., 2018; Essarioui and Sedra, 2017) which increases their vulnerability and compromises

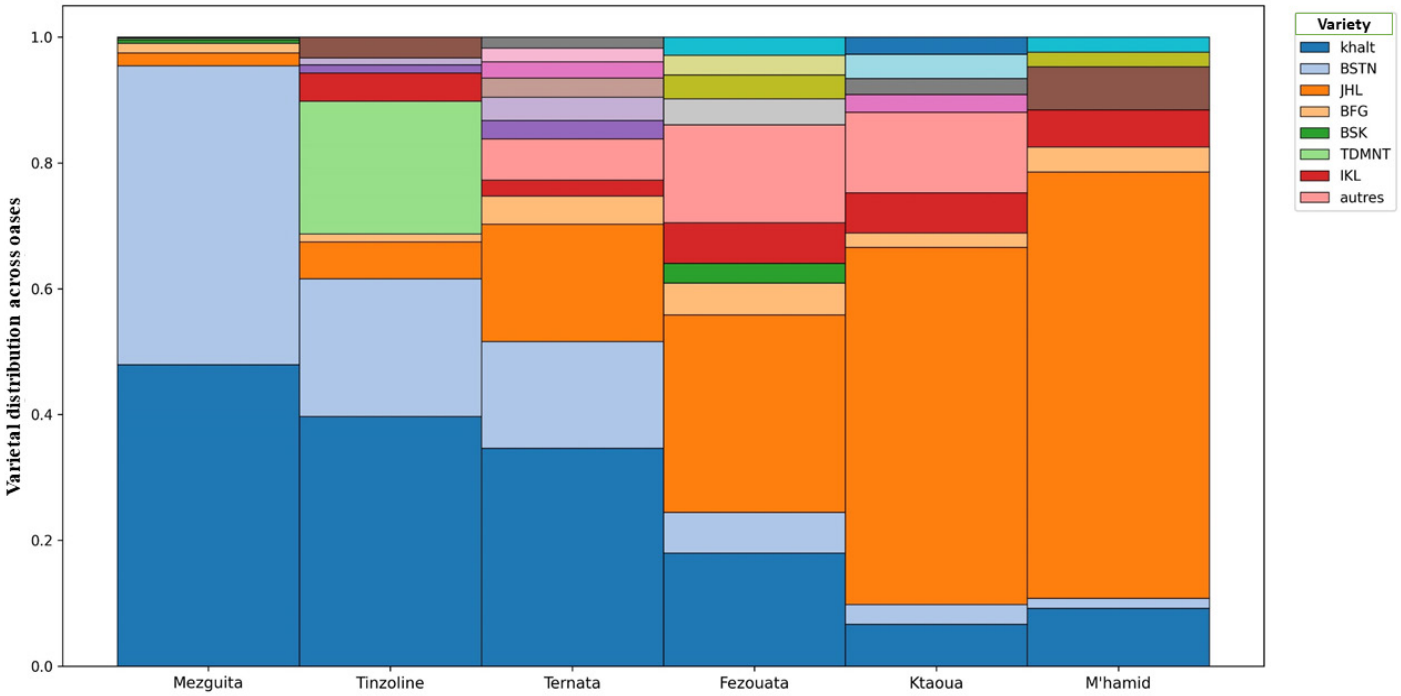

Figure 3: Distribution of varieties within the Middle Draa palm groves. BFG: *Boufeggous,* BSK: *Bouskri,* BSTN: *Black Bousthammi*, IKL: *Iklane,* JHL: *Jihel*, TDMNT: *Tadment*, BRR: *Bourar*.

their persistence in infected palm groves. Most of the recorded varieties (50 varieties) represent only a very small proportion of the palm groves. These palms are vegetatively propagated through empirical selection carried out by farmers over generations and are predominantly identified by local names.

The varietal profile varies from one palm grove to another, both in terms of percentages and presence of different varieties (Figure 3).

The results marked variability among the studied palm groves. The Ktaoua palm grove displays the highest varietal richness with 28 recorded varieties, closely followed by Ternata (26 varieties) and Fezouata (22 varieties). These three palm groves thus stand out as hotspots of genetic diversity. In contrast, Mezguita shows the lowest varietal richness with only 14 varieties, followed by Tinzoline (17 varieties) and Mhamid (20 varieties).

This relatively reduced varietal richness could be explained by the fact that oases located in upstream areas host a great diversity of fruit trees, such as almond, apricot, apple, and plum trees (Ahmed and Daoud, 2024), leading farmers to assign less importance to date palm. This could also explain the massive presence of seed-origin palm trees (*Khalts*) observed in these oases. Based on the analysis of the research results, a marked difference in variety percentages from one palm grove to another was observed. The proportion of *Khalts* gradually decreases from upstream to downstream in the Middle Draa, as does that of the *Black Bousthammi* variety. In contrast, the *Jihel* variety shows an opposite trend, with its frequency progressively increasing from upstream to downstream.

Our results align with those reported by the Centre de Ressources Pilier 2 (2012), which indicates that the *Jihel* variety dominates in the two downstream palm groves of Ktaoua and Mhamid, accounting for approximately 60% of the population, while *Khalts* predominate in the upstream palm groves of the Middle Draa. This distribution can be explained by the shallower groundwater table in these areas, and the fact that the Mezguita and Tinzoline oases benefit from their proximity to the El Mansour Eddahbi dam, even before the construction of the Agdez dam. This promotes more favorable hydrological conditions for the germination of pits that grow naturally and give rise to *Khalts*.

Statistical analysis of relationships between ecological diversity indices

The assessment of genetic diversity in the Middle Draa palm groves was carried out using three ecological indicators: species richness, the Shannon index, and the evenness index.

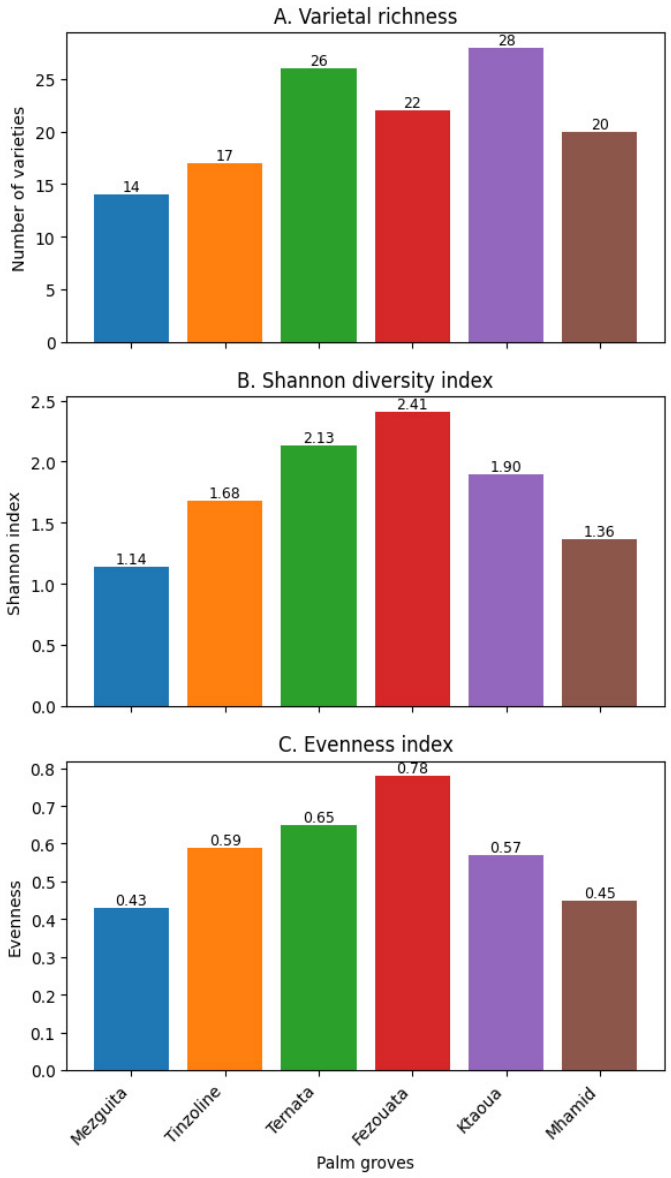

Figure 4: *Graphical representation of varietal richness, Shannon index, and evenness index in the Middle Draa palm groves.*

Comparison of the three indices reveals significant variations among the studied palm groves (Figure 4). Ktaoua displays the highest number of varieties; however, its evenness index remains moderate, suggesting the dominance of certain varieties over others. Fezouata stands out as the most balanced palm grove, with high values for all three indicators. It combines species richness, diversity, and a good distribution of varieties. Ternata also shows high richness and good balance, ranking just after Fezouata in terms of overall ecological performance. Tinzoline displays average values across all criteria, reflecting moderate diversity and a relatively balanced distribution. In contrast, Mezguita and M'hamid recorded the lowest scores for all indicators, indicating reduced biodiversity and an unbalanced distribution of varieties.

Analysis of the relationships between ecological diversity indices provides a better understanding of the structure and dynamics of varietal diversity within the Middle Draa palm groves (Figure 5). Examination of Pearson correlation coefficients reveals distinct ecological dynamics: the relationship between varietal richness and the Shannon index shows a moderately positive correlation ($r = 0.676$), indicating that the increase in species number significantly influences species diversity. Meanwhile, the relationship between richness and evenness also displays a moderate correlation ($r = 0.470$), suggesting that the mere number of species does not automatically guarantee a balanced distribution of individuals. However, the most pronounced and statistically significant relationship ($p = 0.002$) emerges between the Shannon index and the evenness index ($r = 0.967$), demonstrating a strong positive correlation that positions equitability as the main determinant of ecological diversity.

This hierarchy of ecological relationships implies that although varietal richness contributes to diversity, it is primarily the balance in species distribution that governs optimal diversity. This is illustrated by the case of Fezouata, which harmoniously combines all three indices, unlike Ktaoua which, despite its maximum richness, displays only moderate evenness, thereby limiting its overall diversity potential. These results underscore the crucial importance of conservation strategies aimed at maintaining or improving equitability, rather than focusing solely on maximizing species numbers, thus offering new perspectives for the sustainable management of oasis ecosystems.

Identification of Khalts with high agro-economic value

The prospecting of high-quality *Khalts*, based on the analysis of morphometric traits, enabled the identification of around ten individuals exhibiting distinctive characteristics. Among these, the *Khalts* illustrated in Figure 6 show remarkable performance compared with the Moroccan variety *Najda*.

The results reveal significant variability among the studied palm trees across all measured morphometric and qualitative parameters. Date fruit size is an important factor for producers and traders (Sabri *et al.*, 2017). Regarding mean fruit weight, it ranges from 20.00 g (*Khalt* 5) to 26.80 g (*Khalt* 1), whereas it

reaches only 18 g for the *Najda* variety. Excluding the *Majhoul* variety (22.43 g), the average weight of the five *Khalts* studied remains markedly higher than that of the Moroccan varieties, which is 8.38 g (Harrak, 2022), and also exceeds that of the *Deglet Noor* variety (14.63 g) reported by Roumani *et al*. (2024).

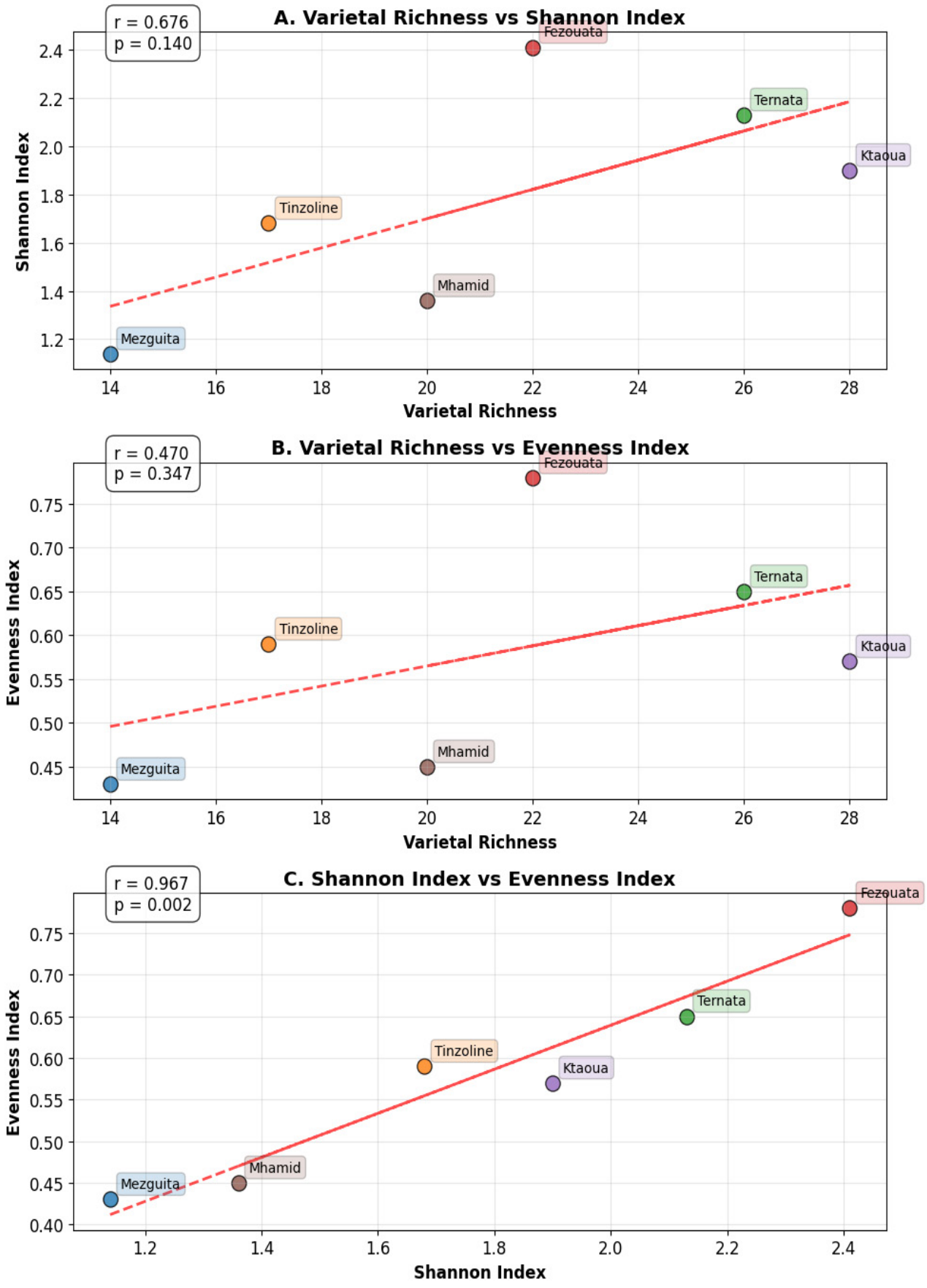

Figure 5: *Correlations between diversity indices (H', S, and E') for the surveyed date palm varieties.*

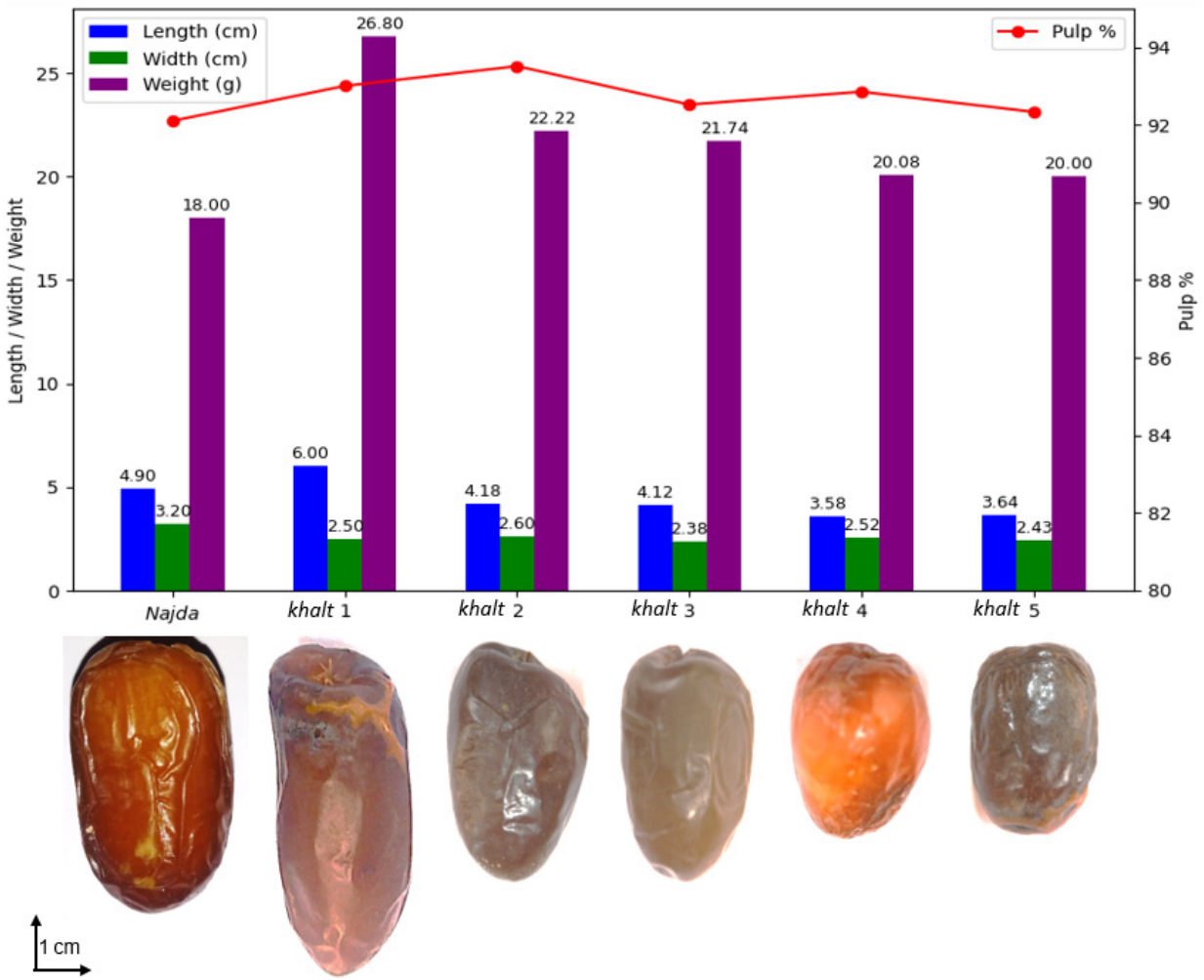

Figure 6: *Morphological and fruit traits of Khalts selected for their superior quality.*

The pulp content is relatively homogeneous, showing a slight variation between 92.33% and 93.51%, which indicates excellent flesh quality across all clones. Higher pulp percentages are particularly desirable, as they are generally associated with greater consumer appreciation of dates (Ghnimi *et al.*, 2017). From a qualitative perspective, fruit color exhibits marked diversity, ranging from red to dark brown, including black and greenish hues. This chromatic variability reflects the phenotypic richness of the studied clones and represents an important criterion for varietal identification. Date texture is predominantly soft to semi-soft, a trait generally preferred for fresh and semi-dry consumption. Moreover, dates characterized by a light brown color combined with a medium texture offer better visual quality and a more attractive presentation for the market, as also reported by Kamal-Eldin and Ghnimi (2018); and Sedra (2015). This study confirms the high genetic diversity of date palms in the oases of the Middle Draa. The identified *Khalts* offer valuable potential for exploitation through participatory breeding programs, in vitro propagation, or genetic improvement. However, further studies are still required, particularly on resistance to bayoud disease, post-harvest conservation, and productivity. The *Najda* variety illustrates the potential success of such an approach, combining high fruit quality with resistance to Fusarium wilt (Sedra, 2015; Zirari, 2010).

Conclusions and Recommendations

This study conducted in the six palm groves of the Middle Draa confirmed the high varietal diversity of date palms in this region, with 60 identified varieties, establishing it as one of the richest areas at the national level. Certain varieties, such as *Boufeggous, Najda, Jihel,* and *Black Bousthammi*, stand out due to their wide distribution, while others, like *Iklane, Tadmant, Jaafari*, and *Flika*, exhibit a more limited distribution. The study also enabled the identification of several high-quality *Khalts* with promising agronomic and economic potential for enriching the national varietal portfolio. Despite certain constraints related to sampling and the effects of prolonged droughts, these results open research perspectives focused

on biochemical characterization and evaluation of Bayoud resistance, to facilitate the registration and valorization of the most performing genotypes.

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Novelty Statement

This study provides an updated, field-based assessment of date palm varie-tal diversity in the oases of the Middle Drâa Valley, several decades after the last available evaluations. It reveals a marked imbalance between persis-tently high genetic richness and the strong dominance of a limited number of varieties, thereby highlighting new priorities for the conservation of ge-netic resources and the sustainable management of oasis systems.

Authors Contribution

Ali Ait Youssef: Done conceptualization, methodology, formal analysis, investigation, and drafting the manuscript.
Allal Douira and Reda Meziani: Supervised the study and contributed to manuscript review and editing.
Samira Serghat: Reviewed the manuscript and verified the translation.
Mbarek Benzine: Contributed to data collection.
Sana El Moutaouakil: Helped in proofreading.

Generative AI or AI assisted technology statement
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Conflicts of Interest
The authors declare no conflict of interest.

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