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Agrosystem Particularities Enhance the Resilience of Pomegranate (*Punica granatum* L.) Cultivation and High Quality Fruit Production in Testour, Northern Tunisia

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ABSTRACT

Pomegranate (*Punica granatum* L.) is one of the ancient fruit crops traditionally cultivated in Tunisia. The arrival of the Moriscos from Spain further strengthened its cultivation, making the pomegranate tree the emblem of the region of Testour. To better characterize and understand the resilience of pomegranate production systems in Testour, prospections and surveys were conducted across the region. These surveys considered farmers' sex and age, species and varietal diversity, traditional knowledge, fruit marketing practices, production constraints, and farmers' willingness to continue pomegranate cultivation. A total of eleven pomegranate-producing areas were identified. Thanks to the intergenerational transmission of valuable knowledge, the Testour region has preserved a wide range of pomegranate varieties along with traditional agricultural techniques. Old, diversified "Andalusian-type" orchards remain well maintained alongside newer intensive plantations. Local farmers play a crucial role in conserving and managing plant genetic resources and biodiversity. Pomegranate fruits from the region have acquired particular renown; however, some varieties have become rare and require targeted conservation efforts to safeguard their genetic heritage. The edaphoclimatic and agrotechnical characteristics of the Testour agro-system, combined with inherited and refined agricultural know-how as well as historical and landscape particularities, have created highly favorable conditions for the resilience of pomegranate cultivation. Polyculture practices and the interaction of diversified system components contribute to the production of superior-quality fruits. In this context, the ongoing process of labeling "Pomegranates of Testour" represents a key step in reinforcing the resilience of this agro-system of global significance, facing climatic and socioeconomic changes.

Introduction

Pomegranate (*Punica granatum* L., Punicaceae) has been cultivated in Tunisia since ancient times (Evereinoff, 1949; Mars and Marrakchi, 1999). Today, Tunisia ranks among the world's ten most important pomegranate-producing countries (Kahramanoglu, 2019). In 2024, the cultivated area of pomegranate reached 12,402 ha, with a total production of 102,906 t (G.I. Fruits, 2024). Traditionally, pomegranate has been grown across the country under diverse agroclimatic conditions. Certain historical events have played a decisive role in the development of this fruit crop. Most notably, the arrival of the Moriscos from Spain at the beginning of the 17th century marked one of the most significant ethnic contributions in Tunisian history, with nearly 80,000 settlers or more (Sayari et al.,

2013). The majority dispersed throughout northern Tunisia, settling mainly in three regions: Bizertin Sahel, the Medjerda Valley, and the Cap Bon Peninsula. The settlement of the Moors (1609–1614) led to the establishment of new communities (Karray et al., 2023), including the creation of several "Andalusian" towns characterized by both rural and sedentary lifestyles, which reshaped the landscape of northwestern Tunisia—particularly in Testour (Karray et al., 2021). This small town in northern Tunisia was regarded as "the greatest Morisco center" built *ex nihilo* in the country (Saadaoui, 1996). Seeking to recreate towns reminiscent of their Spanish homeland, the Moriscos found in Testour the model they had envisioned (Karray et al., 2023). Their establishment contributed to the predominance of a sedentary lifestyle in the plains of the region. Through collective land management practices, centuries of accumulated knowledge, and innovative techniques, they created a new and distinctive agrarian landscape that symbolized their community. The terracing of the Medjerda Valley, soil leveling, orchard plot layouts, irrigation methods, cultivation practices, and the introduction of new plant species all attest to the profound impact of Morisco contributions on shaping the region's agricultural landscape (Sayari and Rejeb, 2009). In more recent times, intensive fruit cultivation has expanded, particularly with olive and pomegranate trees, along with apricot and fig trees. A wide variety of vegetables and forage crops have also been introduced, further enriching the agricultural system. Today, Testour stands as one of the main centers of pomegranate production in Tunisia, distinguished by its unique agroecological landscape and rich natural environment. The region is home to numerous valuable fruit tree genetic resources; however, the pomegranate remains its emblematic species and is celebrated annually through a dedicated festival.

Despite its cultural and agricultural significance, limited research has documented the traditional knowledge and genetic resources of pomegranate (*Punica granatum* L.) in Testour. The present study therefore aims to explore the genesis of this characteristic agro-system, assess the current status and varietal diversity of pomegranate, and examine local agricultural practices, farmer preferences, visions, and willingness for future cultivation.

Materials and Methods

Description of the study area

The delegation of Testour (36.55° N, 9.45° E) is located in northwestern Tunisia and forms part of the Béja governorate. Situated in the Medjerda Valley, it overlooks a vast agricultural plain. Altitude ranges from 70 m in the lowest parts to 107 m in the highest. The region falls within the upper semi-arid bioclimatic stage, characterized by intense evaporation and pronounced thermal amplitudes. The mean annual temperature is 18 °C, and average annual precipitation is approximately 390 mm.

Testour is encircled by mountains on all sides. On the left bank of the Medjerda, the Al Hindi, Sanâ al-Jamal, and Tallat Mabrûka mountains dominate, while the Jarwil, Shablî, and Kharrûba mountains rise on the opposite bank. Between the city and the surrounding mountains stretch fertile plains, traversed by the Medjerda River and its two tributaries, the Siliana and the Khalled (Hermi-Sayari et al., 2020).

Soil characteristics vary according to topographic position. Lands situated about 6 m above the main riverbed consist of alluvial deposits—sandy, humid, and relatively deep—making them well suited for market gardening and shrub cultivation. In contrast, soils at roughly 13 m above the riverbed are drier and better adapted to perennial fruit trees and pastoral shrubs (Karray et al., 2023).

Survey procedure

To achieve a deeper characterization of local pomegranate-based agro-systems in Testour, prospections and surveys were conducted throughout the region. A representative sample of 54 orchards was selected in close collaboration with the local agrarian authorities (CTV Testour), based on the relative importance of pomegranate cultivation in different sectors. In total, 11 areas were included in the surveys, with orchards distributed as follows: Slouguia (18), Testour (9), Ghnima (8), Sidi Aguil (5), Souani El Rommen (2), El Berguine (3), Sidi Néji (3), Bou Sleh (3), Ben Sandel (1), Ain Youness (1), and Zeldou (1) (Fig. 1).

The data collected concerned orchard characteristics, cultivated pomegranate varieties, agricultural practices, traditional knowledge, methods of harvesting and marketing, as well as the natural, technical, and economic constraints faced by farmers in each area. Farmers' willingness to maintain or expand pomegranate cultivation was also assessed. The surveys were conducted through repeated on-site visits, direct observations, and structured interviews.

Participatory four cell analysis 'FCA' of local pomegranate varieties

The "Four-Cell Analysis" (FCA) was applied to classify the pomegranate varieties under study according to both the size of their cultivation area and the number of householders growing them. This participatory approach facilitates the categorization of varieties and helps to identify common, unique, and rare components of plant genetic diversity (Sthapit et al., 2012).

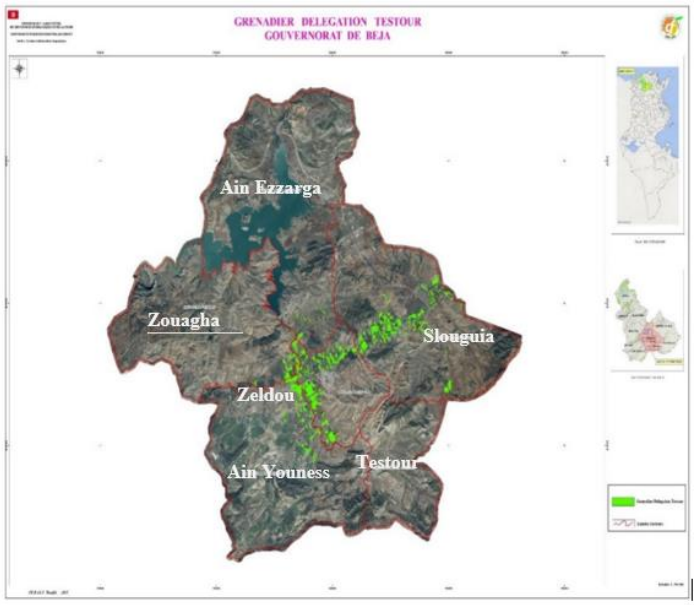

Fig. 1. Map of Testour delegation showing the geographical distribution of pomegranate plantations (in green) in different sectors (G.I. Fruits, 2019).

Results

Socio-cultural overview on farmers

The surveys highlighted several agro-specificities of the Testour region. All surveyed farmers were native to Testour and demonstrated strong mastery of local agricultural practices. The results showed that 46% of farmers were between 30 and 50 years old, while 48% belonged to the 51–70 age group. Only 6% were over 70 years old. The vast majority of respondents were men (98%), with women representing a very small proportion.

In terms of education, more than half of the farmers had not progressed beyond primary school, and only 8% had attained a secondary level. Notably, a significant proportion—42%—held a university degree. This group showed particular interest in pomegranate cultivation, often practicing it as a secondary activity alongside other occupations.

Farmers' experience in agriculture was also appreciable. Over 25% had been engaged in agricultural activities for 40 to 50 years, 35% for about 30 years, and 12% for at least 6 years.

Landscape and farm characteristics

The majority of surveyed orchards were situated in aesthetically pleasing landscaped settings. The surrounding landscapes were largely homogeneous, consisting primarily of pomegranate, olive, apricot, and field crop plantations. The agrarian morphological structure of the older orchards in *Souani El Romèn* and *El Barguil* was notable for its remarkable regularity and subdivision into small plots, arranged in a "square model" locally known as *El Marabaâ*.

Farm size distribution highlighted the predominance of smallholdings. Farms of less than 2 ha accounted for about 16% of the total, while those ranging from 2 to 4 ha represented more than 45%. A typical agroforestry practice in Testour involves the use of local olive trees as windbreaks, which provide combined environmental, economic, and social benefits.

Age and rejuvenation of pomegranate plantations

More than 45% of the surveyed pomegranate trees were old and, according to their owners, in need of rejuvenation and rehabilitation. New plantations aged 4 to 10 years accounted for 44.5%, while medium-aged trees represented only 9.25% of the total. Many of the old trees, often reaching up to 50 years of age, were concentrated in the traditional orchards of *Soueni El Rommen*. Other areas with significant old plantations included Testour, Slouguia, Sidi Aguil, and Ghnima. In contrast, younger plantations were mainly located in Slouguia, Ghnima, Testour, and Sidi Néji. In the old orchards of *El Barguil*, however, all aged plantations had been replaced by new ones.

The distribution of varieties by tree age revealed that the *Tounsi* variety was the oldest in the Testour region. Approximately 8% of *Tounsi* trees were over 50 years old, 37% were between 30 and 40 years old, and 13% were between 20 and 30 years old. The *Gabsi* variety was predominantly found in newer plantations: about 20% of trees were between 10 and 20 years old, while 45% were less than 10 years old. These figures highlight the continuous renewal and expansion of pomegranate cultivation over time in the region.

Importance of pomegranate trees in the cropping system

The pomegranate tree holds a central place in the cropping system of the Testour region, representing 89.85% of the total fruit trees recorded in the surveyed orchards (Table 1). Crop association was observed in 46% of cases, mainly within traditional farms. Orchards containing two associated crops represented 18.5% of the total, with apricot and olive trees being the most frequent companions of pomegranate. Orchards with three associated fruit crops accounted for 20%, while those with four crops constituted 6% of the total.

Among the associated species, the apricot tree was the most common, present in 21 orchards and representing 2.23% of all fruit trees. The olive tree ranked second after the pomegranate, accounting for 3.68% of the total, although it was typically planted along the periphery of orchards. Pear and citrus trees represented 1.55% and 0.99%, respectively. Other fruit trees—including apple, plum, fig, and peach—were less frequent, each representing less than 1% of the total and occurring only in a limited number of orchards.

Table 1. Relative importance of fruit species in Testour.

Fruit species	Orchards Number	Number of trees	Percentage (%)
Pomegranate tree	54	93582	89.85
Apricot tree	21	2326	2.23
Olive tree	19	3832	3.68
Fig tree	2	510	0.49
Peach tree	1	60	0.06
Plum tree	1	600	0.58
Apple tree	1	600	0.58
Pear tree	3	1610	1.55
Citrus	3	1030	0.99
Total		104150	100 %

In general, four types of interplanting were observed in the surveyed orchards in the region of Testour (Fig. 2):

- two rows of pomegranate trees and a mixed row (2 pomegranate trees - one apricot tree): 36% of plantations (Fig. 2a);
- two rows of pomegranate trees and a mixed row (one pomegranate tree - one apricot tree): 24% of plantations (Fig. 2b);
- two rows of pomegranate trees and one row of apricot trees (2/3 pomegranate - 1/3 apricot): 16% of plantations (Fig. 2c);
- a block of pomegranate trees – a block of another fruit species (apricot, olive, plum, peach or citrus): 24% of plantations (Fig. 2d).

In traditional orchards, planting densities were generally about 400 trees ha^{-1} (5m × 5m) or 500 trees ha^{-1} (5 m × 4 m). Whereas in new plantations, the planting densities adopted were generally 625 trees ha^{-1} (4m × 4m). Planting densities of 666 trees ha^{-1} (5m × 3m) and 833 trees ha^{-1} (4m × 3m) were also recorded.

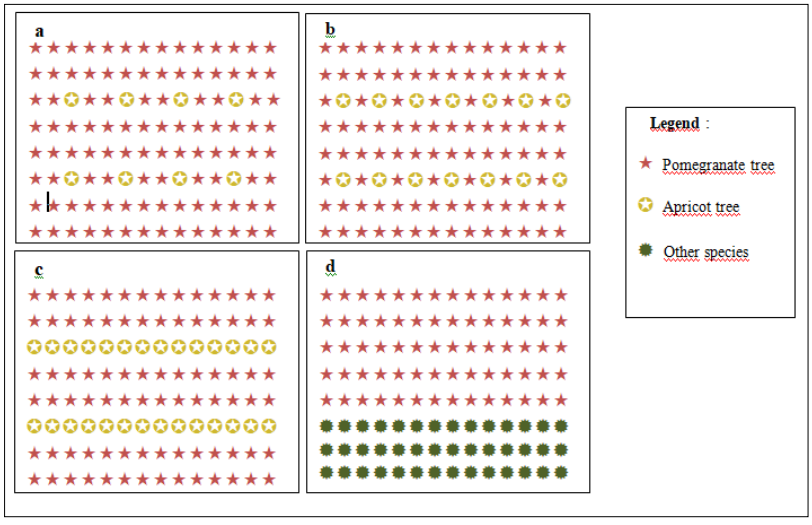

Fig. 2. Pomegranate tree plantation models at Testour.

Pomegranate varietal diversity and relative abundance

A total of seven pomegranate (polyclonal) varieties were identified in the surveyed orchards: *Tounsi*, *Gabsi*, *Chelfi*, *Nebli*, *Jebali*, *Zehri*, and *Chemlali*, each with varying degrees of relative importance (Table 2). The dominant varieties in the Testour region were *Tounsi* and *Gabsi*. Earlier surveys conducted in 1993 (Mars and Gaaliche, 1993) and 2008 (Ben Achour et al., 2008) revealed that *Tounsi* was the most widespread, representing 62.4% of the total, followed by *Gabsi* with 33.8%. In subsequent years, however, *Gabsi* was massively planted due to its higher commercial value, which led to a significant shift in varietal distribution.

By 2022, *Gabsi* had become the leading variety, representing 69.89% of the total and occurring in 49 orchards. *Tounsi*, still widely present in 38 orchards, ranked second (Fig. 3). All surveyed orchards contained *Tounsi* and/or *Gabsi*, though at varying proportions. The variety *Wonderful* was introduced more recently but was found only in a single new plantation.

Monovarietal orchards represented 32% of the total (23 orchards), and among these, 88% (18 orchards) consisted exclusively of *Gabsi*. In contrast, the other varieties were rare and contributed only marginally. *Nebli* accounted for just 0.27% of the total, with 253 trees distributed across five orchards. *Zehri* and *Chelfi* were present in limited numbers, with only dozens of trees recorded in certain orchards. *Chemlali* was identified in two orchards, while *Jebali* was found in only one.

Table 2. Distribution and numbers of the different identified pomegranate varieties.

Variety	Number of orchards containing	Number of trees	Percentage (%)
Tounsi	37	26305	28.11
Gabsi	49	65405	69.89
Chelfi	6	41	0.03
Nebli	5	253	0.27
Zehri	7	80	0.09
Chemlali	2	6	0.01
Jebali	1	5	0.01
Wonderful	1	1500	1.60
Total		**93582**	**100**

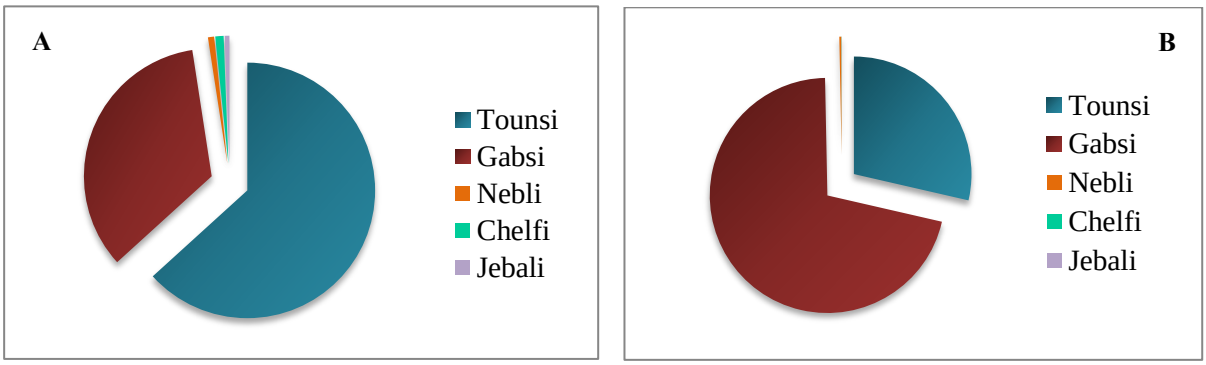

Fig. 3. Evolution of the distribution of pomegranate varieties in Testour orchards. (A) year 2008; (B) year 2022.

The variety *Tounsi* was the most productive, with an estimated yield ranging from 40 to 150 kg tree^{-1} (Table 3). Farmers consistently reported that *Tounsi* pomegranates were distinguished by their red internal color, superior taste due to high sugar content, and high juice yield. Owing to its thicker skin, *Tounsi* was also considered more resistant to diseases and fruit cracking. The harvest period varied between varieties: *Tounsi* was late-maturing and harvested at least two weeks later than *Gabsi*. In contrast, *Gabsi* fruits were larger in size with attractive external coloration. These traits enhanced the visual appeal of the fruit and strongly influenced consumer acceptance. Although *Gabsi* was less productive (20–80 kg tree^{-1}) and more sensitive to cold storage, it retained a high commercial value (Table 3). Moreover, consumer appreciation of this variety was primarily linked to the external color and size of the fruits.

Table 3. Characteristics of pomegranate varieties in Testour according to farmers.

Variety	Harvest period	Production (kg tree^{-1})	Specific characteristics
Tounsi	- In general: 10-25 October -For 8% of farmers: throughout the month of November	40-150 kg	- Fruits of medium size, with an attractive internal color, a high juice yield and a well-appreciated taste. - Soft seeds - Good aptitude for transformation (jam, juice) - Possibility of traditional fruit preservation
Gabsi	- In general: beginning of October - For 12% of farmers: throughout the month of September	20-80 kg	- A good visual appearance (large fruit size and attractive external color) - Susceptible to cracking and sunburn - Poor suitability for cold storage - Relative low tonnage - Good marketing
Nebli	beginning of October	10-30 kg	- Presence of thorns - Large fruit size - High juice acidity
Zehri	August - September	30-60 kg	- Good fruit size - Low red color of arils - Hard seeds - Low sugar level - Poor suitability for cold storage - Not well appreciated by consumers
Chelfi	October - November	30-60 kg	- Late maturity - Medium size of fruits - Good taste
Jebali	End of October	30 kg	- Late harvest period - Medium fruit size
Chemlali	End of October		- Late harvest period - Good production - Medium fruit size - Resistance to diseases and fruit cracking - Soft to medium hard seeds

The participatory "Four Cell Analysis" technique was applied to assess the abundance and distribution of local pomegranate varieties based on *in situ* observations and farmers' perceptions (Fig. 4). Seven local varieties were considered, resulting in four distinct groups. *Tounsi* and *Gabsi* were classified as common varieties, as they were cultivated over large areas and by many households. A threatened group included the varieties *Chemlali* and *Jebali*, whose cultivation was limited to small areas and maintained by only a few households, highlighting the need to promote their expansion. The varieties *Nebli*, *Chelfi*, and *Zehri* were categorized as rare because they were grown on small areas but by several households. These varieties were mainly reserved for family consumption, either consumed fresh as table fruits or processed into products such as jam and juice. Therefore, particular attention should be given to conserving these varieties and encouraging their wider dissemination.

Traditional knowledge

Traditional agricultural practices have been developed over decades, even centuries, through accumulated experience and established traditions. The recorded information confirmed that local traditional knowledge continued to persist among all surveyed farmers in the region. Farmers had inherited considerable expertise, particularly in irrigation management, soil fertility maintenance through the integration of livestock farming (Fig. 5), and pruning practices. One notable example was the traditional irrigation system known as the *noria*, a water-lifting device powered by animals and introduced by the Andalusians (Puy and Balbo, 2013). However, this technique had largely been abandoned in recent decades.

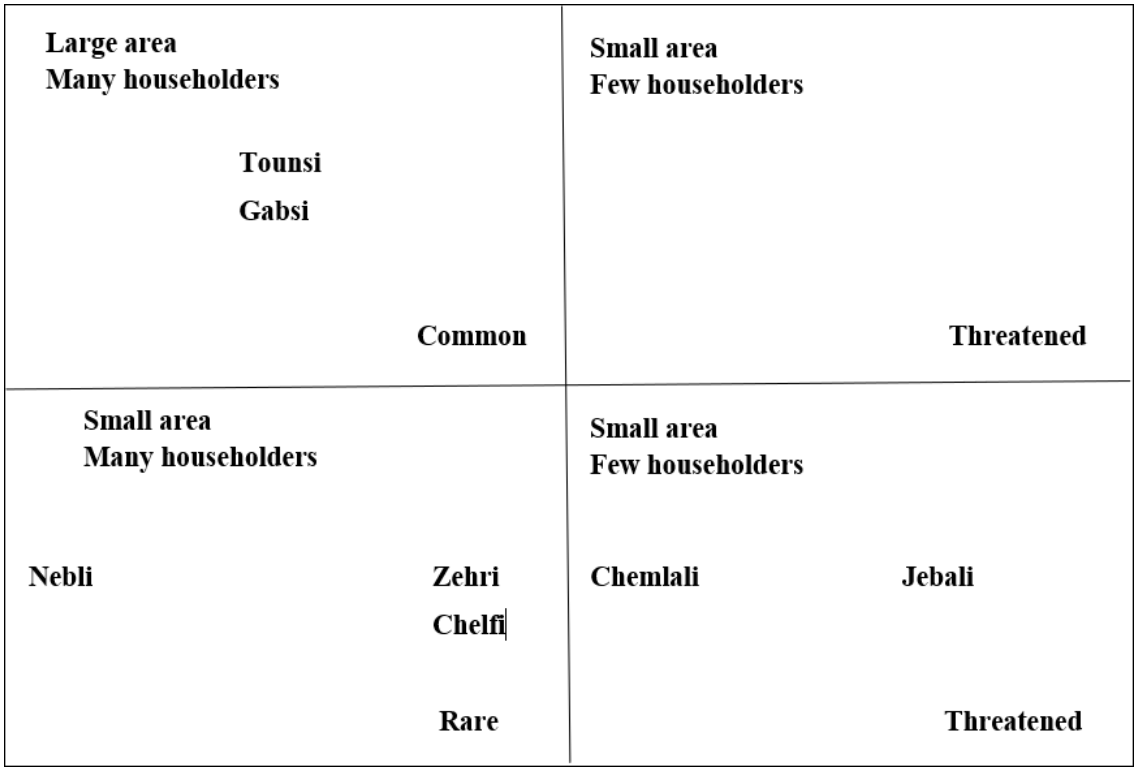

Fig. 4. Classification of local pomegranate varieties according to their distribution following FCA in Testour.

Fig. 5. Diversifying and integrating livestock into production systems and growing multi-stem pomegranate trees.

The traditional orchards were managed using conventional methods, including infrequent tillage, the application of organic manure, pruning, and limited treatments. A propagation technique inherited from ancestors, known as *Chatba* and applied by all farmers, consisted of rooting 1–2-year-old branches detached from the mother plant. These orchards were irrigated through a flood irrigation system, and pomegranate trees were maintained with multiple stems (Fig. 5). Together, these practices reflected a highly appropriate body of technical knowledge for managing pomegranate trees. Some surveyed producers also practiced traditional post-harvest preservation of *Tounsi* pomegranates. This technique involved stacking the fruits in layers separated by straw and covering them with cypress branches, while ensuring good ventilation of the storage area. Farmers reported that traditionally preserved *Tounsi* pomegranates retained their visual appearance (attractive color, without skin hardening or blackening) and maintained good taste. The traditional storage period could extend beyond one and a half months, allowing effective marketing of Testour pomegranates once the fruit supply from southern Tunisia had been depleted.

Harvest, packaging, uses and marketing of pomegranate fruits

In Testour, the pomegranate harvest extended over several weeks. It began in early September with the *Zehri* variety, followed by *Nebli* and *Gabsi* in early

October, and continued from late October to the first week of November with *Tounsi*, *Chelfi*, *Jebali*, and *Chemlali*. Harvesting was carried out in two to three rounds, spaced one to two weeks apart. It was performed manually in the early morning, with fruits cut at the peduncle using secateurs.

The most important reported marketing circuit was that of resellers, who harvested and distributed the production of 40% of farmers. More than 15% of farmers sold their harvest at the local market, while 22% marketed their fruits at the national level. Almost 18% were able to access external markets through intermediaries. More than 40% of farmers stored their pomegranates—particularly the *Gabsi* variety—in refrigerated rooms; however, 52% preferred direct sales due to the high costs of storage. Testour also hosted an annual Pomegranate Festival, which attracted thousands of visitors and created a vibrant social atmosphere. This festival had become one of the key agricultural landmarks in both Testour and Tunisia, renowned for showcasing products of "the highest quality." It highlighted the importance of coordinated efforts by government and private institutions to expand marketing opportunities for these typical products. Rural women played a central role in the event, exhibiting a variety of homemade pomegranate-based foods, such as the traditional "Mesfouf" of Testour. Pomegranate co-products—including syrup, jam, marmalade, juice, and others—were frequently presented in a market setting that directly connected producers with consumers.

Discussion

Peri-urban horticulture in Testour is an ancient practice, dating back at least to the arrival of the Andalusians in Tunisia. Most of the Moriscos were skilled farmers, trained in diverse agricultural techniques. Through the practices they introduced to the region, where they settled nearly four centuries ago, they established a rural way of life that reflected the "pueblos" of southern Spain and created a distinct "shaping" of nature and its appearance (Sayari et al., 2013). Among their major contributions was the development of pomegranate cultivation, which became the emblematic crop of the region and acquired a privileged status among fruit trees. The pomegranate (*Punica granatum* L.) has since marked the history of Testour, holding a special place in the preferences and habits of its inhabitants.

Through centuries of accumulated knowledge and experience, the Moriscos of Testour built an emblematic cultural landscape, shaped by inherited practices, cropping systems, and a distinctive form of agriculture. The agrarian morphology of the old orchards was characterized by remarkable regularity and subdivision into small plots, organized according to the principle of the so-called square arrangement (*El marabaâ*). Traditional water wheels (*norias*), used to lift irrigation water to terraced lands, played a central role in the long-term sustainability of these orchards. These zero-emission devices allowed for the significant expansion of irrigated areas while ensuring ecological balance (Puy and Balbo, 2013; Heider et al., 2021).

In these orchards, pomegranate trees were commonly interplanted with other species, most often apricot. Typically, the pomegranate trees occupied the corners of a quadrangle, with a deciduous tree—usually an apricot—planted in the center. Olive trees, present in nearly all traditional orchards, were generally located along the periphery of the plantation (Sayari and Rejeb, 2009). Our survey revealed that nearly half of the farmers cultivated small to medium-sized farms following an intercropping (polyculture) system. Several original models of this practice constituted a distinctive landscape of traditional pomegranate plantations.

This "Andalusian-type" polyculture system created an environment that was both highly protective and favorable for pomegranate cultivation, resembling the oasis agroecosystem where the species found optimal conditions for growth and fruiting (Boussaa et al., 2018; 2020). The system was also rooted in sustainable practices, including soil fertility maintenance through family-scale livestock integration, infrequent tillage, pruning, and limited treatments. Such practices enhanced resilience and facilitated adaptation to climate change. Inherited agroecosystems of this kind provided soil erosion control, conservation of agrobiodiversity, and preservation of cultural landscapes, while serving as the primary means of transmitting traditional knowledge to new generations and reinforcing local identity (Agnoletti and Santoro, 2022).

The orchards of Testour still preserve a typical and highly diversified biological heritage. Farmers have long been engaged in cultivating a wide range of species and varieties, seeking to conserve biological diversity. Over time, different local "multiclonal varieties" such as *Tounsi*, *Chelfi*, *Nebli*, *Jebali*, *Zehri*, and *Chemlali* were developed and maintained. This varietal assortment extended the harvest and consumption period of pomegranates over several months. Traditional varieties, adapted to diverse climatic and soil conditions, thus represented the most accessible form of pomegranate biodiversity in the region. The diversity of fruit species and varieties also shaped the landscape, particularly during the flowering period, creating a visually pleasing environment.

The role of biodiversity and the genetic resources it carried over decades was essential in ensuring food security, sustainable livelihoods, ecosystem resilience, coping strategies for climate change, adequate nutrition, future insurance, and the biological processes necessary for sustainable

agricultural production (Batello et al., 2010). However, since the 1990s, changes to the traditional plantation landscape have become evident. Many farmers uprooted old apricot trees and other fruit species, and in some cases replaced the typical pomegranate variety *Tounsi* with *Gabsi* or other varieties. As a result, pomegranate cultivation is increasingly threatened by genetic erosion caused by the unsustainable use of plant material. In parallel, new monospecific plantations have emerged, managed with modern intensification techniques such as drip irrigation and pesticide use. Nevertheless, traditional know-how has remained essential, even in these modernized orchards. Farmers were acutely aware that abandoning traditional practices and varieties would lead to unsustainable systems, characterized by dependence on high external energy inputs and heightened vulnerability to environmental shocks.

For this reason, the development of agroecological practices that emphasize the conservation and regeneration of biodiversity, soil, water, and other resources has become necessary to address growing socioeconomic and environmental challenges (Saddoud et al., 2021). A sustainable agricultural system emerges from the co-existence between humans and nature, sustained through traditional techniques that preserve magnificent landscapes, agricultural biodiversity, ancestral knowledge, and strong cultural and social values (Agnoletti and Santoro, 2022). The resilience of pomegranate cultivation in Testour, and the production of superior quality fruits, was made possible by several favorable conditions: the inheritance of valuable knowledge across generations, the farmers' mastery of traditional practices, the particular notoriety of pomegranate fruit, specific edaphoclimatic and agrotechnical conditions, the historical and landscape features of the region, and the continued use of polyculture systems.

Local practices represented a valuable body of technical knowledge well suited to the management of pomegranate trees. Traditional plantations were characterized by a specific microclimate that limited evaporation and excessive sunlight, thereby preventing sunburn and other fruit defects. The combination of local know-how and this favorable microclimate resulted in a product of distinctive quality. One effective strategy for conserving both the biodiversity of fruit trees and the associated traditional knowledge would be the implementation of a Protected Denomination of Origin (PDO) or other forms of geographical labeling such as an IG (Geographical Indication). Such measures would promote the valorization, sustainable use, and conservation of farmers' genetic resources and traditional expertise (Saddoud et al., 2021). Establishing an appropriate quality label would therefore serve to protect and enhance this local heritage while enabling the marketing of a distinguished product with specific qualities and significant added value.

Conclusion

The present study highlighted the traditional knowledge and genetic resources of pomegranate (*Punica granatum* L.) in the Testour region. The region's fertile and varied soils, favorable climate, and abundant water resources created ideal conditions for producing high-quality pomegranate fruits. Farmers inherited well-established know-how, particularly in the management of irrigation, maintenance of soil fertility, and practices of propagation and pruning. Landscape considerations were also central to their practices. The adoption of multiple cropping represented a significant advantage for producers, contributing to ecological stability and productivity. Supporting and promoting traditional agricultural systems and their associated cultural landscapes is therefore the most effective strategy to preserve and valorize agrobiodiversity, as these systems have proven resilient and adaptable to changing conditions. Local know-how enables the production of pomegranates with highly appreciated pomological, nutritional, organoleptic, and sensory qualities. Ongoing qualitative analyses of the fruits will further clarify the relationships between the natural, agrotechnical, and social components of the environment and the resulting pomegranate fruit quality in this region.

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Author Contributions

FB was responsible for data collection and analysis, as well as the preparation of the first draft of the manuscript. All authors contributed to the study's conception and design and have read and approved the final published version of the manuscript.

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Conflict of Interest

The authors indicate no conflict of interest in this work.

References

Agnoletti M, Santoro A. 2022. Agricultural heritage

systems and agrobiodiversity. Biodiversity Conservation Journal 31, 2231–2241. https://doi.org/10.1007/s10531-022-024603.

Ben Achour A. 2008. La culture du grenadier (*Punica granatum* L.) à Testour: état actuel et perspectives d'amélioration. Projet de Fin d'Etudes du cycle ingénieur national, ISA Chott-Mariem.

Batello C, Avanzato D, Akparov Z, Kartvelishvili T, Melikyan A. 2010. Gardens of Biodiversity: Conservation of genetic resources and their use in traditional food production systems by small farmers of the Southern Caucasus, 359 pages.

Boussaa F, Zaouay F, Hernandez F, Noguera-Artiaga L, Carbonell-Barrachina AA, Melgarejo P, Mars M. 2018. Cropping system contributes largely to fruit composition and sensory properties of pomegranate (*Punica granatum* L. var. Gabsi). South African Journal of Botany 115, 170-178. https://doi.org/10.1016/j.sajb.2018.01.016.

Boussaa F, Zaouay F, Burlo-Carbonell F, Noguera-Artiaga L, Carbonell-Barrachina AA, Melgarejo P, Hernandez F, Mars M. 2020. Growing Location Affects Physical Properties, Bioactive Compounds, and Antioxidant Activity of Pomegranate Fruit (*Punica granatum* L. var. Gabsi). International Journal of Fruit Science. 16 pages. https://doi.org/10.1080/15538362.2020.1741058.

Evreinoff VA. 1949. Le grenadier Fruits d'Outre-Mer 4(5), 161 – 170.

GIFruits. 2024. Statistics of pomegranate fruit production in Tunisia. http://www .gifruits.com.

Hermi-Sayari M, Moussa M, Rejeb H, Ben Moussa

M. 2020. Analyse des dynamiques de l'espace périurbain et mutations de l'agriculture à Testour. Annales de l'Institut National de la Recherche Agronomique de Tunisie. 93, 332-348. http:/ww.annalesinrat.tn/index.php/sample-data/item/36.

Kahramanoglu I. 2019. Trends in Pomegranate Sector: Production, Postharvest Handling and Marketing. International Journal of Agriculture for Life Science 3(2), 239-246.

Karray S, Ruiz Pulpón AR, Rejeb H. 2021. Elements of maintaining of the moorish identity through the principles of the geniusloci and the requirements of a systemic local development: cities of Testour and GharEl Melh. 8 pages.https://www.researchgate.net/Publication/352030765.

Karray S, Ruiz Pulpón AR, Rejeb H. 2023. New Socio-Spatial Reading of a Remarkable Landscape Located in Testour, toward a Heritage Setting of a Moorish Site. Heritage 6, 2247–2267. https://doi.org/10.3390/heritage6020119.

Mars M, Gaaliche F. 1993. Les variétés de Grenadier en Tunisie, document technique publié et diffusé par le G.O.V.P.F. 32 pages.

Mars M, Marrakchi M. 1999. Diversity of pomegranate (*Punica granatum* L.) germplasm in Tunisia. Genetic Resources and Crop Evolution 46, 461- 467. https://doi.org/10.1023/A:1008774221687.

Nciri R, Rjeb H, Moussa M. 2015. Les paysages de l'eau dans la région du nord-ouest de la Tunisie : Gouvernorats de Béja, Jendouba, Le Kef et Siliana. Revue des Régions Arides 37, 43-70.

Puy A, Balbo AL. 2013. The genesis of irrigated terraces in al-Andalus. A geoarchaeological perspective on intensive agriculture in semi-arid environments (Ricote, Murcia, Spain). Journal of Arid Environments 89, 45-56. https://doi/org/10/1016/j. jaridenv.2012/10/008.

Saadaoui A. 1996. Testour du XVIIe au XIXe siècle, Histoire architecturale d'une ville morisque de Tunisie, Tunis. Publications de la Faculté des Lettres de La Manouba, 558 pages.

Saddoud-Debbabi O, Khanfir E, Dridi MA, Mars M. 2021. Ethnobotanical and on Farm Genetic Surveys of Fig (*Ficus carica* L.) Genetic Resources in Kerkennah Islands. International Journal of Horticultural Science 8 (2),153 163.http://doi.org/10.22059/jhst.2020.310191.396.2020.

Sayari N, Rejeb H. 2009. Origine du paysage andalou dans le nord-ouest tunisien : Testour et son héritage morisque. Cahiers de la Méditerranée 319-335. https://doi. org/10.4000/cdlm.4934.

Sayari N, Moussa M, Rejeb H. 2013. L'ancien système d'irrigation « morisque » à Testour : Un savoir-faire ancestral, ed., ESTEPA, Univ. Valence Espagne., Resp J.P Hermosilla ; In « La Culture de l'eau au bassin méditerranée » 91-111.

Sthapit B, Rana R, Subedi A, Gyawali S, Bajracharya J, Chaudhary P et al. 2012. Participatory four-cell analysis (FCA) for understanding local crop diversity. In: Sthapit B., Shrestha P., Upadhyay M. (Eds.), On-farm management of agricultural biodiversity in Nepal. Good Practices, revised edition 13–16.