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# Evaluation of agrodiversity in the oasis agroecosystems of the Béni-Abbès region (southern Algeria)

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**Abstract.** This study is a contribution to the assessment of agro-diversity in traditional agro-systems of the wilaya of Béni-Abbès (southern Algeria). It made it possible to carry out an inventory of local varieties, crops grown, and traditional know-how. The study is based on field investigations and surveys conducted among oasis farmers. These surveys, structured in the form of questionnaires, made it possible to collect data on agro-biodiversity and the socio-economic aspects of traditional oasis agro-ecosystems. In total, 54 oasis farmers were interviewed in order to collect and characterize the local phytogenetic heritage of the species cultivated in the three studied oases. The results of the surveys and the systemic analysis of the data collected show a remarkable diversification of speculations, with more than 44 different crops recorded, represented by 15 market garden species, 10 cereal and fodder species, 19 condiment, medicinal, and aromatic plants, 5 fruit species, and 5 date palm cultivars among the most consumed. This diversification is also observed in animal production, with a diversity of species (goats, sheep, and poultry). These oases are characterized by the practice of mixed farming and present a remarkable diversity of genetic resources of fruit trees, market garden crops, fodder crops, and local cultivars adapted to arid, dry, and extreme agro-ecological conditions. The inventory carried out on agro-biodiversity constitutes a key element of sustainability and an original database on existing varietal diversity in order to propose appropriate actions for the safeguarding and conservation of this genetic heritage of oasis agroecosystems.

**Keywords:** diversity, agro-system, inventory, sustainability, oasis, Algeria

## 1. Introduction

Oases are anthropized spaces cultivated by intensive agricultural activity within vast arid and desert areas. They are distributed in most of the large dry regions of the world: around the Sahara, in the Maghreb and the Sahel, in the Middle East, on the west coast of Latin America, and in Central Asia [1–3].

For a long time, the inhabitants of the oases have developed their cultures in contact with the plants that they continue to use for several purposes: food, medicine, energy. Plant genetic resources for agriculture constitute the biological basis of local food security and provide livelihoods for all the inhabitants of the region. They represent one of the fundamental elements of the sustainability of the oases and constitute an important natural bulwark against the various factors of degradation of the oasis ecosystem [4–6]. For the oases, plant genetic resources are one of the attributes of their sovereignty and a permanent source of supply to meet their increasingly diversified, dynamic, and growing needs. Agricultural products and by-products are today a major challenge for a population in full demographic growth [6]. Oases play a crucial role in human societies and the conservation of biodiversity, especially in harsh environments like arid zones. They serve as sanctuaries for agrodiversity, preserving diverse agricultural resources under challenging climatic conditions [7].

In North Africa, oasis agroecosystems cover approximately 380,000 hectares, which represents cc. 32.4% of the oases in the Middle East and the North African region [8]. In Algeria, oases are distributed in 17 wilayas, ranging from the north of the Sahara (southern limit of the steppe) to the far south. The oases occupy an area of more than 180,000 ha with more than 1,100 cultivars of date palms recorded and an annual date production of around one million tons [9–10]. Oases are part of Algeria's natural and heritage wealth.

However, Algerian oases have been experiencing a loss of agro-biodiversity for several decades, which continues to accelerate. Indeed, they are now faced with numerous socio-economic and agro-ecological threats and constraints (abandonment, conflicts of use, inheritance, excessive fragmentation, urbanization, tourism, climatic hazards, aridity, silting, wind and water erosion, genetic erosion, water scarcity, monoculture, salinization of groundwater and soils, the ravages caused by certain diseases such as Bayoud, rural exodus), which contribute to increasing their vulnerability and leading to the disappearance of traditional oases [3, 6, 11, 12].

Faced with this situation, the prospection, conservation, and reintroduction of the phytogenetic heritage of the oases are essential to preserve their agrobiodiversity. Senoussi et al. [11] indicate that one of the sustainability factors of the oasis agrosystem is the variability of its genetic resources, both floristic and faunal. The ecological diversity of the Algerian Sahara is at the origin of a diversification of

palm groves, exploitation and management models appropriate to each type of oasis, and its human component. The objective of this study is to inventory and evaluate the existing agrodiversity in the oasis agrosystems of the wilaya of Béni-Abbès (southern Algeria).

## 2. Materials and methods

### *Study area*

The wilaya of Béni-Abbès, located in the extreme southern of Algeria in the Saoura region (*Figure 1*), has been the capital of a new wilaya since 2021. It covers an area of 112,000 km² and is home to a population of 60,000 inhabitants with a density of 1.1 inhabitants/km² [13].

It is bordered to the north by the wilaya of Béchar, to the east by Timimoune and Adrar, to the west by the Kingdom of Morocco and Tindouf, and to the south by the wilaya of Adrar. It contains twenty-eight oases across its vast territory, with a total area of the oases of the Béni-Abbès region. Farmers practise agriculture on a total of 546 oases [14].

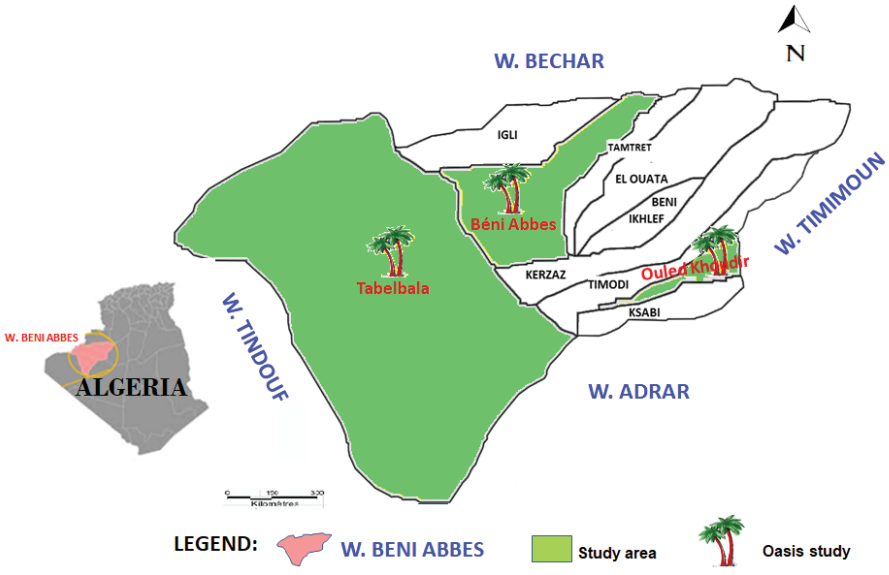


Figure 1. Geographical location of the study area (wilaya of Béni Abbès)

## *Choice of study stations*

The choice of the three studied oases fell on Tabelbala, Béni-Abbès, and Ouled Khoudir following a north, centre, and south transection. These three oases are considered representative of the agroecological diversity of the wilaya of Béni-Abbès. These ancient oases were selected for their diversity and the traditional techniques developed by the Ksourian population (*Table 1*).

– Oasis of Tablebala, in the commune of Tabelbala, covers a total area of 400 ha. The population is 25,992 inhabitants. The climate is of the continental Saharan type with temperate winters.

– Oasis of Béni-Abbès, in the commune of Béni-Abbès, covers an area of approximately 42 ha. It has a hyper-arid Saharan climate characterized by low precipitation that hardly exceeds 50 mm/year.

– Oasis of Ouled Khoudir, in the commune of Ouled Khoudir, covers an area of approximately 541 ha. The climate is dry Saharan with a continental tendency. Annual precipitation is rare and irregular, not exceeding 80 mm, and the temperature can reach 45 °C in the summer.

Table 1. Geographic coordinates of the studied oases

| **Oasis** | **Béni-Abbès** | **Tabelbala** | **Ouled Khoudir** |
|---|---|---|---|
| *Latitude* | 30°7’60”N | 29°24’22”N | 29°15’16”N |
| *Longitude* | 2°10’0”W | 3°15’33”W | 1°3’27”W |
| *Altitude (m)* | 499 | 518 | 380 |
| *Area (ha)* | 42 | 400 | 541 |

## *Methodological approach*

In order to know the situation of the oasis systems of the wilaya of Béni-Abbès, located in southern Algeria, we carried out a diagnosis of the different agricultural land exploitation systems.

### *a. Conducting the surveys*

The assessment and inventory of oasis agrodiversity were based on the technique of semi-directed surveys using questionnaires designed for this purpose. A total of 55 farmers were surveyed and investigated in the three oases of the Béni-Abbès region during the period of March 2021 – June 2022. In each oasis, surveys were conducted with a sample of 20% of the farmers (*Table 2*).

The prospection and inventory of the phytogenetic resources of the three studied oases aim to assess the specific diversity of the three levels (phoenicicole, fruit

and herbaceous arboreal: market gardening, fodder, industrial crops). This will also enable the characterization of the different production factors: surface area of the farms, types of crops, cultivation practices, cultivars, number of date palms, sources and frequency of irrigation, fertilization, labour, animal production, and the parameters for measuring fruit agrodiversity (specific richness, varietal richness).

The surveys of farmers are structured by a questionnaire that guides the interviews and includes aspects relating to agrodiversity and socioeconomics. The importance of each speculation is assessed by estimating the surface area per farm of each crop, the percentage of each crop in relation to the total surface area of the farm, and the ratio between the surface area of each crop and the total surface area reserved for crops on each farm surveyed.

Table 2. Number of farmers surveyed in the studied oases

| Oasis | Béni-Abbès | Tabelbala | Ouled Khoudir | Total |
|---|---|---|---|---|
| Number of farmers | 60 | 80 | 133 | 273 |
| Number of farmers surveyed | 12 | 16 | 27 | 55 |

### *b. Analysis of the surveys*

A careful analysis of the questionnaires will facilitate our subsequent data analysis. The analysis consists of displaying all the parameters and indicators taken into consideration for each site surveyed. The survey data are processed by the Microsoft Excel software.

## 3. Results and discussions

### *3.1. Analysis of some production parameters*

### *a. Areas and land status of the farms*

In the studied oases, the cultivated plots are of small size, with an average area exploited per farmer of around 1.3 hectares. The plots cultivated by farmers in the oasis of Béni-Abbès have an average area of 1.26 ha, of which 83% are exploited by a mixed type in crops and livestock. In the oasis of Ouled Khoudir, the average area is 1.09 ha: 74% of the farmers surveyed are of the mixed type (grow crops and breed livestock), and 89% are of the owner-inheritance type. In the oasis of Tabelbala, the average area is 1.2 ha, of which 100% are of the mixed type combining plant and animal production (*Table 3*).

The majority of the farms are of the family inheritance type, which is to say there is a joint land ownership (passed down in the family), with 75% of the

farms in the two oases of Béni-Abbès and Ouled Khoudir and 89% of inherited farms in the 3rd oasis, of Tabelbala. This predominance of micro-plots exploited, of reduced size by small owners of a family nature, generally in joint ownership, indicates a significant fragmentation of production units (0.5 to 1.5 ha/farmer) in all of the oases.

Table 3. Characterization of farm production in the studied oases

| **Oasis** | **Béni-Abbès** | **Tabelbala** | **Ouled Khoudir** |
|---|---|---|---|
| Average farm area (ha) | 1.26 | 1.2 | 1.09 |
| Owner type (inheritance) | 75% | 75% | 89% |
| Investment | 25% | 13% | 15% |
| Crops (plant production) | 17% | 74% | 25% |
| Mixed (crops and livestock) | 83% | 100% | 0% |

The fragmentation of land, due to the transmission of inheritances, has led to a drop in farmers' income. This situation has also been noted in previous works on oasis agrosystems [15–18]. Indeed, excessive land fragmentation in these oases has a direct negative impact on agricultural productivity, access to means of production, and farmers' incomes, compromising the sustainability of these oasis systems. Policies of land consolidation or incentives for the grouping of plots may be necessary to improve this situation.

### *b. Demographic analysis of operators (age, gender, and academic level)*

The survey was conducted among 55 farmers in the three studied oases. The average age of the farmers was 48, 53, and 54 years of age in the oasis of Béni-Abbès, the oasis of Ouled Khoudir, and in Tabelbala respectively. The population covered by the surveys is relatively old. This choice aims to interview experienced people, with considerable agricultural know-how.

The academic level shows that the illiteracy rate is high, ranging from 38% to 44% depending on the oases: 42% in Béni-Abbès, 44% in Ouled-Khoudir, and 38% in Tabelbala. Secondary education levels vary from 22% to 33% depending on the oases: 33% in Béni-Abbès, 22% in Ouled Khoudir, and 31% in Tabelbala (*Figure 2*).

Concerning the gender-based division of labour among the respondents, men (90%) practise the various agricultural works on the farms (ploughing, planting, irrigation), and women (6%) carry out certain secondary works (harvesting, small livestock, etc.).

These elements highlight the challenges faced by farmers in these oases, particularly in terms of land fragmentation, small cultivated areas, and a relatively low level of education.

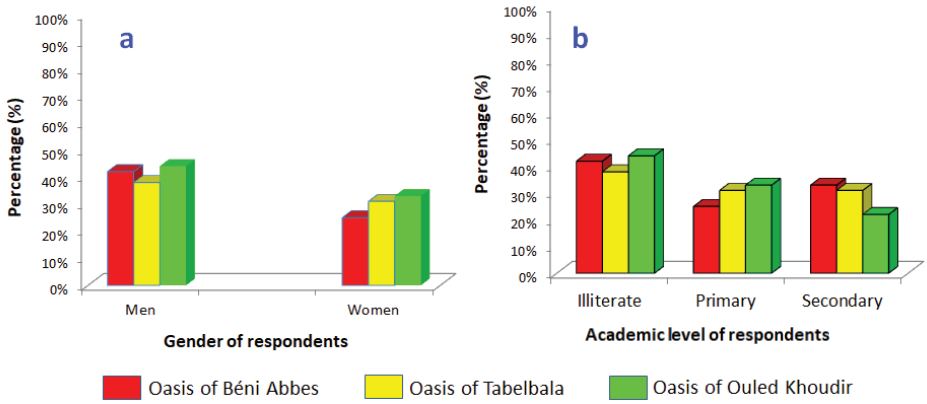


Figure 2. Demographic characterization of respondents in the studied oases (a. gender, b. academic level)

The agricultural practices of local populations are part of the cultural heritage accumulated throughout the history of the region, in the face of a hostile desert climate. This refers to the ancestral knowledge and techniques used by local populations in their agricultural activities. This know-how is the result of long experience and adaptation over time to a hostile desert environment. It is an integral part of the cultural heritage of this region.

Older farmers are very important sources of know-how, but they have a low potential for developing oasis agricultural activities.

## *3.2. Irrigation*

Water resources and irrigation practices vary significantly between the three studied oases (*Figure 3*).

In the oasis of Béni-Abbès, 67% of the farmers use wells for irrigation, with a water cycle of 83 minutes and a frequency of twice a week. In the oasis Ouled Khoudir, the duration of the water cycle is 75 minutes, with an irrigation frequency of once a week (67%), where 85% of the irrigation source comes from wells, compared to 15% from boreholes. For the Tabelbala oasis, the duration of the water cycle is 80 minutes, with an irrigation frequency of once a week (50%), where 44% of the irrigation source comes from wells, compared to 56% from borehole water (*Table 4* and *Figure 5*).

These different strategies show that farmers adapt to the specificities of their oasis, taking account of the available water resources (wells, boreholes) and by accordingly adjusting the frequencies and durations of irrigation [19–21].

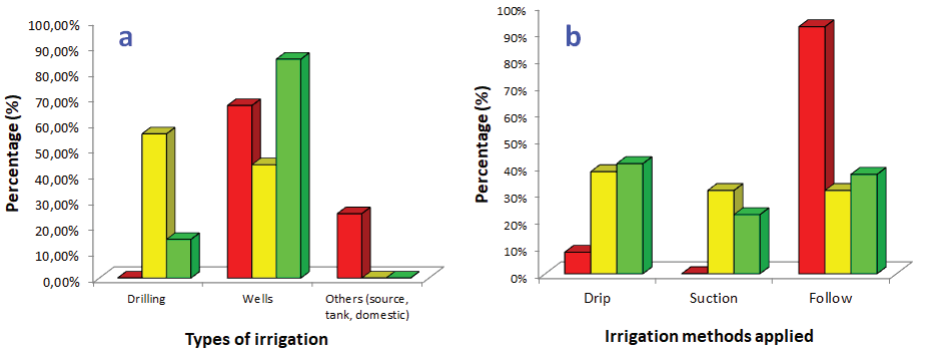


Figure 3. Irrigation practised in the studied oases
(a. types applied, b. methods applied)


Figure 4. Water sources in the studied oases
(a. source, b. well, c. accumulation basin)

Table 4. Fertilization mode in the studied oases

| Oasis | Béni-Abbès | Tabelbala | Ouled Khoudir |
|---|---|---|---|
| Organic manure | 100% | 100% | 100% |
| Mineral fertilization | 70% | 0 | 30% |

### *3.3. Soil improvement*

All farmers surveyed use organic manure to fertilize their plots, once a year and with ploughing. Only 30% of them, in Ouled Khoudir, use chemical fertilizer supplements such as urea and ammonium nitrates (*Figure 6*).

Organic manure has many agronomic, environmental, and qualitative advantages over chemical fertilizers, which explains its widespread use by the farmers surveyed [16, 19].


Figure 5. Fertilization and soil improvement (a. organic manure, b. fertilization method with ploughing)

### *3.4. Characterization and evaluation of agro-biodiversity in oasis production systems*

The oases of the Béni-Abbès region are traditional agrosystems, made up of an association of three plant strata: date palms, fruit trees, and market gardening and fodder crops.

#### *3.4.1. Date palm (Phoenix dactylifera L.)*

The oases of Béni-Abbès bring together almost 17 varieties of date palm [14]. The diversity of cultivated palms is reflected in varieties of early, late, dry, or soft dates. The most dominant date palm cultivars in the oases are: *Cherka*, *Machret*, *Ghars*, *Rdemtirno*, *Faggous*, as well as a few *Dhokkar* trees. The total number of date palms counted in the prospected plots is approximately 896 trees (*Table 5* and *Figure 6*). In Ouled Khoudir, the abundance of date palm is notable, with approximately 1,748 trees. The most popular varieties are *Degla*, *Hamira*, *Tinacer*, *Hartane*, and *Cheikh*, as well as other less profitable varieties and *Dhokkar*. As for

in Béni-Abbès, *Degla, Hamira*, *Tinacer*, and *Hartane* largely dominate in terms of frequency (*Table 6*). In contrast, the Tabelbala oasis shows a very advanced state of degradation with only 397 date palms. The most common varieties are *Faggous*, *Hamira*, *Tinbata*, *Khalt*, and *Adma*, with other varieties present in low percentages and often older.

Table 5. Date palm varieties recorded and frequencies of presence in the studied oases

| No. | **Oasis of Béni-Abbès** | | **Oasis of Tabelbala** | | **Oasis of Ouled Khoudir** | |
|---|---|---|---|---|---|---|
| | *Varieties* | *Number of date palm trees* | *Varieties* | *Number of date palm trees* | *Varieties* | *Number of date palm trees* |
| 1) | Cherka | 311 | Hamira | 90 | Hamira | 516 |
| 2) | Machret | 259 | Tinbata | 78 | Degla | 615 |
| 3) | Ghars | 149 | Khalt | 58 | Tinacer | 279 |
| 4) | Rdemtirno | 128 | Adma | 35 | Hartane | 238 |
| 5) | Faggous | 49 | Faggous | 136 | Cheikh | 100 |
| | Total | 896 | | 397 | | 1,748 |

Figure 6. Phoeniciculture in the studied oases

In traditional mixed farming systems, the date palm (*Phoenix dactylifera*) plays a key role, providing an ecological shelter that maintains a high level of biodiversity. Date palm (*P. dactylifera*) represents an important genetic heritage. It is also the main crop that contributes to the income of date palm farms. It creates a microclimate that is favourable to the development of other crops by moderating the harmful effects of strong winds and intense sunlight. Finally, it constitutes a

food source for humans and their herds, as well as a source of materials for crafts, construction, and energy production [22–25]. The date palm is the only species naturally adapted to this environment and its very hostile climate.

Date palm plays a major ecological role as a structuring species of the ecosystem, but it has a secondary economic role. However, it constitutes an important genetic heritage and represents the main crop in the oasis, ensuring a source of income for oasis farmers compared to other crops [24, 26–28].

### *3.4.2. Biodiversity of fruit species*

Fruit tree growing ranks second in the oasis system. It is also of great interest to farmers due to its low water requirements, fruit production, and the income it generates. The farmers surveyed in the oases of the Béni-Abbès region attach great importance to the conservation of local varieties of certain tree species such as vine, fig tree, apricot tree, peach tree, and olive tree. At the same time, they seek to diversify their production by introducing other species such as lemon and orange trees (*figures 7–8*). Their density is very low, and they are distributed irregularly in the plots. Their production is intended mainly for household consumption.

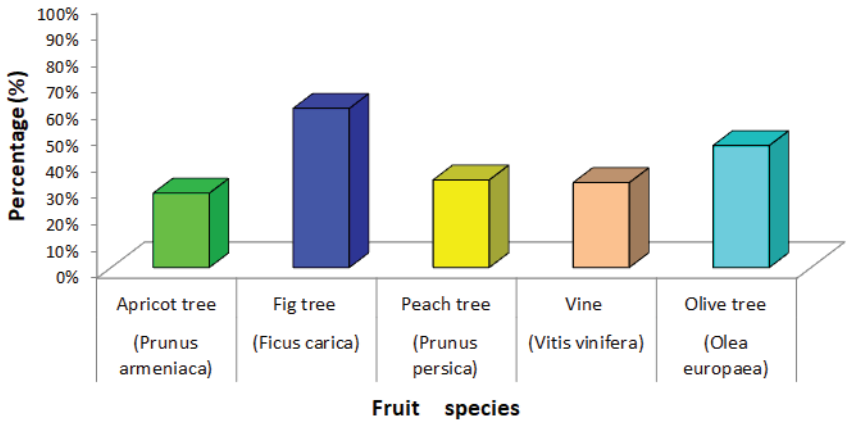


Figure 7. Fruit species in the studied oases

Fruit trees are of particular interest due to the richness of the crops and the diversity of the varieties, and they are a characteristic of traditional agrosystems. Indeed, in the oasis orchards, no less than 14 large fruit species have been identified. Among these species, we can mention:

– Fig tree represents the emblematic tree species of the oasis. It is cultivated by all farmers.

– Vine tree occupies second place in terms of varietal richness.

– The olive tree takes an increasingly important place in the oases of the study area because farmers resort to planting vines in the new extensions in order to support olive cultivation to ensure an annual income.

– Apricot cultivation has shown significant varietal richness despite the small areas.


Figure 8. Fruit species (a. lemon tree, b. peach tree, c. olive tree)

The production of peach, lemon, and orange trees is generally limited to family consumption and is of no economic interest to farmers. In general, the diversity of fruit species is very important. The three emblematic species of the Mediterranean, the olive tree, the fig tree, and the vine, are well represented there [15].

### *3.4.3. Biodiversity of herbaceous crops (cereals and fodder)*

This level is composed of market garden crops, fodder crops, and industrial crops. These crops are grown relatively intensively, with several species being able to succeed each other in the same plot during the year. The cultivated species are very diverse, and several local varieties are still maintained by farmers.

Cereal cultivation is practised by all farmers in the oases studied. It is conducted semi-intensively, with the possibility of several successive species to be cultivated in the same plot throughout the year. The cereal species cultivated are very diverse, including soft wheat, durum wheat, barley, and maize, all local varieties being supported by the farmers (*Table 6* and *Figure 9*).

Table 6. Main cereal and fodder crops in the studied oases

| Oasis | | Béni-Abbès | Tabelbala | Ouled Khoudir |
|---|---|---|---|---|
| *Cereals* | *Soft wheat* | 0 | 100% | 93% |
| | *Durum wheat* | 100% | 0 | 100% |
| | *Barley* | 83% | 88% | 33% |
| | *Corn* | 25% | 0 | 0 |
| *Forage crops* | *Barley* | 83% | 88% | 88% |
| | *Oat* | 67% | 25% | 30% |
| | *Alfalfa* | 25% | 19% | 41% |
| | *Millet* | 67% | 88% | 48% |
| | *Corn* | 25% | 0 | 33% |
| | *Sorghum* | 42% | 62% | 44% |

Fodder crops in relation to the breeding of sheep and goats are increasingly widespread. The feed based on oat, barley, millet, and sorghum makes the cultivation of the latter highly widespread across the oasis. Sorghum is used partly to feed the herd and also constitutes an additional source of income for farmers thanks to its sale on the weekly markets. This plant tolerates and resists salt well, as do other species that are also commonly present in the oasis such as alfalfa (*Medicago sativa*).

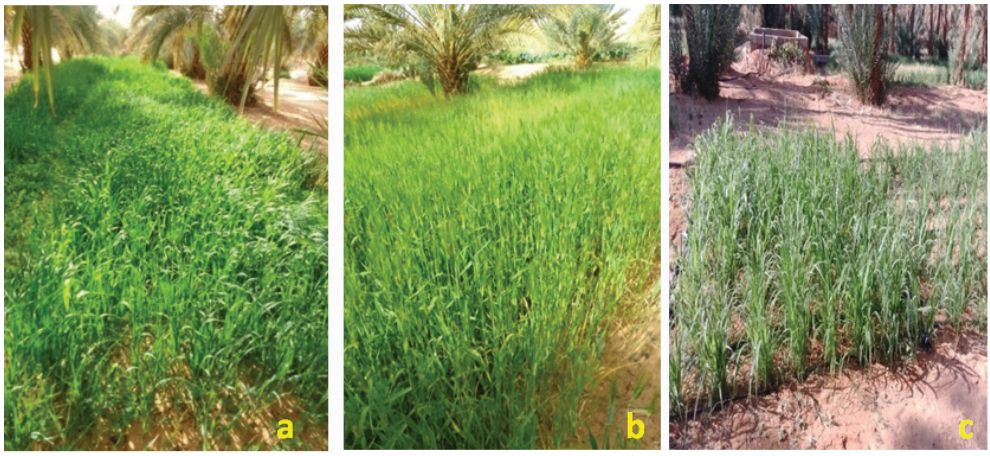


Figure 9. Cereal and fodder crops (a. durum wheat, b. barley, c. millet)

According to the work of [29] and [16], farmers give more importance to fodder crops (such as alfalfa) because of the importance of domestic livestock, often consisting of goats and sheep, in the production system.

### *3.4.4. Biodiversity of vegetable species*

Herbaceous crops in the oases of Béni-Abbès are the most developed plant category, including vegetable crops, cereal crops, and fodder crops, as well as other crops such as condiment crops. This practice is almost universally adopted by the farmers surveyed.

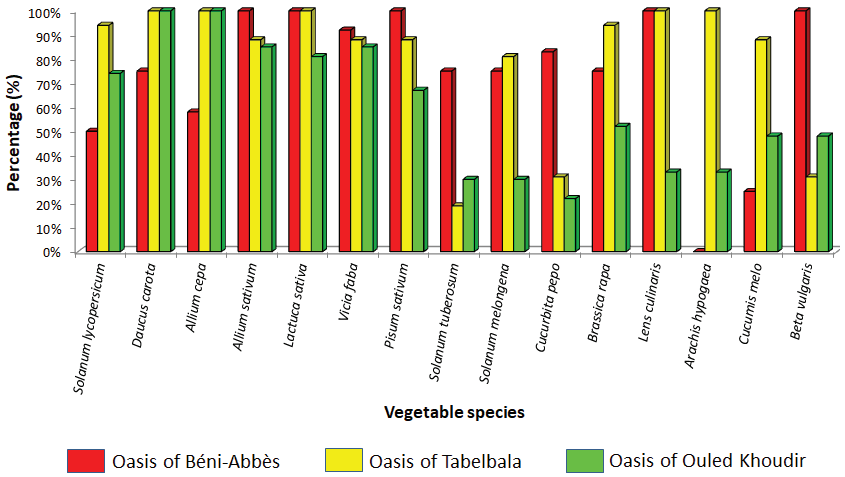


Figure 10. Market gardening crops practised at the studied oases

The cultivation of many species is recorded, with a total of 16 species listed, or an average of 11 species per plot. Market gardening is practised intensively, and the species cultivated are highly diverse, including in particular tomato, carrot, onion, garlic, lettuce, broad bean, eggplant, pumpkin, turnip, melon, and beet.


Figure 11. Market gardening crops (a. beetroot, b. potato, c. bean)

### *3.4.5. Biodiversity of condiment, medicinal, and aromatic species*

Despite the many factors limiting the development and expansion of areas allocated to the cultivation of medicinal, condiment, and aromatic plants, they continue to resist in the oases of Béni-Abbès. In general, they are cultivated in association with other crops.

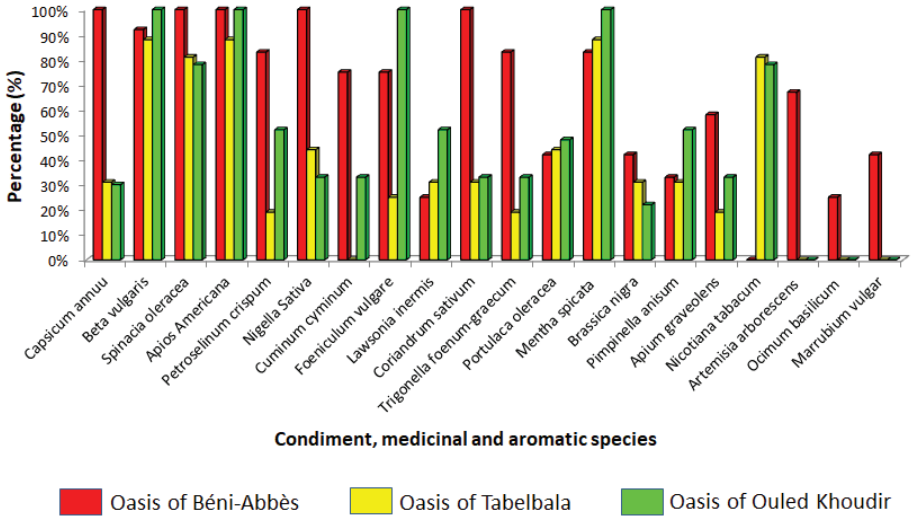


Figure 12. Farmers surveyed practising medicinal and aromatic plant cultivation


Figure 13. Medicinal and aromatic plants (a. parsley, b. wild bean, c. henna)

The main species are henna, tobacco, and pepper. As for the other species, they are currently practised by a very limited number of farmers (*figures 12–13*). There are also special cash crops such as henna and tobacco.

### *3.4.6. Animal biodiversity in oasis farms*

The production system encountered in the study area is characterized by a diversity of production that integrates plant and animal production (Benaradj et al., 2020).

Table 7. Distribution of livestock numbers in the studied oases

| Oasis | Béni-Abbès | Tabelbala | Ouled Khoudir |
|---|---|---|---|
| Sheep | 116 | 114 | 244 |
| Goats | 44 | 49 | 62 |
| Cattle | 0 | 0 | 4 |
| Poultry | 26 | 19 | 72 |

*Table 7* provides details on livestock farming in the three studied oases: Béni-Abbès, Ouled Khoudir, and Tabelbala. In Béni-Abbès, the number of sheep amounts to 116 heads, including 64 ewes, 44 goats, including 32 goats producing 13 litres of milk per day and 26 poultry. As for Ouled Khoudir, there are 244 sheep, including 131 ewes, 4 dairy cows producing 7 litres of milk per day, and 62 goats, including 42 goats producing about 18 litres of milk per day, while the number of poultry is 72. In Tabelbala, the number of sheep is 114 sheep, including 65 ewes, 49 goats, and 32 goats producing about 14 litres of milk per day, and 19 laying hens (*Figure 14*).


Figure 14. Main types of livestock farming (a. goat, b. sheep, c. poultry)

The development of fodder crops is important in all oases, especially with the integration of livestock farming into the oasis agrosystem. The importance of oasis livestock farming is partly based on the sale of animals during the Eid el-Kebir festivals.

In fact, the oasis system is essentially made up of small and medium-sized subsistence farms characterized by the use of traditional farming techniques and intensive and semi-extensive livestock farming, mainly by sheep and goats. For all the studied oases, the agrodiversity is very rich, with the presence of 50 cultivated species recorded: 4 cereal species, 5 vegetable species, 23 market garden species, 5 fodder species, and 13 fruit species. The varietal profile of the date palm tree, which is the keystone species of the oasis agroecosystem, includes several adapted cultivars (*Hamira, Faggous, Ghars Cherka, Machret, Rdemtirno, Degla, Tinacer, Hartane, Tinbata, Khalt, Adma*, etc.).

At the level of the oasis of Béni-Abbès, the crops grown are highly diverse (42 crops) and cover all the major crops: cereals (4), legumes (4), market garden crops (21), fruit crops (10), and fodder crops (3). In the oasis of Ouled Khoudir, 30 crops are recorded in all of the oasis farms: 4 cereals, 2 legumes, 13 market garden crops, 10 fruit crops, and only alfalfa as a fodder crop. Indeed, in the oasis of Tabelbala, 32 crops are recorded: cereals (3), legumes (2), market garden crops (14), fruit crops (11), and fodder crops (2).

In Algeria, most oasis production systems are essentially based on the association of four levels: phoenicicole level (date palm), arboricultural level (fruit arboriculture), herbaceous level (market garden and fodder crops), and livestock level.

According to Kradi et al. [30], this diversification of crops allows the family not only to meet its needs but also to finance (source of self-financing) certain agricultural works (ploughing, sowing, harvesting).

This set, which contains a significant genetic diversity, constitutes a harmonious and complementary system [16, 17, 19, 31–32]. This differentiation by the importance of diversity in the different strata reflects a certain specialization. This difference in diversity is due to several factors, including geographical particularities, water availability, and local knowledge [29].

According to Ater and Hmimsa [15], Boucherit et al. [33], Houssni et al. [26], Loumerem et al. [31], Salhi [17], and Aljane et al. [34], oases, like all traditional agroecosystems, are characterized by the practice of mixed farming and generally show a remarkable level of diversity, constituting a self-subsistence system to meet household needs.

In this system, various early and late cultivars are grown to cover consumption throughout the year. All production (dates, vegetables, and fruit) is intended for household consumption. Surplus production is intended for the local and regional market. Oasis agroecosystems constitute a refuge for agricultural diversity and represent a very important opportunity to conserve agrodiversity and maintain

agricultural activities well adapted to local ecosystems, with a view to the sustainable development of these regions [26].

## 4. Conclusions

This inventory work undertaken in the three oases of the wilaya of Béni-Abbès shows a very high phytogenetic diversity of cultivated plant bioresources by identifying adapted local cultivars. This diversity reveals 44 species distributed between 15 species of market garden crops, 10 species of cereals and fodder, as well as 19 condiments, medicinal, and aromatic species. In addition to the 2,500 date palm trees dominated by cultivars (*Hamira, Faggous, Ghars Cherka, Machret, Rdemtirno, Degla, Tinacer, Hartane, Tinbata, Khalt, Adma,* etc.), there are also 5 fruit species in the oases studied, among which the fig tree stands out as the most dominant species. As for agrodiversity, it is staged in three layers and constitutes an important phytogenetic heritage in desert regions with a hyper-arid climate.

The oases and in southern Algeria represents systems based on a strong agrobiodiversity and good practices of farmers, ecological territories, and favourable habitats. These factors are economic drivers for local populations. The oases of Béni-Abbès are characterized by the dominance of the date palm with an interesting varietal diversity. The underlying crops are also very diverse. The date palm occupies a preponderant place, followed by fruit trees, market gardening, and fodder crops. The great diversity of cultivated species and their vertical distribution in three strata are: (i) the tree layer of date palm, (ii) the tree-shrub layer of various fruit trees, and (iii) the underlying herbaceous layer dominated by cereal and fodder crops. This important agrobiodiversity has a true biological potential of plant genetic resources and constitutes a challenge for the in-situ conservation and sustainable development of the studied oases.

In perspective, the safeguarding of endangered species and varieties, the reintroduction of extinct species, and the conservation of the phytogenetic heritage of the oasis are essential to preserve the adaptation and production potential of oasis cultivation systems. Therefore, it is necessary to preserve these genetic bioresources of oasis species in their natural environment, which allows maintaining their adaptive potential in the face of environmental fluctuations. This conservation can be based on the production of local seeds, the creation of specialized nurseries, the conservation plots of adapted indigenous varieties/cultivars, and their reintegration into the productive process of the oases. These advantages of phytogenetic resources deserve to be supported for a better preservation of this plant heritage, which can be integrated into sustainable development and participatory conservation actions. The preservation of the oasis space and agrobiodiversity will allow to maintain the socioeconomic and ecological interest of the region and to sustainably enhance its potential.

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