# Confronting a date monoculture in Tunisia: Can underused date varieties decrease farm economic vulnerability?

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***Abstract***

*Crop diversity is promoted for its environmental benefits. However, few analyses have been conducted on whether crop diversity can reduce farm economic vulnerability to multiple production stresses. Deglet Noor is the most frequently grown variety of date in Kebili Region, Tunisia. Other date varieties, termed "common date varieties", were formerly considered to be less profitable and hence marginalised. Date production in this region is facing constraints linked to climate change, decreasing water availability and rising labour costs. The study compares the economic benefits of producing Deglet Noor dates and common date varieties at farm level, when faced with different production stresses. A survey was made of 123 farmers producing dates in Kebili Region. In the absence of stress, Deglet Noor is the most profitable variety, but its profitability is particularly vulnerable to different stresses. By contrast, the profitability of common date varieties is much less sensitive to these stresses. Stress-free environments become increasingly rare in Tunisian oases. Hence, re-directing interest towards common date varieties could help build less vulnerable oasis farming systems.*

***Keywords***: *Climate change, Crop diversification, Dates, Economic vulnerability, Profitability, Underutilised crops, Tunisia.*

## 1. Introduction

Crop diversity has frequently been shown to enhance the environmental sustainability of agricultural systems (Beillouin *et al*., 2019; Tamburini *et al*., 2020). In practice, however, many agrosystems worldwide are organised around a single or a few crops (Martin *et al*., 2019). In ag-

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ricultural systems in which most farms produce for the market, for crop diversity to be adopted or be maintained, a key enabling factor is that plot or farm level diversity produces a higher average income. However, monoculture may be more profitable or may be considered by farmers to be more profitable than diversified systems, particularly in the short term (Lin, 2011). Incentives to monoculture may include sustained market demand, especially thanks to the creation of specialised value chains and supporting public policies, plus the possibility of driving down costs including through mechanisation, simplified farm management, or limited labour needs (Salaheen, 2019; Bravo-Peña and Yoder, 2024). In addition, even when crop diversity does reduce farm economic vulnerability, farmers may not have sufficient information and consequently continue to favour monocropping (León Araya, 2023).

The many studies on the benefits of crop diversity analyse its impacts on the environment and on agricultural production but are less focused on farm profitability (Beillouin *et al*., 2019). The few studies that considered farm profitability showed that there is no standard correlation between crop diversity and farm profit: the relation is context-specific (Bravo-Peña and Yoder, 2024). Thus, a problem is what kind of economic data could be made available to the actors of specific agrosystems to inform the discussion of whether farmers would be better off if they diversified their crop production.

Moreover, over the past decade, there has been a growing interest about the role of neglected and underutilized species as a component of agricultural system diversification (Padulosi *et al*., 2021). Broadly, these species can be defined as species that: 1) have long-standing cultivation in a specific environment and are well-adapted to it; 2) have limited production and value chain or have been marginalised; and/or 3) have received minimal attention from agricultural innovation systems (Mabhaudhi *et al*., 2019). These species are increasingly praised for the key role they can play in transitions towards more sustainable agricultural systems in a context of climate change and natural resource degradation (Hossain *et al*., 2021). Studies on neglected and underutilised species have often focused on their environmental or nutritional benefits (Ali and Bhattacharjee, 2023; Chivenge *et al*., 2015), whereas few studies have considered whether these species can become a profitable alternative to major crops. Their authors generally found that there was a need to improve marketing and processing options to improve their profitability so that they become of genuine economic interest to farmers (Bandula *et al*., 2023; Morimoto *et al*., 2021).

Crop diversity is a major issue in southern regions of Tunisia. More than 250 local date varieties can be found in oases located in these regions (Rhouma, 2005). In the 1970s, the government developed an agro-industrial value chain to export dates (Gendre *et al*., 2007). The chain focused on the variety Deglet Noor because of its high yield potential, easy storage, and market demand. In the 2022/2023 season, Deglet Noor accounted for 85.7% of dates exported from Tunisia (Onagri, 2023). Kebili Region has become the main region for the production and export of dates in Tunisia, and Deglet Noor is now at the core of the entire agricultural system of the region (Benmoussa *et al*., 2022). However, production of Deglet Noor is currently affected by an increasing number of risks. First, in 2021, an outbreak of mites affected date production and caused serious damage to Deglet Noor palm trees in particular. Second, Deglet Noor palm trees require a lot of irrigation and water is becoming increasingly scarce in traditional oases (Mekki *et al*., 2022). Third, production of Deglet Noor is costly, especially due to labour needs, and the cost of labour has been increasing rapidly in recent years. Compared with Deglet Noor, common date varieties have lower production costs and the palm trees of theses varieties are known to adapt to water scarcity better than Deglet Noor.

In this context, some farmers and staff of the regional office of the Ministry of Agriculture in Kebili Region have shown increasing interest in investigating whether producing more common date varieties could help reduce the vulnerability – particularly the economic vulnerability – of farms facing increasing risks that affect date production. However, little local economic data is available to inform a discussion on this issue. The present article compares the economic benefits of producing Deglet Noor dates and those

of common date varieties at farm level, in the face of various production stresses.

Moreover, common date varieties can be considered as neglected and underutilised species. North Africa possesses a rich but underexploited genetic heritage of date palm varieties (Ismaïl and Hassine, 2021; Ouamnina *et al*., 2024). Discussions about the role of neglected and underutilised species in fostering more resilient agricultural systems have been ongoing for several decades in sub-Saharan Africa, Latin America, Europe, and Asia (Padulosi *et al*., 2021). However, apart from a few studies (e.g., Dop *et al*., 2019; Koussani *et al*., 2022), this discussion has been relatively limited in North Africa. In many regions of North Africa, the production of capital-intensive crops has contributed to economic development but has led to increasingly fragile agricultural systems, because of climate change and the often-unsustainable use of natural resources (Kadiri *et al*., 2022). Thus, the promotion of common dates could become a promising example of making use of the rich agrobiodiversity in North Africa so as to improve the long-term sustainability of agricultural systems.

## 2. Impacts of crop diversification on farm economic vulnerability to production stresses

The few studies on linkages between agrobiodiversity and economic vulnerability of farms generally found that crop diversification reduces income variability, although this is not always the case (Lennox, 2015). Moreover, some authors report that the impact of crop diversification on average farm income is positive and others that it is negative (Asare *et al*., 2014; Schroth and Ruf, 2014). Many factors influence the linkage between crop diversity and farm income, including the specificities of each agrosystem or farming practices (Bravo-Peña and Yoder, 2024; Niether *et al*., 2020). Linkage depends on the respective weights of "economies of scale", i.e. increasing the production of one product increases farm productivity, versus "economies of scope", i.e. when the integrated production of multiple outputs increases productivity (De Roest *et al*., 2018).

Studies of the economic impacts of diversification on farm income variability have mostly considered stress caused by climate, markets, and diseases. Several studies focused on a single stress: Clément *et al*. (2023) simulated the impact of fluctuations in the price of farm products on farm income in one region in Vietnam. Bozzola and Smale (2020) measured the impact of diversification on the variability of farm income in Kenya in a context of climate variability. Auffhammer and Carleton (2018) used a regional approach in India to study the impact of crop diversification on farm income variability in the face of drought. Other studies of crop diversification considered different stresses simultaneously, for example, climate and markets (Lennox, 2015) but they did so without measuring the specific economic impact of each type of stress. Kozicka *et al*. (2020) considered risks concerning climate and plant diseases to simulate the income of a representative farm under various crop diversification scenarios in Uganda. The model used in their study accounted for multiple factors and evaluation criteria, but the complexity of the model makes it difficult to present the data obtained to agricultural system actors.

Some analyses of the impacts of crop diversification on farm vulnerability have focused on underutilised crops. These crops are generally considered to decrease production risks. Indeed, such crops often only require limited quantities of pesticides and fertilizers (Chivenge *et al*., 2015), they are generally adapted to local soil, water availability and quality, and to local climate conditions, and their production may be less damaging to the environment (Baldermann *et al*., 2016; Mattas *et al*., 2024; Tadele, 2018). Some of these crops may have limited markets but still play a major role in home consumption (Boulay *et al*., 2021). Such studies often argue that underutilised crops offer cross-cutting solutions to multiple constraints (Mabhaudhi et al., 2019). However, there is limited knowledge on the impact of producing underutilised species on farm economic vulnerability.

In terms of methods, most studies that analysed the economic benefits of crop diversity measured farmers' income in situations of low versus high crop diversity without considering

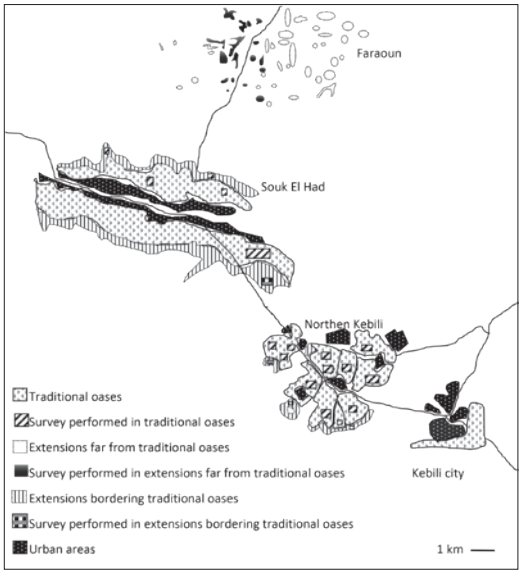
how risks can affect these benefits (e.g. Hayran *et al*., 2018; Kurdyś-Kujawska *et al*., 2021; Zabala *et al*., 2023; Mzyece *et al*., 2023). Other studies considered farmers' perception of risks as an explanatory factor of diversity, without calculating the real impact of diversification on farmers' incomes (Bernzen *et al*., 2023). Only a few authors measured the impact of crop diversity on farm benefits when farms face with specific stresses (e.g. Clément *et al*., 2023), and such studies generally only assessed the impact of one type of production stress. However, to be able to discuss the economic advantages of crop diversification with local actors, all major production stresses need to be included. To our knowledge, to date, no study has measured farmers' incomes by comparing a situation of monoculture and crop diversity when the farm faced different types of stress.

## 3. Method

### 3.1. *Study site*

Dates have been produced for centuries in traditional oases in Kebili Region. From the 1990s on, farmers started planting new palm groves, locally referred to as "extensions". At first, the extensions were located in the vicinity of traditional oases. Later on, farmers started drilling individual boreholes much farther away from these oases, to create additional extensions. This led to a major increase in land planted with date palm trees. In 2022, traditional oases in Kebili Region accounted for 10,500 ha and extensions for 32,700 ha (Mekki *et al*., 2022). In traditional oases, most irrigation water is obtained from collective boreholes that are managed by water user associations. Plots in these traditional oases often have insufficient access to water, both in terms of quantity and in terms of frequency, as the time between water turns ranges from 25 to 60 days. As a result, some farmers in traditional oases have drilled individual boreholes to supplement the water supplied by the water user associations. Drilling boreholes in traditional oases and in extensions is illegal, as the administration considers that the aquifer is overexploited, but farmers continue to drill.

Figure 1 - Study area in Kebili Region, Tunisia.




Two study areas were selected for the present study (Figure 1). The first comprises the traditional oases plus the surrounding extensions in northern Kebili district. This area was selected because it has the largest number of common date palm varieties in Kebili Region. The second one is Faraoun extension area in Souk El Had district. This area is representative of the new palm groves that have been developed far from traditional oases thanks to easy access to groundwater.

There are three categories of date varieties: semi-dry dates, dry dates and soft dates. Soft varieties are harvested continuously, while semi-dry and dry varieties are harvested all at once. Dry and semi-dry varieties can be stored and are consequently easy to export. Deglet Noor is a semi-dry variety. Soft varieties are characterised by high-water content, which exposes them to fermentation and makes them difficult to store. They have to be sold within two to four weeks after harvest. Most soft varieties are grown for self-consumption and any excess is distributed to family members and neighbours.

### 3.2. *Methodological framework*

Farm economic vulnerability is sometimes assessed "ex ante", i.e. an assessment of the extent to which farms could be affected by possible

Table 1 - Framework for the comparison of common date varieties with the reference Deglet Noor variety in different situations and stresses.

| *Type of stress* | *Situation involving limited stress* | *Situation involving high stress* |
|---|---|---|
| Water scarcity | Plot in a palm grove extension or in a traditional oasis but with access to an individual borehole (no problem of access to enough water) | Plot located in a traditional oasis with no access to an individual borehole (major problems linked to access to water) |
| Mite infestation | Year 2022 (minor problem) | Year 2021 (major problem) |
| Cost of labour | Year 2022 (minor problem) | Future scenario for the year 2030 (major problem) |

risks. In this approach, vulnerability is generally measured using a set of indicators that consider exposure, sensitivity and adaptive capacity of the farm to several risks (Baca *et al*., 2014; Shaibu *et al*., 2020). In the present paper, we consider economic vulnerability "ex post", i.e. the degree to which a farm is harmed due to a perturbation or stress (Turner *et al*., 2003). Additionally, methods differ in the indicators used to measure vulnerability (Sneessens *et al*., 2019) and whether the point of view is static or dynamic (Dardonville *et al*., 2021). Hereafter, we focus on the extent farm annual income was affected by a specific stress that happened. We consider various settings in which farm exposure, sensitivity and adaptive capacity differ to compare farm vulnerability to stresses that really exist.

We built a methodological framework to compare the economic benefits of producing Deglet Noor versus common date varieties when faced with three kinds of stress: water availability, mite infestation, and labour costs (Table 1). The reference situation with no stress is production in extension areas where access to irrigation water is easy and the year was 2022, when labour costs were a minor issue and farming practices successfully limited mite infestation. We compared yields and farm incomes, measured as net benefit per date palm tree, which is what the farmers in Kebili Region usually do. Production costs were calculated and included the capital costs of drilling boreholes and installing solar panels, which is almost the only source of energy in the in extensions (Mekki *et al*., 2022) and the cost of the irrigation equipment (see Appendix A for details). The capital costs of drilling a borehole in traditional oases were also considered.

We compared a situation in which a stress is present and a situation in which the same stress is absent or only has a minor impact on production. Thus, in the present paper, our definition of economic vulnerability only applies to the "short-term" and does not account for the "long-term" capacities of farms to evolve, to reduce sensitivity to stresses and apply adaptive actions.

The first stress – water availability – was taken into account by comparing the situation in three different types of plots. The first situation refers to plots located in the extensions, where access to water is easy. The second situation covers plots in traditional oases that have an individual borehole, so access to water is consequently also easy. However, in traditional oases, the plots owned by farmers are usually fragmented as a result of inheritance, the date palms are sometimes more 60 years old so yields are decreasing, and pests circulate between the farm plots easily. Consequently, the production conditions are much better in extensions than in plots in traditional oases even in cases where the latter have access to sufficient water. The third situation refers to plots located in traditional oases but have no individual boreholes, meaning water availability is a major constraint. We compared net income per Deglet Noor palm and per common date palm in the three situations.

The second stress was caused by the dust mite Oligonychus afrasiaticus, which is one of the four main date palm pests in Tunisia. These mites can cause severe damage to the fruit (Ben Chaaban *et al*., 2011). Infestation by these mites increases during heat waves (Palevsky *et al*., 2003), which are becoming more frequent under climate change. Deglet Noor was found to be

more sensitive to dust mites than several common date varieties (Ben Chaaban *et al*., 2011). Dust mites have been present for years in Kebili Region but in the past, their impact was limited and farmers rarely treated their date palms against mites. In 2021, infestation by mites was very high due to high temperatures and a drought and seriously affected yields and farm incomes. In 2022, a new treatment method had become available and information concerning it was given to farmers, which resulted in a much more limited infestation than in the previous year. We thus compared the income per Deglet Noor palm and that of common date varieties in 2021 and 2022, while also accounting for the different situations in terms of water availability, as it had an impact on tree sensitivity to stress.

In southern regions of Tunisia, agricultural labour is becoming increasingly scarce and expensive, as young people are less interested in farming and migrate in search of better jobs (Carpentier, 2018). Over the past decade, labour costs have increased above and beyond inflation and the cost of labour for date production increased at an annual rate of 14.5% between 2015 and 2022 (calculated in constant currency i.e. adjusting for inflation). Other production costs and the selling price of dates increased broadly at the same pace as inflation over the same period. We built a business-as-usual scenario by 2030 in which we considered that all costs and prices would follow national inflation and that labour costs would continue to increase at the same rate above and beyond inflation. We calculated the impact of increased labour cost on the profitability of date production in this scenario. We compared the income per Deglet Noor palm with the income per common date palm in 2023 and under such a scenario by 2030 (considering the situation in traditional oases and in extensions).

### 3.3. *Data collection and analysis*

A survey of 123 farmers was carried out in May 2023. Farmers were asked how many date palms they had, about their production costs (detailing cost categories as detailed in Appendix A), yields, and the selling prices for all date palm varieties they grew in 2021 and 2022. They were also asked about the date varieties and number of palm trees they had planted over the period 2007-2022 and the date varieties and the number of trees they planned to plant in the period 2023-2032.

Together, the 123 farmers managed a total of 182 plots, of which 122 plots are located in traditional oases and 60 plots in extensions. Nineteen percent of farmers who owned plots in traditional oases had their own borehole they used to irrigate the plot in addition to the water they obtained from collective boreholes. The average planting density in plots located in traditional oases was 150 palms per hectare and farmers had an average of 0.63 ha, usually divided into several plots. The planting density in plots in the extensions was on average 120 palm trees per hectare, while the farmers farmed on average 4.5 ha.

The farmers interviewed reported that the Deglet Noor variety dominated both in traditional oases (70% of palm trees) and in extensions (90%). Taken together, the farmers we interviewed grew 41 varieties of common dates in traditional oases and 26 varieties in extension areas. Female trees of common date varieties represented 28% of all trees in traditional oases and 9.5% in extensions. The remainder were male palm trees whose pollen can fertilize female palm trees of any variety.

Apart from Deglet Noor, the most prevalent common semi-dry variety was Alig, which accounted for 47% of common date palm trees in traditional oases, and 56% of common date palm trees in the extensions. Alig is often planted to make date paste which is used in pastry making; it has an established international market and fetches a good price. Kenta was the most prevalent dry variety in traditional oases and in extensions and represented 17% of common date palms in the oases and 19% in the extensions. In recent years, actors of the date value chain in Kebili Region have been paying increasing attention to the Kenta variety because it has an international market often in countries where consumers want cheap dates. Moreover, it is increasingly used to manufacture date powder, since dry dates are easily ground and dried. Gosbi was the most prevalent soft variety, representing 2.2% of common date palm trees in

traditional oases and 2% in the extensions. Our comparative economic analysis with the reference variety Deglet Noor only included the three common varieties most present in each category, i.e., semi-dry (Alig), dry (Kenta) and soft (Gosbi), in the traditional oases and extensions of the study area.

## 4. Results

### 4.1. *Production costs*

Table 2 lists the production costs for Deglet Noor, Alig, Kenta and Gosbi varieties in the plots located in traditional oases without access to an individual borehole and in extensions. In the traditional oases, the cost of irrigation water corresponds to the amount paid to the water user association. When farmers also have an individual borehole in traditional oases, irrigation costs increase by 6.6 Tunisian Dinars (TND) per tree (on top of what they pay to the water user association), thus total production costs were 96.9 TND for Deglet Noor variety and 58.9 TND for Alig, Kenta and Gosbi varieties (in May 2022, 1 US$ = 3.1 TND). The Deglet Noor variety is labour-intensive, the labourers have to climb the trees several times in the season to perform tasks including pollination, chiselling and destemming, bagging, removing palm fronds and harvesting. Other varieties only require two tasks: pollination and harvesting. Chiselling and destemming are not done for common date varieties because these dates are not marketed according to size. Bagging is not used for common dates because they are more resistant to rainfall and are harvested before the beginning of the rainy period. Dry palm fronds are not removed from common date palm trees because these trees are considered to be more resistant than Deglet Noor trees to insects that may develop in these parts of the trees. Common date palm trees also require less fertiliser than Deglet Noor. The overall cost of producing Deglet Noor, in both extension and traditional oases, is thus much higher than the cost of producing Alig, Kenta and Gosbi.

### 4.2. *Reference situation and impacts of water scarcity*

Table 3 lists the yields of the four main varieties found in both traditional oases and extensions, in the three above-mentioned plot situations in 2022. In traditional oases, the com-

Table 2 - Production cost of Deglet Noor, Alig, Kenta, and Gosbi in 2022.

| | *Plot in a traditional oasis (without access to an individual borehole)* | | *Plot in a palm grove extension* | |
|---|---|---|---|---|
| | *Deglet Noor* | *Alig-Kenta-Gosbi* | *Deglet Noor* | *Alig-Kenta-Gosbi* |
| Average cost per palm tree in 2022 (Tunisian Dinars - TND) | | | | |
| Irrigation water | 7.3 | 7.3 | 8.3 | 8.3 |
| Labour related to irrigation | 1.8 | 1.8 | 4.2 | 4.2 |
| Labour for other date production tasks | 49.0 | 20 | 49.0 | 20.0 |
| Plot cleaning (removing dry palm fronds, etc.) | 0.6 | 0.6 | 0.8 | 0.8 |
| Fertilisation | 7.1 | 3.8 | 7.7 | 4.4 |
| Tillage | 6.3 | 6.3 | 6.3 | 6.3 |
| Positioning plastic bags to protect the dates | 4.1 | 0 | 5.8 | 0 |
| Sulphur treatment to prevent against mite attacks | 11.0 | 11.0 | 12.5 | 12.5 |
| Transportation cost to buyer | 1.6 | 0 | 2.0 | 0 |
| *Total production costs* | 88.8 | 50.8 | 96.6 | 56.5 |
| Share of labour in total production cost (%) | 55 | 39 | 51 | 35 |

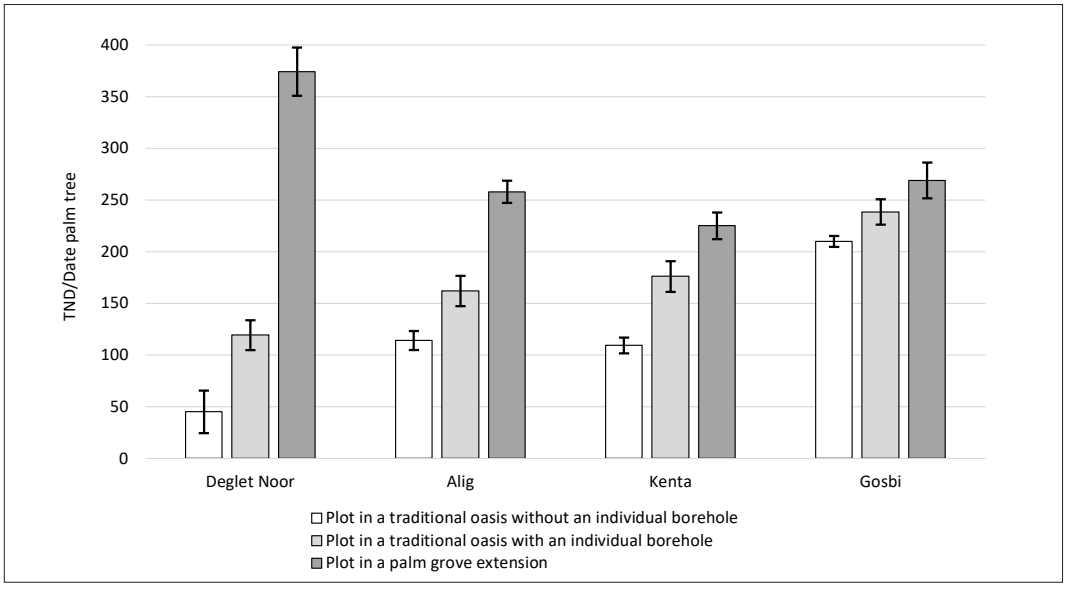
Table 3 - Yields and selling prices of the four date varieties in traditional oases and extensions.

| *Variety* | *Deglet Noor* | *Alig* | *Kenta* | *Gosbi* |
|---|---|---|---|---|
| *Yields* | | | | |
| Plot in a traditional oasis without an individual borehole (kg/tree) | 85 | 112 | 180 | 65 |
| Plot in a traditional oasis with an individual borehole (kg/tree) | 130 | 120 | 200 | 75 |
| Plot in a palm grove extension (kg/tree) | 185 | 155 | 221 | 85 |
| Decrease in yield between a plot with an individual borehole and one without a borehole in a traditional oasis (%) | 34 | 6.6 | 10 | 13 |
| *Average selling price (TND per kg)* | | | | |
| In traditional oases<br>In extensions | 1.6<br>2.5 | 1.7<br>2.1 | 1<br>1.3 | 4<br>4 |

parison between plots with and without access to an individual borehole shows that water stress reduces Deglet Noor yield by one third. Common date varieties are more resistant to water scarcity. Table 3 also shows selling prices. Deglet Noor dates are classified according to their quality, each class has a specific selling price (Table B1 in appendix). The price given for Deglet Noor in Table 3 represents the average price that accounts for the different quality classes. This classification is not used for other varieties, for which there is only one overall price.

Figure 2 shows the income per palm tree in the three plot situations in 2022 (in this figure and in following one's bars represent standard errors). Income per Deglet Noor palm tree was low in a situation of water stress resulting from a marked drop in yield along with high production costs. In plots located in traditional oases and equipped with a borehole, the income was also low. This was not due to water scarcity, but rather because in 2022, problems connected with mite infestations of Deglet Noor palm trees were still affecting these oases. Common date varieties were more profitable than Deglet Noor in traditional oases. However, the price of Alig and Kenta varieties has only increased significantly in the past 10 years and farmers seldom plant new trees in traditional oases. This explains why Deglet Noor was still the most planted variety in

Figure 2 - Income per date palm tree in 2022.



traditional oases. Moreover Figure 2 only gives the income if the entire yield is sold. Gosbi is a soft variety, it is consequently highly perishable and can only be sold in the two weeks following harvest, which limits its sales potential. As a result, a considerable proportion of the yield (approximately 80%) is destined for home consumption or given to relatives.

### 4.3. *Impacts of mite infestation*

The major mite infestation of date palms in 2021 affected many of the palm trees belonging to the farmers we interviewed (Figure 3). That year, high temperatures and long periods between irrigation water turns in traditional oases created a favourable environment for the development of mites. In traditional oases, Deglet Noor trees appeared to be more affected by the mite than common date varieties. According to a representative of the Kebili date technical centre, mites develop preferably on tender leaflets, which is the case of Deglet Noor palm trees. By contrast, most common date palm trees have hard leaflets. Moreover, there are more mites on trees that are harvested late in the season. Deglet Noor is harvested between November and December, i.e. later than Gosbi (mid-August), Kenta (early October), and Alig (late October). In the extensions, water is present and irrigation is regular. This creates a humid microclimate that is unfavourable for the development of mites.

In 2022, a sanitary protocol for mite prevention had been communicated to farmers: 86% of the farmers in the extensions we interviewed and 57% of farmers in traditional oases applied it. Thus, palm trees were much less infested both in traditional oases and in extensions, compared with in 2021. Still, there were differences: farmers more generally cleaned the palm groves and sprayed sulphur power as a preventive treatment in the extensions. In traditional oases, fewer farmers applied the treatment and the palms belonging to a farmer who had applied the treatment could still be infected later on because neighbours had not carried out the treatment. Thus, in 2022, mite infestation remained higher than in traditional oases than in extensions.

Due to inflation, production costs and selling prices for Deglet Noor were higher in 2022 than in 2021 (respectively 15% and 23% higher). This was due to mite infestation, especially because there were far fewer dates of good quality available on the market. However, the sharp increase in price between 2021 and 2022 did not affect the fact that, between 2015 and 2022, produc-

Figure 3 - Percentage of palm trees infested by mites in 2021 and 2022.

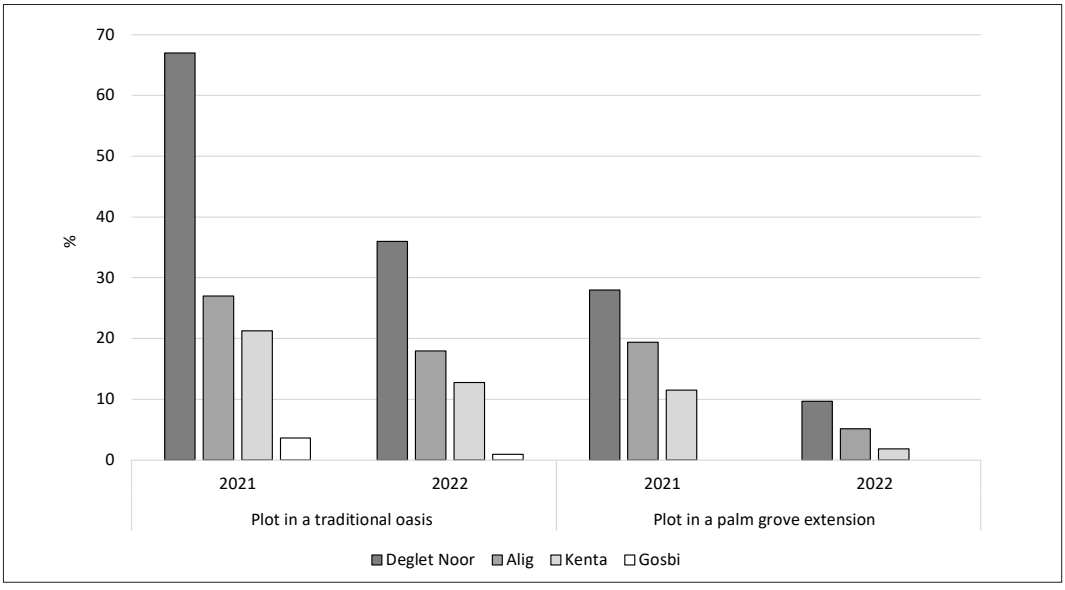
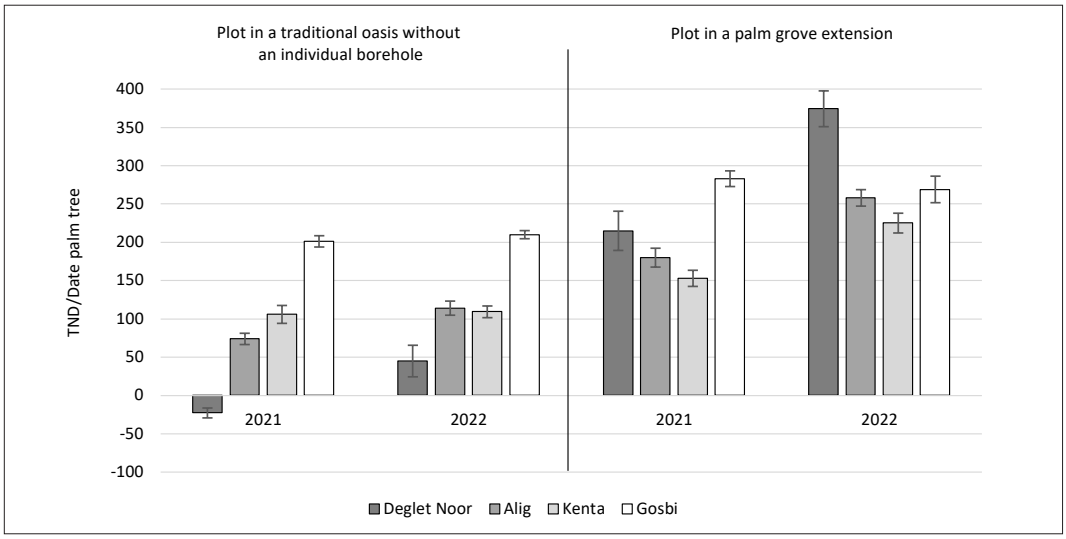


Figure 4 - Comparison of palm tree income between 2021 (high mite infestation) and 2022 (limited mite infestation).




tion costs and the selling price followed national inflation rates. By contrast, the selling prices for common varieties remained stable between 2021 and 2022. In 2021, due to the drop in yield, the income from the Deglet Noor variety (calculated on average for a whole plot) was negative in a plot located in a traditional oasis with no access to a borehole (Figure 4). By contrast, the income from common date production in plots located in traditional oasis without access to an individual borehole was not much affected by the mite infestation. In the extensions, the Deglet Noor variety remained profitable in both years, because the infestation rate remained low.

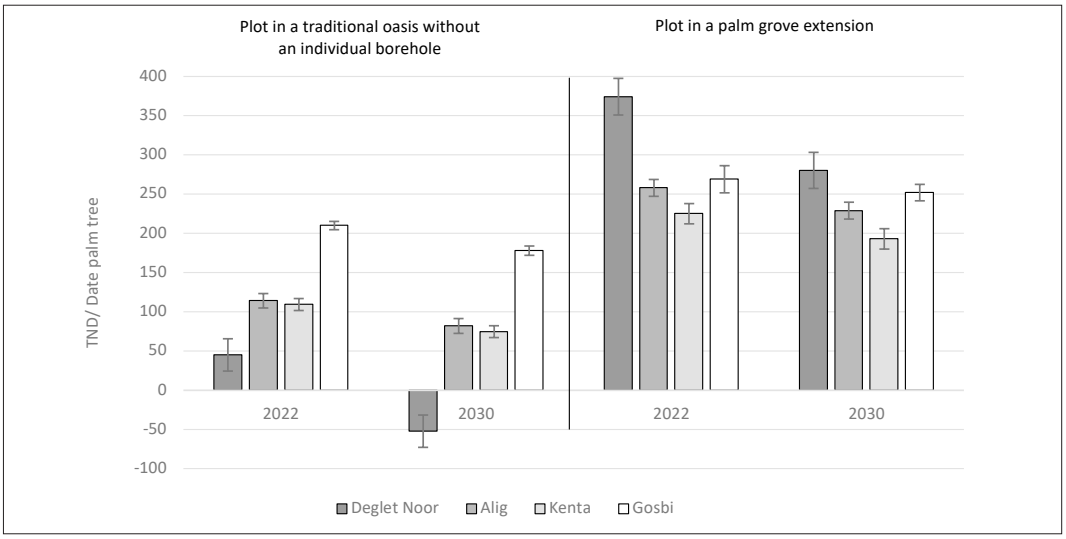
### 4.4. *Future impacts of increasing labour costs*

Figure 5 shows date palm tree income in traditional oases (without access to a borehole) and in extensions, according to a future scenario for 2030 whereby: 1) production costs (excluding labour) and selling prices increase at the same pace as national inflation; 2) labour costs continue to increase at the same rate over and above the inflation rate as they did between 2015 and 2022. In Figure 5, prices in 2030 are presented using constant dinars as of 2022. In such a scenario, by 2030, labour costs for Deglet Noor will represent 84% of total production costs in an extension and 86% in a traditional oasis. In the extensions, Deglet Noor will remain the most profitable variety even though the increase in production costs reduces the difference in profitability between Deglet Noor and other varieties. In such a scenario, in traditional oases, income from Deglet Noor will become negative due to rising labour costs. The decrease in the profitability of common date varieties is much lower and these dates will remain profitable in traditional oases under this scenario. In fact, growing common date varieties can help solve the growing problem of labour scarcity not only because less work is required for production, but also because harvesting of common date varieties is spread out over a much longer period than that of Deglet Noor.

### 4.5. *Plantation of palm seedlings*

Farmers mostly plant palm seedlings in extensions, as space is available there to extend cultivated areas. In plots located in traditional oases, planting new trees would require removing existing palm trees, which in practice, very seldom happens. In the extensions, most of the farmers we interviewed planned to continue planting Deglet Noor (75% of planned trees) and Kenta, Alig and Kentichi will represent most of common date varieties (together more than 23% of

Figure 5 - Palm tree income in a future scenario by 2030 involving increasing labour costs.




planned trees, Table 4). Kentichi is a dry variety used for making date powder, a product whose national and international markets have expanded in recent years. The number of farmers who planned to plant the Alig variety during the period 2023-2032 was three times higher than the number of farmers who planted Alig during the period 2007-2022. The same evolution is expected for Kenta.

Farmers continued to favour Deglet Noor because the market for the variety remained stable, especially the export market but the farmers we interviewed confirmed that they had become aware of the interest of cultivating common date varieties in order to continue making a profit despite increasing risks. Alig, Kenta and Kentichi were the preferred common date varieties because they had also an acknowledged export market. Moreover, unlike some other common date palm varieties, their seedlings are easy to find. More specifically, the 20 farmers who planned to plant Kenta, Alig or Gosbi (instead of Deglet Noor) mentioned that (i) demand on the national and export market was high for Alig and Kenta (15 farmers); (ii) these 3 varieties were resistant to water stress and diseases and required limited labour (12 farmers); (iii) they value biodiversity per se, which is considered to be a local patrimony (7 farmers); and (iv) 5 farmers planned to grow Gosbi for self-consumption.

## 5. Discussion

In situations where production is fully under control, i.e. access to sufficient water, controlled labour costs, prevention of diseases and pest infestations, etc.), Deglet Noor is clearly more profitable than common date varieties. However,

Table 4 - Past and scheduled plantation of main palm varieties.

| | *Deglet Noor* | *Alig* | *Kentichi* | *Kenta* | *Gosbi* |
|---|---|---|---|---|---|
| Share of interviewed famers having plots in extensions that planted each date variety during 2007-2022 (%) | 57 | 7 | 5 | 7 | 2 |
| Share of interviewed farmers having plots in extensions than plan to plant each date variety during 2023-2032 (%) | 43 | 20 | 8 | 20 | 5 |

the profitability of Deglet Noor is much more at risk than the profitability of common date varieties in the event of drought, high labour costs and pest infestations. Common date palms are physiologically more robust to different types of stress and since their cost of production is lower, the income obtained from their production is less affected by changes in these costs.

In the future, date production factors in Kebili Region will probably be increasingly difficult to control. Water in traditional oases will probably become increasingly scarce, due to the growing difficulties of running water user associations (Mekki *et al*., 2022). Extensions already face a continuing drop in groundwater levels due to intense pumping for irrigation (Mekki *et al*., 2022). Moreover, the increasing number of abandoned plots in traditional oases (already observed in 2023), will likely significantly increase the occurrence of pests and diseases. Due to climate change, conditions will increasingly favour infestation by dust mites. Consequently, in extensions, and to an even greater extent in traditional oases, factors enabling Deglet Noor profitability may be increasingly less certain in the future. Moreover, in extensions in which farmers still plant trees, choosing the variety of date and hence the degree of crop diversification will increasingly involve a trade-off between profitability and risk management (e.g. Kurdyś-Kujawska *et al*., 2021).

Increasing numbers of studies point out that, while "modern" agricultural systems perform well when production conditions make it possible to get the best out of new crops (or varieties), when such conditions are not met, "traditional" varieties fare better e.g. thanks to their ability to cope with harsh climate conditions (Assefa *et al*., 2021). Underutilised species are increasingly acknowledged to have a promising role to play to build sustainable farming systems under climate change (Hossain *et al*., 2021). The present study has shown that the profitability of common date varieties is already valid compared with Deglet Noor, like in other examples of underutilised species (Galappaththi and Schlingmann, 2023). Common dates involve lower economic risks than "modern" input-intensive crops, due to their lower investment costs. Thus, they do fit the three criteria proposed by Gruere *et al*. (2006) for defining underutilised species: "they are locally abundant but globally rare, that scientific information and knowledge about them is scant, and that their current use is limited relative to their economic potential".

## 6. Conclusion

Deglet Noor monoculture has been the backbone of agricultural – and more generally of the economic – development of Kebili Region since the 1970s. This model is increasingly jeopardised by the increased occurrence of production stresses. In addition to the well-known ecological advantages of diversification, the present study shows that producing common date varieties can reduce the economic vulnerability of farms to several production stresses.

At a time of climate change and degradation of natural resources, Tunisian agricultural policies should focus less on economic growth of the date sector and instead identify pathways to build more resilient agricultural systems in oases. The promotion of common date varieties can be a major pillar of a strategy towards resilient agricultural systems. First, the type of analysis presented in this paper could be disseminated to help change in the opinion of many actors (farmers, other actors of date value chains, staff of public administrations) who still consider Deglet Noor to be the only variety to be promoted and marketed. Second, specific support could be provided to help farmers plant common date varieties in traditional oases – where these varieties will become more and more adapt to local production stresses than Deglet Noor. Third, support to the marketing of common dates is needed, both on the national and on the international market.

Many crop diversification studies analyse the factors that explain farmers' decisions to opt for crop diversification. Such studies are very useful when the case for diversification is clear and the main question is what can be done to support farmers in diversifying. In Kebili Region, like in many other regions worldwide, the debate is still underway about how and to what extent it makes sense to opt for more crop diversity, es-

pecially from the farmer's perspective, and in some places the debate has hardly even started. One of the obstacles to this debate, which should include among others farmers and public actors in charge of agricultural policies, is lack of data. The present study shows it is indeed possible to build an "economic case" for crop diversification. By comparing the farm level profitability of various diversification options when farmers face a series of stresses, the method detailed in the present paper can produce data that can be easily used to inform discussion concerning the appropriate level of crop diversity in an increasingly uncertain environment.

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## Appendix A

Hereafter we detail the costs considered for undertaking economic analysis.

a) Irrigation water

In traditional oases, this corresponds first to the cost paid to the water user association. This is calculated as the tariff per hour multiplied by the number of irrigation hours during one year. In case farmers have a borehole (in extension and in traditional oasis), this cost includes the capital cost of drilling a borehole and buying irrigation equipment and solar panels (duration of equipment considered as being 20 years). Energy costs are generally nil because of the wide spread use of solar energy and maintenance costs are negligible.

b) Labour related to irrigation

Cost of date palm irrigation labour per irrigation multiplied by the number of times trees are irrigated per year.

c) Labour for other date production tasks

Producing Deglet Noor variety requires that labourers climb palm trees several times per season: once for removal of the palm, twice for pollination, once for chiselling and manipulation of the date regime, once for bagging, and once for harvesting. Each ascent involves a special labour price per tree. By contrast, common date trees require only two ascents for pollination and harvest.

d) Plot cleaning

One hectare requires three days of cleaning for one employee.

e) Fertilisation

This task is two-pronged. First, every year, farmers deposit ammonium nitrate around each tree. Second, once every three years, farmers plough around the trees, put diammonium phosphate, and add manure around date palm trees.

f) Tillage

Every year, farmers hire a service-provider that comes with a tractor and till the whole plot.

g) Positioning plastic bags to protect the dates

Plastic bags are used to protect date bunches from rainfall and mosquitoes. A palm tree in a traditional oasis contains an average of 12 bunches as palm trees are older, whereas in the extension it contains an average of 17 bunches, one mosquito net bag per bunch. They are renewed on average once every three year.

h) Sulphur treatment to prevent against mite attacks

Farmers spray sulphur two times, from 2021 onwards. The calculation did not take into account additional treatment in case of mite attack.

i) Transportation cost to buyer

Yield of Deglet Noor date is generally high in each farm so farmers need to hire a truck to transport harvested dates to middle men. By contrast, due to small quantities, farmers transport common dates using their own vehicles.

## Appendix B

Table B1 - Classification of the Deglet Noor variety.

| *Categories of dates fruits of Deglet Noor* | *First choice* | *Second choice* | *Third choice* | *Dates in bulk (fallen from the fruit bunch)* | *Livestock feed* |
|---|---|---|---|---|---|
| Selling price of the Deglet Noor variety (TND/kg) | 3.7 | 2.5 | 1.5 | 1 | 0.2 |
| Percentage of quantity sold for each choice in 2022) | | | | | |
| Plot in a traditional oasis without an individual borehole (%) | 17 | 25 | 15 | 7 | 36 |
| Plot in a traditional oasis with an individual borehole (%) | 25 | 25 | 15 | 7 | 28 |
| Plot in a palm grove extension (%) | 50 | 10 | 25 | 5 | 10 |