



A prioritised inventory of crop wild relatives and wild harvested plants of Tunisia

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Abstract An inventory of crop wild relatives (CWR) and wild harvested plants (WHP) occurring in Tunisia, based on the integration of the last available floristic checklists, is presented. The taxa were prioritised according to economic value of the related crop, potential for crop improvement, threat status, endemism, inclusion in the ITPGRFA (Annex I) and average annual contributions to dietary energy (kilocalories) per capita per day by applying a scoring system based on 4 priority levels. Of a total of 2912 taxa belonging to the Tunisian Flora, 2504 CWR and/

or WHP (86% of the total), from 143 families and 686 genera, were identified, 2445 of which are CWR and 847 are WHP. In detail, 1654 are solely CWR and 59 are WHP only, whereas 788 are both CWR and WHP. The final priority list for active conservation includes 1036 CWR (43% of the total CWR taxa), with 139 taxa rated as high priority, 660 medium priority and 237 low priority. The final priority list for WHP is composed of 344 taxa and includes eight high priority, 254 medium priority and 82 low priority taxa. Our results confirm Tunisia as a hotspot of CWR and WHP diversity in the Mediterranean area. The inventory here proposed provides the basis for the development and implementation of a more targeted national CWR/WHP conservation strategy for Tunisia.

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Introduction

Crop wild relatives (CWR) are wild plant species closely related to cultivated species of socio-economic value, such as those providing food, fodder, industrial materials, ornamentals, and biofuels (Maxted et al. 2006). CWR play a central role for breeding purposes due to their potential or actual ability to supply beneficial genetic traits for crop improvement (Harlan and de Wet 1971; Maxted et al. 2006, 2010). The Mediterranean region is a centre of diversity for wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), olive (*Olea europaea* L.), carrot (*Daucus carota* L.), cabbages (Brassicaceae) and other major food crops. In this area, some native plants host useful traits that can improve the cultivation of their related crops, such as *Brassica insularis* Moris, a SW Mediterranean endemic that occurs in coastal habitats, which confers resistance to the fungal pathogen *Leptosphaeria maculans* (Sowerby) P.Karst. in hybrids with *B. oleracea* (Mithen and Lewis 1988), or *Aegilops ventricosa* Tausch, which is used in providing resistance to numerous pests and diseases in common wheat (e.g., cyst nematode, leaf rust, stem rust) (Vincent et al. 2013). Additionally, CWR, as components of natural and semi-natural ecosystems, together with other wild species play a role in ecosystem functioning and in broader environmental sustainability and the maintenance of ecosystem services (FAO 2019a). In the frame of a more sustainable, low-input agriculture (Crespo-Herrera and Ortiz 2015; Duru et al. 2015), CWR often represent an under-exploited source of genes for ensuring food security (FAO 2006, 2009a). Furthermore, global challenges, such as climate change and a continuous rise in the human population, are posing a huge threat to biodiversity, affecting both CWR and wild harvested plants (WHP)—undomesticated species typically harvested from the wild by local people. Consequently, potential loss in beneficial and useful traits (Hajjar and Hodgkin 2007; Castañeda-Álvarez et al. 2016; Dempewolf et al. 2017) suitable for granting everyone access to nutritious and safe food, is emerging as a major

concern, together with the awareness that protecting biodiversity and ensuring food security are part of a single agenda (Godfray 2011). Food security is pursued by several means and, among them, by the development of new varieties resistant to diseases, pests, or environmental stresses, such as extreme temperatures, drought, and flooding, that require less inputs for their cultivation. Many crop varieties are being replaced with stress tolerant varieties to ensure yield stabilization and continuity of cultivation in altered environments due to climate change, soil degradation or pollution (Mammadov et al. 2018). Crop improvement can be obtained by using existing crop agrobiodiversity (Jacobsen et al. 2015) but also broader-based diversity can be introgressed through the introduction of traits from their wild relatives, which are adapted to diverse habitats and have not passed through the genetic bottleneck of domestication (Vollbrecht and Sigmon 2005; Hajjar and Hodgkin 2007). The conservation of these plant genetic resources (PGR) is therefore a priority for agriculture and environmental sustainability because it can help to increase sustainable crop production (Reeves et al. 2016) and reduce negative impacts on future food security.

WHP have for millennia provided the primary source of fuel, construction material and food, and even today they are a valid supplement to the diet and medicine for peoples of the Mediterranean Basin (Vavilov 1926; Harlan and de Wet 1971; Morales et al. 2013; Landucci et al. 2014; Maxted and Vincent 2021). According to the World Health Organization, 65% of the world population rely on plant derived products as sources of therapeutic agents for their health care (Fabricant and Farnsworth 2001). Lavania (2005) estimated that nearly 6000 species of plants are exploited for their traditional, herbal, or medicinal characteristics. There is also a clear link between medicinal plants and food as demonstrated by the Mediterranean diet (Willett 2006; Sofi et al. 2010) where leafy vegetables are collected to add variety and nutrition to the diet (Heywood 1999). These plants, used as a food source locally, also have the potential to increase food security and nutrition of people living in harsh environments (Uljan et al. 2020). After a surge in their use at the turn of the two World Wars or during famine and food scarcity periods (Petropoulos et al. 2018), and a slight decline at the end of the twentieth century, today the interest in these plants as additional

sources of healthy functional food, non-nutrient bioactive compounds and medicine has been rekindled, not only in developing countries (Keller et al. 2005; Termote et al. 2011), but also in the wealthy ones (Padulosi et al. 2011; Menendez-Baceta et al. 2012; Sánchez-Mata et al. 2012; Geraci et al. 2018; Ulian et al. 2020). Nowadays, much of the research on these plant species is focused on their nutritional, toxicological, and medicinal aspects (Soumaya et al. 2013; Zouari et al. 2013; Pinela et al. 2017), but there are still other features to be investigated, such as agronomic aspects for their potential domestication and cultivation (Molina et al. 2016). An example is *Argania spinosa* (L.) Skeels, whose oil is exported all over the world and represents a real economic resource for Morocco (Lybbert et al. 2011). Conserving WHP is therefore of paramount importance not only from a biodiversity point of view but also because they represent a substantial part of that ethnobotanical knowledge which is today at risk (Schultes 1991; Menendez-Baceta et al. 2012). They contribute either directly or indirectly to the balance of ecosystems, providing several services, such as landscape diversity, bee-activity and pollination, and pest control (Cardinale et al. 2012; Bretagnolle and Gaba 2015).

Like all the other wild plants, both CWR and WHP are subject to threats of genetic erosion due to excessive exploitation, habitat modification and population reduction (Brummitt and Bachman 2010; Bilz et al. 2011; Kell et al. 2012). The importance of these PGR and the need to conserve them are recognized through international commitments made by governments such as the Second Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture (Second GPA), a strategic framework for global conservation and sustainable use of PGR (FAO 2011), and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (FAO 2009b). The issue of PGR conservation has also been stressed by the Strategic Plan for Biodiversity 2011–2020, its Aichi Targets (<https://www.cbd.int/sp/targets/>), and the Global Strategy for Plant Conservation 2011–2020 (GSPC) (CBD 2012), which are now under an update process for the preparation of the post-2020 Global Biodiversity Framework (CBD 2018). It plans to implement broad-based action to bring about a transformation in society's relationship with biodiversity. Therefore, the need of national CWR and WHP

inventories as a basis for planning sound conservation strategies is well recognized (Maxted et al. 1997; Kell et al. 2008; CBD 2015; FAO 2017). The Mediterranean Basin is the third world hotspot of CWR diversity in terms of the number of global priority CWR after Western Asia and China (Vincent et al. 2013). In theory, all CWR/WHP should be preserved, but using the broad concept of CWR (Maxted et al. 2006) can ultimately result in the inclusion of an extremely large number of taxa. For example, in Europe, where 83% of the entire flora can be classified as CWR in a broad sense (Kell et al. 2008), active conservation of all taxa would obviously exceed the available resources. Hence, the need for prioritisation of taxa emerges when effective conservation strategies must be planned and conducted (Ford-Lloyd et al. 2008; Maxted and Kell 2009; Kell et al. 2017). Maxted et al. (2013) distinguish between checklists, annotated checklists, and inventories. In summary, checklists report only the names and some basic data; annotated checklists add more data about the related crops; inventories add to the checklists important data that characterize the considered taxa (related crop, degree of relatedness, Red List status, etc.).

A global CWR inventory containing 1667 priority taxa, 195 of which are from North Africa (Algeria and Morocco), was developed by Vincent et al. (2013). At the same time the importance of local, national, and regional inventories has been recalled several times (Maxted et al. 2007; Maxted and Kell 2009). In Europe, all countries already have national CWR checklists generated by the PGR Forum project (Kell et al. 2005, 2008) and some have prioritised inventories of CWR (e.g., Magos Brehm et al. 2008; Fielder et al. 2015; Labokas et al. 2018; Ciancaleoni et al. 2021). For Africa, there is a regional inventory of CWR of the Southern African Development Community (SADC) region (Allen et al. 2018) and one of the North African region (Lala et al. 2018). However, even if there are several SADC countries with CWR checklists and inventories (e.g., Allen et al. 2019; Mponya et al. 2020), this information is lacking for the North African countries. A checklist of 5780 CWR taxa from North Africa, representing 76% of its flora, was recently presented (Lala et al. 2018). The inventory reported 502 taxa identified as a priority for conservation.

With the aim of extending and deepening the information available about the conservation and

threat status of CWR and WHP in North African countries, in this paper we present a prioritised inventory of crop wild relatives and wild harvested plants of Tunisia based on the latest available checklist of the Tunisian flora (Le Floch et al. 2010).

Materials and methods

CWR and WHP checklist

The checklist of the flora of Tunisia (Le Floch et al. 2010) was integrated with the data available in the African Plant Database (version 3.4.0) (<http://www.ville-ge.ch/musinfo/bd/cjb/africa>; Dobignard and Chatelain 2010–2013) and Euro + Med Plantbase (<http://ww2.bgbm.org/EuroPlusMed>).

Based on this integrated checklist, CWR taxa, all taxa within the same genus as a crop, were identified, after checking for synonyms, using the crop genus list of Kell et al. (unpublished data), similarly to other authors' approaches (e.g., Kell et al. 2015; Contreras-Toledo et al. 2018; Rahman et al. 2019). The taxonomic nomenclature was harmonized by referring to International Plant Name Index (IPNI 2020), The Plant List (2021) and Plants of the World online (POWO 2019). The level of crop relatedness of each taxon, according to the Gene Pool (Harlan and de Wet 1971) and Taxon Group concepts (Maxted et al. 2006), was determined by using the resources available at Germplasm Resources Information Network (USDA 2021) and at The Harlan and de Wet CWR inventory (Vincent et al. 2013). Ancillary information in the database were compiled according to Thormann et al. (2017): family; genus; species; taxonomic rank; native, introduction or invasive status; endemism; Red List status; common and scientific name of the related crop; type and level of relatedness; local cultivation status (i.e., whether under cultivation or not); gross production value of the related crop; synonyms and use category.

The WHP taxa identification was based on their known uses in Tunisia and derived from direct knowledge and interviews conducted during the last two decades across the country by the first author. Ethnobotanical surveys were carried out in the villages of 19 out of the 24 Governorates of Tunisia in the period from September 2001 to May 2021, as shown in Table 1. Folk uses of plants were investigated through interviews and discussions with the knowledgeable

persons of the visited villages or/and communities (AFG: Aged Forest Guards, EF: Elderly Farmers, S: Shepherds, THS: Traditional Herb Sellers). The specimens mentioned by the informants were identified on site or collected together in the field to confirm the identity of the discussed ethnosppecies. The gathered data were filled in a database reporting the diverse known uses/remedies of different used parts of each ethnosppecies. The identified taxa were then sorted and matched with their related scientific names. In order to verify and confirm our findings, the results of these surveys were then compared and integrated with relevant previous ethnobotanical studies within various Tunisian regions/localities (e.g., Le Floch 1983; Boukef et al. 1982; El Mokni 2004; Ben Haj Jilani et al. 2011; Ben Ismail 2013; Ben salah et al. 2019; Dop et al. 2020; Karous et al. 2021). This ethnobotanical database was finally combined in the above-mentioned checklist of the flora of Tunisia to select the taxa definable as WHP. The use categories chosen were: drink, environmental, ethnobotanical, fodder, food, food addition, fuel, material, medicinal, ornamental, and social. In addition, it is indicated if the taxa investigated are poisonous or if they are of interest for honey production.

Prioritisation

The prioritisation process used the following criteria (derived and adapted from Maxted and Kell 2009; Magos Brehm et al. 2010, 2017; Kell et al. 2015, 2017; Lala et al. 2018): (a) the economic value of the related crop, derived from FAOSTAT (2012–2016) for Tunisian agricultural gross production (FAO 2019b), and organized according to the classifications of products used for the statistical purposes in FAOSTAT Commodity List; (b) the degree of relatedness following the Gene Pool (GP) concept (Harlan and de Wet 1971): GP1B (for wild or weedy forms of the crop, i.e. crossing is easy and hybrids are generally fertile), GP2 (secondary wild relatives, i.e. less closely related species from which crossing is still possible but more difficult), GP3 (tertiary wild relatives, i.e. species from which gene transfer to the crop is impossible, or requires sophisticated techniques). When information on crossability between CWR and crop species was unavailable, the Taxon Group (TG) concept (Maxted et al. 2006): TG1b (same species as the crop), TG2 (same series or section as the crop), TG3 (same

Table 1 Ethnobotanical surveys conducted in Tunisia from 2001 to 2021 with the different types of informants

Tunisian biogeographical entity	Governorate	Village/Community	Period	Informants		
Kroumirie	Jendouba	Aïn Draham	2001–2021	AFG		
		Fernana		AFG		
		Ghar Dimaou		AFG-EF		
		Tabarka		S		
Mogods	Bizerta	Ghar El Melh	2001–2021	S		
		Mateur/Bazina		AFG-EF		
		Mateur/Sidi Nsir		AFG		
		Ras Jebel		AFG		
	Beja	Utique	2014–2015	EF-THS		
		Beja South/M'farig		EF-S		
Valley of Medjerda	Beja	Nefza	2012–2021	AFG		
		Beja North/El Manchar	2014–2018	EF-S		
		Beja North/Ksar Mezouar		EF-S		
		Testour	S			
Northeastern part	Bizerta	Bizerta North/Nadhour	2001–2021	AFG		
		Bizerta South/Rimel		AFG		
Cap Bon	Tunis	Ariana/Sidi Amor	2012–2014	AFG-S		
	Nabeul	Beni Khiar/Ghardaïa	2018–2020	EF		
		Beni Khiar/Soumâa		EF		
Haouaria	AFG					
Central Tunisia	Monastir	Moknine/Amira	2015–2021	S		
	Mahdia	Kerker		S		
	Sousse	Enfidha/Takrouna		S		
	Siliana	Kesra	Makthar	2017–2018	AFG	
					Siliana South/Sidi Hmada	AFG
					Siliana South/Sidi Hmada	AFG
	Kasserine	Thelpete	Rouhia	2004–2011	EF	
					Sbeitla	S
					Sbeitla	S
	Kairouan	Oueslatia	2015–2016	S		
Tunisian Dorsal	Sidi Bouzid	Sidi Bouzid North/Mghila	2014–2015	EF-S		
	Beja	Teboursouk	2018–2019	S		
		Le Kef		Dahmani	2019–2020	S
	Le Kef	Nebeur	Sers	S		
		Sers		S		
	Southern Tunisia	Zaghouan	El Fahs	2004–2011	EF	
Zaghouan			AFG			
Medenine		Medenine North/Tajera	2001–2004	AFG-S		
		Medenine South/Béni Ghzaeil		S		
		Medenine South/Naffeteya		S		
		Béni Khdêch/Ain Tanout		S		
Sidi Bouzid		Sidi Bouzid South/Bouhedma	2012–2018	AFG		
Tataouine		Bir Lahmer	Douiret	2001–2004	S	
	Douiret				S	
	Remada				May 2021	THS

Table 1 continued

Tunisian biogeographical entity	Governorate	Village/Community	Period	Informants
	Tozeur	Tozeur East/Dghoumes	2014–2015	AFG
		Tozeur North	2001–2011	S
	Gabes	Chenini	2011–2015	S
		Matmatas		AFG-S
	Gafsa	El Ksar/Lalla	2017–2019	AFG-THS
		Metlaoui/Selja	2017–2018	THS

AFG: Aged Forest Guards, EF: Elderly Farmers, S: Shepherds, THS: Traditional Herb Sellers

subgenus as the crop) and TG4 (same genus as the crop). When CWR were related to multiple crop taxa, the most closely related species was used to define the GP or TG (Jarvis et al. 2015), and in case of GP/TG parity, the most economically important related crop cultivated in the country was given priority; (c) threat status based on the IUCN Red List of Threatened Species (IUCN 2021) and other threat assessments (CoE 1979; Garzuglia 2006; MEDD 2009); (d) endemism to Tunisia or North Africa (African Plant Database; MEDD 2009; Dobignard and Chatelain 2010–2013; Domina and El Mokni 2019); and, (e) the related crop importance estimated by the combined use of inclusion in Annex I of the ITPGRFA (FAO 2009b) and, only for CWR, the inclusion on ITPGRFA Annex I or the Food supply contribution calculated as the average annual (2014–2018) contributions to dietary energy (Kcal/capita/day) for the Northern African region (FAO 2021). (Table 2).

The CWR were identified as all taxa within the same genus as a crop with some exceptions due to nomenclatural updates or to genera universally recognized as ancestors of other cultivated genera (e.g., *Aegylops* ancestor of *Triticum*). The taxa were scored, on a scale of 0 to 10, against each of the 5 above-mentioned criteria, and a final score (FS) was calculated as the average of the scores for all criteria. Four priority levels were then established: *High*— $5 \leq FS \leq 10$, *Medium*— $2 \leq FS < 5$; *Low*— $0 < FS < 2$ and *No-Priority* if $FS = 0$. Criteria (a), (b), and (e) were not applied for WHP taxa. *Opuntia stricta* (Haw.) Haw., a known alien invasive species (Le Houérou 2002; GRIIS 2018) was excluded from the prioritisation process. Furthermore, taxa known only to occur in cultivation (i.e., those in GP1a and TG1a that have no wild distributional range), were excluded from the analysis.

Results and discussion

Checklist description

The obtained integrated checklist of the Tunisian flora accounted for 2912 taxa, including subspecies, varieties, and botanical hybrids. Among them, 2504 CWR and/or WHP taxa (86% of the total), belonging to 143 families, 686 genera and 2301 species, were identified. This high percentage is expected, and similar results have been found for other countries and regions since, at this stage, CWR are considered in a broad sense (i.e., any taxon within the same genus as a crop) and without the exclusion of introduced, invasive and cultivated taxa (Kell et al. 2008, 2015). Approximately 94% of the CWR and/or WHP taxa (2343 taxa and 2147 species) are native to Tunisia, 6.4% (160 taxa) are introduced, and only *Opuntia stricta* is invasive (Le Houérou 2002; GRIIS 2018).

The checklist contains of 2445 CWR taxa in 2243 species, 643 genera, and 137 families, whereas 847 taxa are WHP distributed in 365 genera and 113 families. Seven hundred and eighty-eight taxa are both CWR and WHP, whereas 1654 are solely CWR and 59 only WHP. Among these taxa, which form the basis for the CWR inventory, there are 644 CWR taxa related to 167 socio-economically important crops according to criteria *a* and *e*. The ten richest families of CWR in the integrated checklist are Fabaceae, Poaceae, Amaranthaceae, Brassicaceae, Asteraceae, Rosaceae, Apiaceae, Alliaceae, Polygonaceae, Solanaceae (in order of importance), which include 551 taxa—22.5% of the total CWR (Fig. 1). The most represented CWR genera are: *Trifolium* L. (32 taxa related to clovers), *Astragalus* L. (31 taxa related to milkvetch), *Allium* L. (27 taxa related to onion, leek and garlic), *Vicia* L. (25 taxa related to broad bean and

Table 2 The scoring system adopted for prioritisation of CWR and WHP taxa

Criteria	Score										
	0	1	2	3	4	5	6	7	8	9	10
(a) Economic value in Tunisia (000 \$ per year) ^a	0	< 1	1–10	> 10–100	> 100–200	> 200–400	> 400–500	> 500–600	> 600–1000	> 1000–2000	> 2000
(b) Degree of CWR–crop relatedness ^a		GP3		TG3, TG4		GP2, TG2				GP1b, TG1B	
(c) Threat status ^b		LC	LESS VU, NT, DD	VU, inclusion in other lists ^c		EN				CR	
(d) Endemicity	Not Endemic										Endemic
(e) ITPGRFA Annex I or Food supply contribution ^a	No										Yes

^aOnly for CWR^bThreat status: *DD* (Data Deficient), *LC* (Least Concern), *NT* (Near Threatened), *LESS VU* (Less Vulnerable), *VU* (Vulnerable), *EN* (Endangered), *CR* (Critically Endangered) (Garzuglia 2006; IUCN 2021)^cCoE (1979), MEDD (2009)

vetch), *Medicago* L. (23 taxa related to medick and alfalfa), *Rumex* L. (19 taxa related to sorrel), *Daucus* L. (17 taxa related to carrot), *Lathyrus* L. (17 related to pea vine), *Atriplex* L. (16 related to orach), *Lotus* L. (16 taxa related to bird's-foot trefoil), *Amaranthus* L. (15 taxa related to amaranth), *Carthamus* L. (12 taxa related to safflower), *Linum* L. (11 taxa related to flax), *Prunus* L. (11 taxa related to almond, apricot etc.), *Solanum* L. (11 taxa related to potato, tomato and eggplant), *Avena* L. (10 taxa related to oat), *Rosa* L. (10 taxa related to rose) (Fig. 2).

The identified CWR species for Tunisia account for about 10% of the crops and CWR of Europe and the Mediterranean area according to Kell et al. (2005, 2008) and for 6% of the total Euro-Mediterranean flora (40,783 taxa according to Raab-Straube et al. 2016). These data noticeably differ from those reported for Tunisia by Lala et al. (2018), (2445 vs. 1792 CWR taxa, respectively). This discrepancy might be due mainly to a different comprehensiveness of the database used for the flora of Tunisia, along with differences resulting from the new genus list used to define CWR taxa (Kell et al. unpublished), and taxonomic and distributive updates. Compared with other national CWR checklists, Tunisia, in its 163,610 km², has a similar number of CWR taxa as Germany (2874 taxa, 357,386 km²; PGRDEU 2021; Labokas et al. 2018), Norway (2538 taxa 385,207 km²; Phillips et al. 2016), Armenia (2518 taxa 29,743 km²; Avagyan 2008; Heywood 2011), Portugal (2262 taxa; 92,212 km² Magos Brehm et al. 2008, 2010) and United Kingdom (2109; 242,495 km²; Fielder et al. 2012), but much less than other Mediterranean countries such as Italy and Greece (Kell et al. 2005, 2008; Ciancaleoni et al. 2021). These similarities/dissimilarities are probably due, among other factors, to its north–south extent corresponding to a great local environmental diversity. On the other hand, this considerable amount of CWR confirms Tunisia as a valuable part of the North African hotspot of CWR diversity in the Mediterranean area (Vincent et al. 2013; Maxted and Vincent 2021).

The ten most numerous WHP families, corresponding to 56% of the total WHP taxa, are Fabaceae, Asteraceae, Lamiaceae, Poaceae, Euphorbiaceae, Apiaceae, Orchidaceae, Rosaceae, Brassicaceae, Cistaceae (in order of importance) (Fig. 3). This list of the most numerous families is comparable to those of other authors regarding different Mediterranean areas

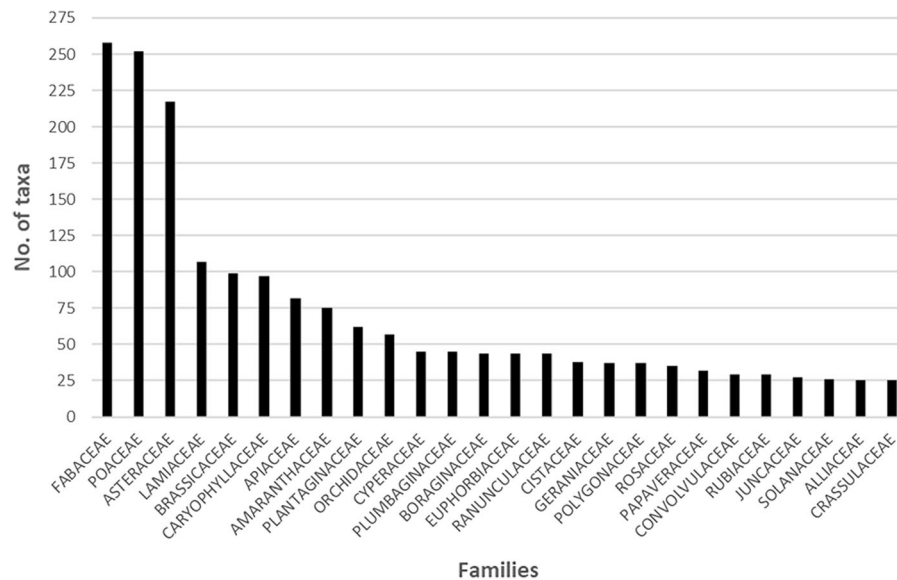


Fig. 1 Number of taxa belonging to the most represented CWR families in Tunisia

with similar environmental conditions such as Cyprus, Crete, Andalusia, Albania, Sicily, Egypt, and Morocco (Lentini and VENZA 2007; Hadjichambis et al. 2008; Nassif and Tanji 2013), suggesting not only flora similarities but also intriguing, even if inextricable, connections between agrobiodiversity and cultural heritage. The ten most numerous genera are *Euphorbia* (39 taxa), *Helianthemum* (25), *Ophrys* (24), *Allium* (13), *Dianthus*, *Hypericum* and *Medicago* (9 each), *Launaea*, *Lolium*, *Lotus* (8 each) (Fig. 4). Altogether they represent 18% of the total WHP taxa.

As detailed before, the large majority (93%) of WHP are also CWR. The total number of WHP taxa (847) accounted for 34% of the integrated checklist and about 2% of the total Euro-Mediterranean flora (Raab-Straube et al. 2016). In Tunisia, the numerical consistency of WHP with respect to the integrated checklist (34%) is higher compared to that of Portugal ($\approx 17\%$; Magos Brehm et al. 2008) and Italy ($\approx 22\%$; Ciancaleoni et al. 2021). This could be due to several factors, such as the high diversity of medicinal and aromatic plants in the African continent (Sofowora 1993), a still higher usage of wild gathered food plants in the diet, especially in rural areas (Hadjichambis et al. 2008), and the relevance of WHP as additional income for the rural people (Borelli et al. 2020). Additionally, it should be noted that the total number of Tunisian WHP taxa can also be considered high

when compared to Hadjichambis et al. (2008), who recorded 406 wild edible plants (WEP) in the circum-Mediterranean area, or to Nassif and Tanji (2013), who recorded 246 WEP species for Morocco, or to Zrira et al. (2013), who listed more than 200 species of aromatic and/or medicinal plants (PAM) for Maghreb. We found that 208 taxa (24%) have some generic ethnobotanical use, 181 (21%) are ornamentals, 129 (15%) fodders, 117 (14%) are used as human food, 94 (11%) are medicinal, 82 (9.5%) have a social use, 57 (7%) have environmental uses, 57 (7%) are used for beverages, 53 (6%) as food additives. The ‘Material’ category was the least represented one with 17 taxa (Fig. 5). In addition, 108 (13%) of them are poisonous and 88 (10%) are used for honey production.

This distribution in use categories is comparable to that reported for Portugal, a Mediterranean country with a similar number of taxa (2262) in the national checklist (Magos Brehm et al. 2008), although with a different number of WHP taxa (497) but a similar ranking of the “top families” with the highest number of taxa (Asteraceae, Lamiaceae, Fabaceae). Interestingly, the percentage of WHP taxa that are used also for honey production resulted significantly higher in Tunisia (10%) when compared to Italy (1.8%, Ciancaleoni et al. 2021) and Portugal (4.8%, Magos Brehm et al. 2008). This is to be related to the high representativeness of these taxa among the top three

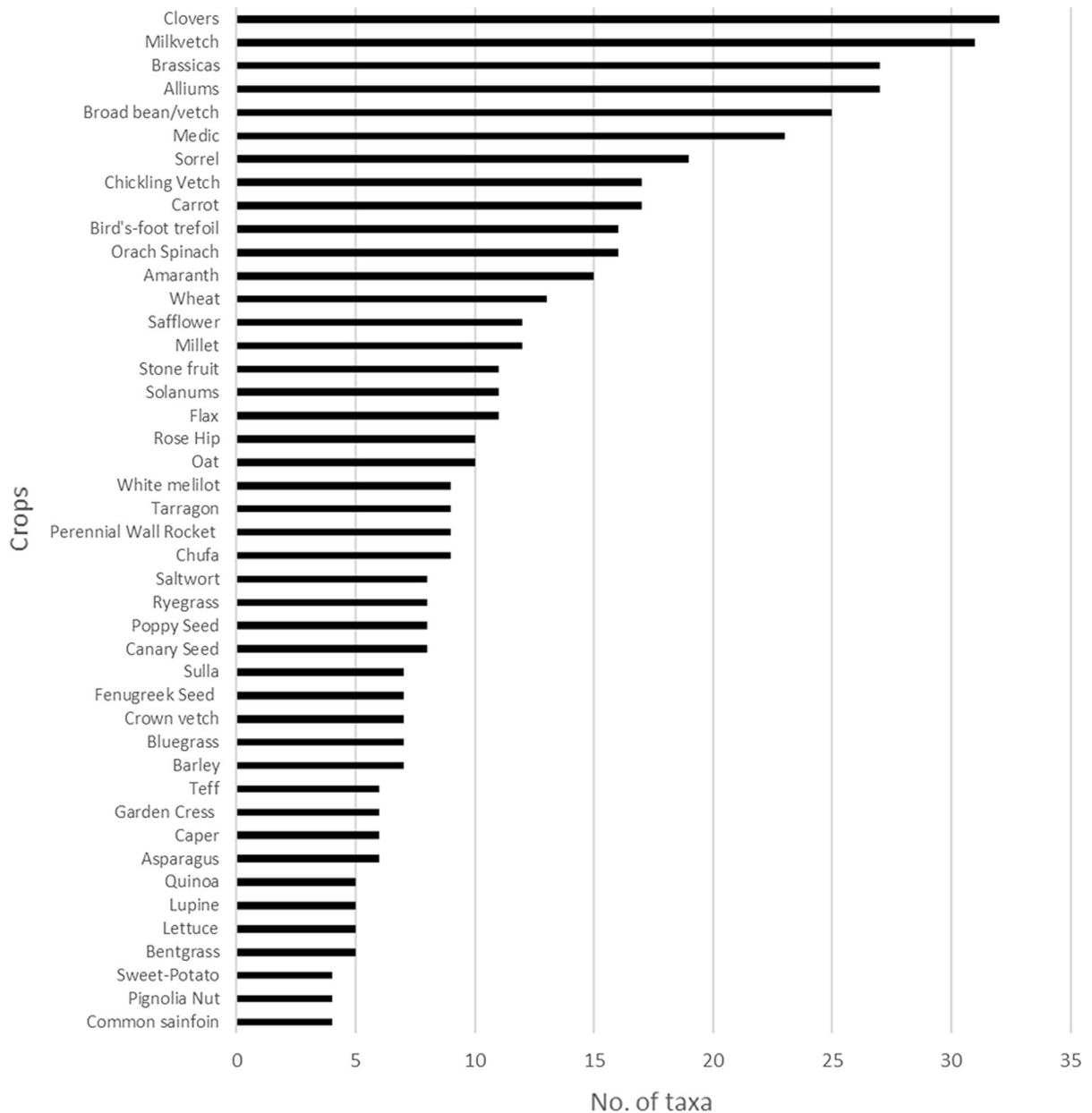


Fig. 2 Number of taxa belonging to the most socio-economically important crops cultivated in Tunisia

families composing the WHP list. Furthermore, it is noteworthy that almost one third of Tunisian WHP taxa have multiple uses. In fact, among the 847 WHP taxa, 205 fall in more than one use category, 77 in more than two, 21 in more than 3, 16 in more than 4, while a maximum of 6 use categories is reported for 6 taxa. In three out of these last six cases, all belonging

to *Calamintha* sp. pl. (Lamiaceae), an aromatic herbaceous genus rich in essential oils that is widely distributed in the Mediterranean area (Debbabi et al. 2020), the most frequent use category combination included medicinal, ornamental, food, food additives, beverages, and honey production.

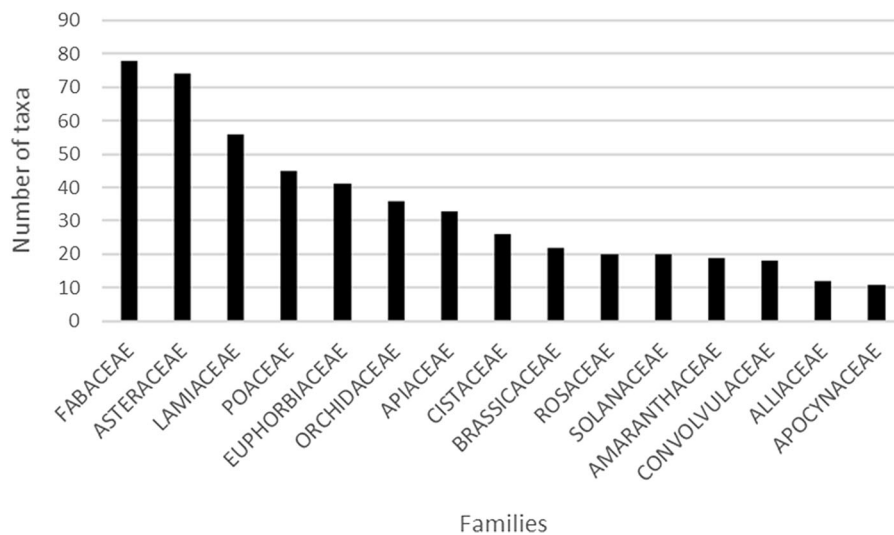


Fig. 3 Number of taxa belonging to the most represented families of WHP in Tunisia

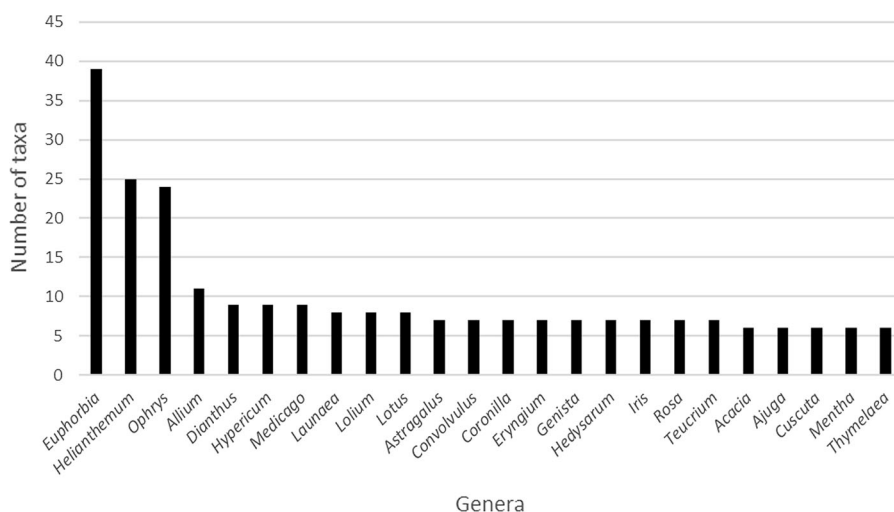


Fig. 4 Number of taxa belonging to the most represented genera of WHP in Tunisia

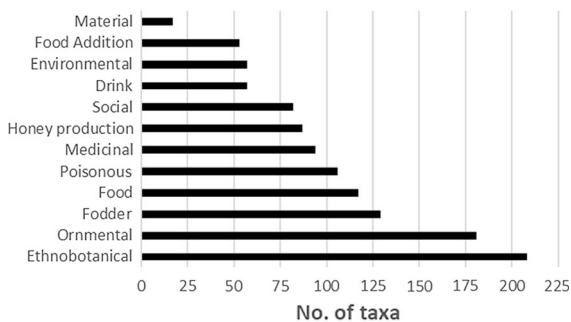


Fig. 5 Number of taxa according to WHP use categories

The most abundant use category (ethnobotanical) included several major taxa of aromatic interest that are also CWR. Concerning these aspects, it is interesting to note that there is a growing economic interest for aromatic and medicinal plants in most of the northern African countries. The area devoted to these plants in Tunisia is reported to pass from 1396 hectares to 2700 hectares between 2011 and 2016 (Neffati 2016), thus increasing the economic contribution of these species to the national income (Ministère des Affaires Locales et de l'Environnement 2019). On the

other hand, this scenario highlights the need for a conservation strategy focusing on preserving WHP and CWR from being overexploited. This could be especially true for species needing urgent active conservation due to overharvesting, such as *Lavandula* L. sp. pl., *Origanum* L. sp. pl., *Salvia* L. sp. pl., and *Thymus* L. sp. pl., as evidenced for Morocco by Lamrani-Alaoui and Hassikou (2018). Among the WHP taxa included in the food use category, the most represented genera are *Capparis* L., *Portulaca* L., *Diploptaxis* DC., *Rosa* L., *Calamintha* Mill., *Centaurea* L., and *Pinus* L.

Prioritisation criteria application

The application of the above-mentioned methodology to the integrated checklist led to the selection of 2468 CWR and/or WHP (2409 CWR and 813 WHP taxa) native and introduced taxa suitable for prioritisation by the application of the five criteria:

Economic value of the related crop

A total of 329 CWR taxa (14% of the total CWR) are related to a crop of economic importance (gross production value > 10,000 \$ per year in Tunisia), according to FAOSTAT (FAO 2019b) and were therefore scored accordingly (Fig. 6). More than half

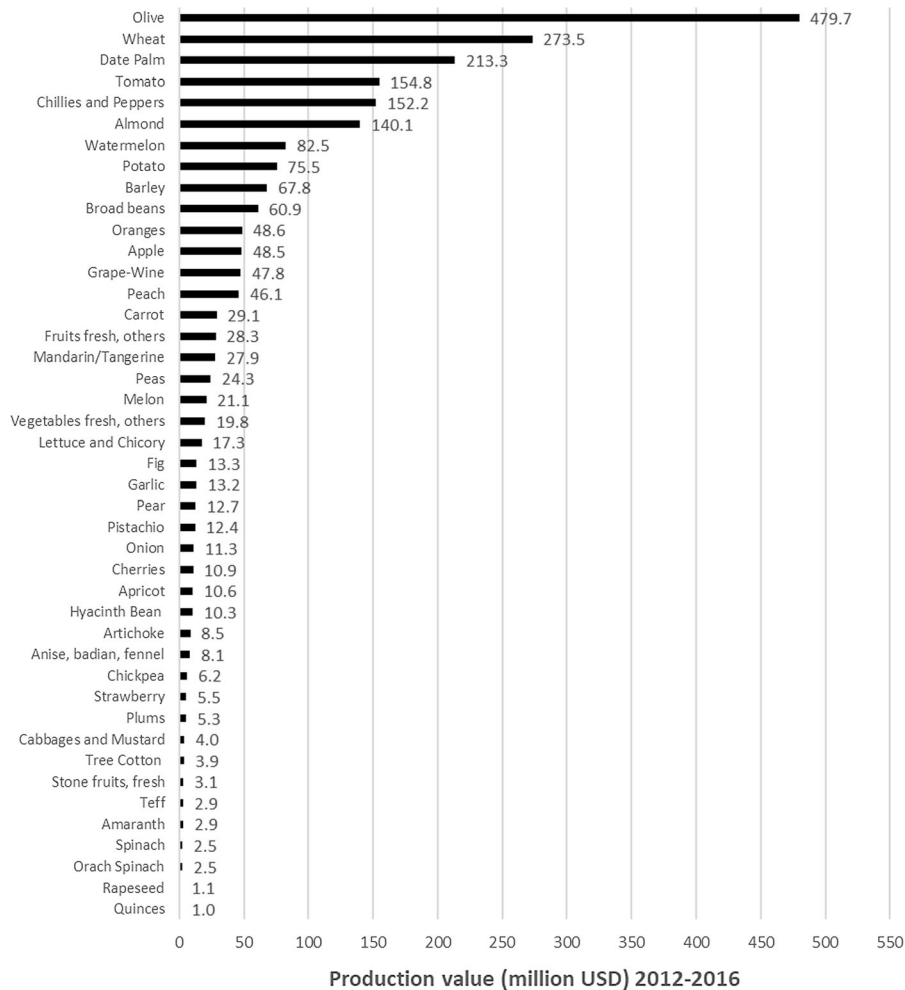


Fig. 6 Crops/crop groups of economic importance in Tunisia, showing their average gross production values (2012–2016) in Tunisia

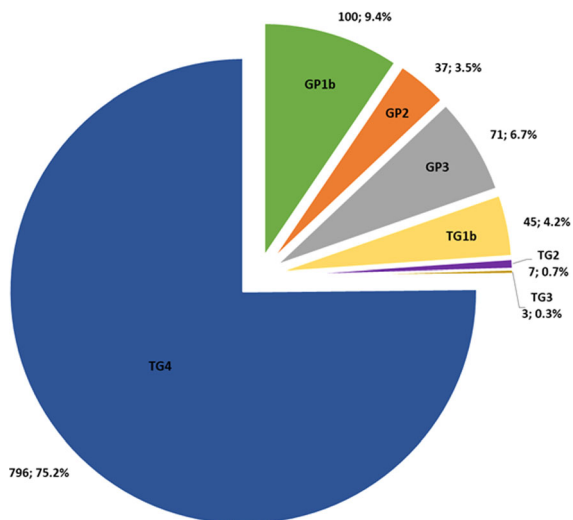


Fig. 7 Percentage distribution of prioritised taxa in the Gene Pool and Taxon Group categories

of these 329 taxa are included in seven FAOSTAT commodity groups, where “Vegetables, fresh not elsewhere specified (nes)”, with 56 taxa, is the most represented one. The other commodity groups “Garlic”, “Carrots and turnips”, “Cereals nes”, “Fruit, fresh nes”, “Spinach” and “Cabbages and other brassicas”, are represented by 23, 22, 21, 21, 18 and 16 taxa, respectively. The remaining 152 taxa belong to 44 other commodity groups. The 10 most represented families are Brassicaceae (43 taxa), Fabaceae (37), Amaranthaceae and Poaceae (35), Apiaceae (29),

Rosaceae (25), Alliaceae (24), Asteraceae (22), Polygonaceae (19), and Linaceae (11).

Degree of relatedness

Forty-four percent of the CWR in the checklist (1059 taxa) were scored according to criterion b. More precisely, 207 taxa were identified by their GP and 852 by their TG, with 144 taxa in GP1b and TG1b, 44 in GP2 or TG2, 71 in GP3, and 799 in TG3 or TG4 (Fig. 7).

Threat status

Four hundred and nine CWR/WHP taxa (16.3% of the CWR/WHP) are considered threatened— 314 of them (78%) are listed in the IUCN Red List (2021), 108 (27%) are included in the national report of the Ministère de l’Environnement (MEDD 2009) as threatened or vulnerable, 22 (< 1%) according to Garzuglia (2006), and three are listed in the Bern Convention. Figure 8 shows the number of prioritised taxa assigned to each category.

Endemicity

A total of 218 CWR and/or WHP taxa (9% of the CWR/WHP) are endemic to Tunisia and North Africa (116 and 102, respectively). Among them, 18 taxa (e.g., *Brassica insularis* Moris, *Daucus syrticus* Murb., *D. virgatus* (Poir.) Maire, *D. reboudii* Coss.

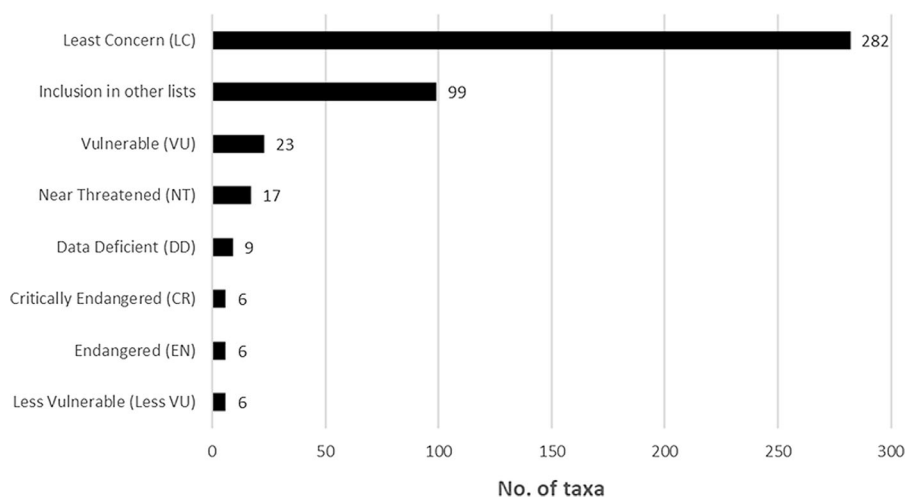


Fig. 8 The threat status of prioritised taxa in Tunisia (CoE 1979; Garzuglia 2006; MEDD 2009; IUCN 2012)

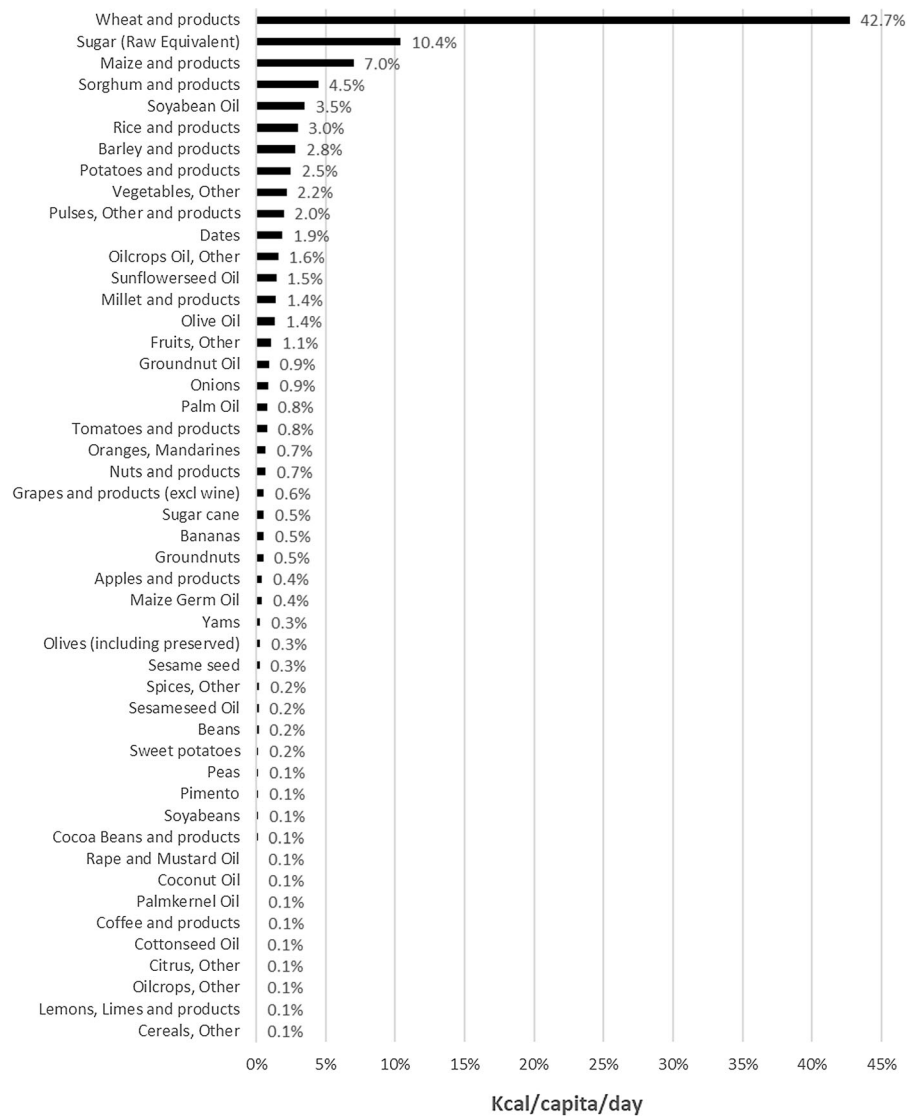


Fig. 9 Average annual contributions of crops/crop groups for North Africa to dietary energy (kilocalories) per capita per day of 0.1% or more over the period 2014–2018

ex Batt., *Linum corymbiferum* Desf. and *Vicia fulgens* Batt.) are related to crops of economic importance cultivated in Tunisia and in some cases to crops (cabbage, kale, carrot, and vetch) of worldwide interest according to ITPGRFA. The number of endemic taxa can be considered high in comparison to that reported for Tunisia by Libiad et al. (2020), probably due to discrepancies in the adopted database and/or nomenclatural attribution issues.

Relevance for food security and nutrition

Six hundred and eight CWR taxa (25%) are related to crops included in Annex I of the ITPGRFA and/or contributing to annual dietary energy per capita per day (Kcal/capita/day) (Fig. 9). Among them, about one third are related to crops cultivated in Tunisia of significant economic importance, such as *Brassica rapa* L., *Daucus carota*, *Hordeum vulgare*, *Malus domestica* Borkh., *Vicia faba* L., and *V. pannonica* Crantz. The crops of high regional importance for food

security in North Africa (i.e., those providing more than 3% of dietary energy supply) that also have wild relatives in Tunisia are *Sorghum bicolor* (L.) Moench, *Triticum aestivum*, *T. dicoccum* Schübl., *T. durum* Desf., *T. polonicum* L. and *Vicia faba* –wheat being the crop that provides the highest daily energy supply (42.7%) among those with wild relatives in the country.

Priority taxa

The prioritisation process led to the selection of 1053 CWR/WHP taxa belonging to 101 families and 330 genera, accounting for 43% of the total CWR/WHP taxa listed in the integrated checklist. A comprehensive list of the priority taxa is given in the supplemental material (Appendix 1).

Regarding the WHP, there are 344 priority taxa (327 of which are both CWR and WHP, whereas 17 are WHP only), including 8 high priority taxa (Table 3), 254 medium priority and 82 low priority. The ten most represented families among the prioritised WHP taxa are Fabaceae (65 taxa), Poaceae (29), Asteraceae (21), Rosaceae (18), Brassicaceae (17), Lamiaceae (16), Apiaceae (15), Amaranthaceae (14), Alliaceae (10), and Orchidaceae (9). The most abundant genera are: *Allium* (10 taxa), *Medicago* (9), *Lolium*, *Lotus*, and *Ophrys* (8), *Astragalus*, *Coronilla*, *Hedysarum* and *Rosa* (7), *Capparis* and *Euphorbia* (6), and *Artemisia*, *Centaureum*, *Diplotaxis*, *Genista*, *Mentha* and *Vicia* (5). Among the 17 taxa which are only WHP, medium and low priority taxa were found (9 and 8, respectively). Preserving these genetic resources might result beneficial, as seen above, for various aspects. These plants harvested in the wild could represent, in fact, an additional nutritive intake and economic income for rural populations. At the same time, they can be a potential source of new marketable foods, active compounds or other secondary products that can stimulate the local economy. This is the case, for example, of two endemic high priority aromatic plants *Artemisia saharae* Pomel and *Thymus algeriensis* Boiss. & Reut, sources of essential oils, with actual and potential medicinal uses (Zouari et al. 2012, 2014; Sobeh et al. 2020). Furthermore, preserving the WHP means, all together, protecting that ethnobotanical knowledge which is nowadays at risk of disappearing. Finally, it must be reminded that, as stressed by FAO (2019a), there is now the need to

act in order to obtain a sustainable harvest from the wild, especially in the case of taxa identified as priorities for conservation.

The list of priority CWR includes 1036 taxa, with 139 taxa (5.8% of the total CWR listed in the integrated checklist) classified as of highest priority for conservation (Tables 4 and 5), 660 taxa (27.4%) of medium priority, and 237 (9.8%) of low priority. One hundred and forty-four taxa (13.8% of the priority CWR) belong to GP1b or TG1b and can therefore be used more easily in breeding programs, while 44 (4.2%) are in GP2 or TG2. The great majority (80%) are in GP3, TG3 and TG4, with 71, 3 and 756 taxa, respectively. The top ten CWR priority families are Fabaceae (233 taxa), Poaceae (116), Asteraceae (59), Brassicaceae (54), Amaranthaceae (50), Apiaceae (37), Lamiaceae and Rosaceae (29), Cyperaceae and Plumbaginaceae (27). The most abundant priority genera are: *Trifolium* (32 taxa), *Astragalus* (31), *Ononis* L. (29), *Limonium* Mill. (27), *Vicia* L. (25), *Allium* (24), *Medicago* (23), *Rumex* (19), *Daucus*, *Juncus* L. and *Lathyrus* L. (17). The top priority taxa related to the most socio-economic important crops, including some staple food, vegetables, and fodder, are in the genera *Daucus* (13 taxa), *Aegilops* L. (8), *Brassica* L., *Prunus* L. and *Vicia* (7), *Allium* (6), *Avena* L. (5), *Linum* L. and *Sinapis* L. (4). Many of these high priority taxa are documented or potential sources of beneficial traits. For example, *Brassica insularis* Moris (high priority GP2, relative of *Brassica oleracea* L.) is a regional endemic with a confirmed use for blackleg resistance (Mithen and Lewis 1988). *Vicia sativa* L. subsp. *amphicarpa* (L.) Batt. (GP1b relative of *Vicia sativa* L.), threatened by heavy grazing, seasonal drought, and erosion (Abd El Moneim and Elias 2003; Rowe and Maxted 2019), and classified as Near Threatened (NT), can be potentially used to confer resistance to broomrape (Sillero et al. 2005), as well as rust and Ascochyta blight (Rubiales et al. 2015).

Tunisia lies in the centre of origin of carrot (*Daucus carota*) and hosts a rich diversity of wild and rare related taxa (Mezghani et al. 2019; Simon et al. 2020). *D. syrticus* Murb. (high priority in our inventory and GP1b), one of the few 18-chromosome carrot wild relatives, 6 wild subspecies (GP1b) of *D. carota* L., and 10 other native species of the same genus are examples of such richness. Consistently to Mezghani et al. (2019), *D. reboudii* Batt. and *D. virgatus* (Poir.)

Table 3 High priority Wild Harvested Plants assessment

Family	Taxon	Rank	CWR	WHP	CROP name	CROP taxa	GenePool— TaxonGroup	Relative degree	Energy Supply- ITPGRFA Priority	Conservation Priority	Endemic Priority	FPS	Priority
ASTERACEAE	<i>Artemisia atlantica</i> Coss	Species	CWR	WHP	Tarragon	<i>Artemisia dracunculus</i> L	TaxonGroup	4	10	0	10	6.67	High
ASTERACEAE	<i>Artemisia campestris</i> subsp. <i>cinerea</i> Le Houër	Subsp.	CWR	WHP	Tarragon	<i>Artemisia dracunculus</i> L	TaxonGroup	4	10	0	10	6.67	High
ASTERACEAE	<i>Artemisia saharae</i> Pomel	Species	CWR	WHP	Tarragon	<i>Artemisia dracunculus</i> L	TaxonGroup	4	10	0	10	6.67	High
FABACEAE	<i>Astragalus gombo</i> subsp. <i>gombiformis</i> (Pomel) Eug. Ott	Subsp.	CWR	WHP	Milkvetch	<i>Astragalus</i> sp. pl	TaxonGroup	4	10	0	10	6.67	High
BRASSICACEAE	<i>Diplotaxis simplex</i> (Viv.) Spreng	Species	CWR	WHP	Perennial Wall Rocket	<i>Diplotaxis tenuifolia</i> (L.) DC	TaxonGroup	4	10	0	10	6.67	High
POACEAE	<i>Festuca numidica</i> (Trab.) Romo	Species	CWR	WHP	Fescue	<i>Festuca</i> sp. pl	TaxonGroup	4	10	0	10	6.67	High
PINACEAE	<i>Pinus pinaster</i> subsp. <i>renouitii</i> (Villar) Maire	Subsp.	CWR	WHP	Pignolia Nut	<i>Pinus pinea</i> L	TaxonGroup	4	10	6	0	5.33	High
LAMIACEAE	<i>Thymus algeriensis</i> Boiss. and Reut	Species	CWR	WHP	Thyme	<i>Thymus vulgaris</i> L	TaxonGroup	4	10	0	10	6.67	High

Table 4 High priority Crop Wild Relatives assessment

Family	Taxon	Rank	CWR	WHP	CROP name	CROP taxa	GenePool - TaxonGroup	Relative degree	Economic Priority	Breeding Priority	Conservation Priority	Endemic Priority	Energy Supply-ITPGRFA Priority	FPS	Priority
POACEAE	<i>Aegilops cylindrica</i> Host	species	CWR		Wheat	<i>Triticum aestivum</i> L.	GenePool	2	10	6	0	0	10	5.2	High
POACEAE	<i>Aegilops geniculata</i> Roth subsp. <i>geniculata</i>	subsp.	CWR		Wheat	<i>Triticum aestivum</i> L.	GenePool	2	10	6	2	0	10	5.6	High
POACEAE	<i>Aegilops geniculata</i> subsp. <i>africana</i> (Eig) H. Scholz	subsp.	CWR		Wheat	<i>Triticum aestivum</i> L.	GenePool	2	10	6	0	0	10	5.2	High
POACEAE	<i>Aegilops kotschyi</i> Boiss.	species	CWR		Wheat	<i>Triticum aestivum</i> L.	GenePool	2	10	6	2	0	10	5.6	High
POACEAE	<i>Aegilops neglecta</i> Bertol. subsp. <i>neglecta</i>	subsp.	CWR		Wheat	<i>Triticum aestivum</i> L.	GenePool	2	10	6	2	0	10	5.6	High
POACEAE	<i>Aegilops subulata</i> Pomel	species	CWR		Wheat	<i>Triticum aestivum</i> L.	GenePool	2	10	6	0	0	10	5.2	High
POACEAE	<i>Aegilops triuncialis</i> L. subsp. <i>triuncialis</i>	subsp.	CWR		Wheat	<i>Triticum aestivum</i> L.	GenePool	2	10	6	2	0	10	5.6	High
POACEAE	<i>Aegilops ventricosa</i> Tausch	species	CWR		Wheat	<i>Triticum aestivum</i> L.	GenePool	2	10	6	2	0	10	5.6	High
ALLIACEAE	<i>Allium ampeloprasum</i> L. subsp. <i>ampeloprasum</i>	subsp.	CWR	WHP	Leek	<i>Allium porrum</i> L.	GenePool	1b	10	10	0	0	10	6	High
ALLIACEAE	<i>Allium chamaemoly</i> L. subsp. <i>chamaemoly</i>	subsp.	CWR	WHP	Leeks and other alliaceous vegetables	<i>Allium</i> sp. pl.	TaxonGroup	4	10	4	2	0	10	5.2	High
ALLIACEAE	<i>Allium commutatum</i> Guss.	species	CWR		Leek	<i>Allium porrum</i> L.	GenePool	1b	10	10	2	0	10	6.4	High
ALLIACEAE	<i>Allium porrum</i> subsp. <i>polyanthum</i> (Schult. & Schult. f.) Jauzein & J.-M. Tison	subsp.	CWR	WHP	Leek	<i>Allium porrum</i> L.	GenePool	1b	10	10	0	0	10	6	High
ALLIACEAE	<i>Allium tourneuxii</i> Chabert	species	CWR		Leeks and other alliaceous vegetables	<i>Allium</i> sp. pl.	TaxonGroup	4	10	4	0	10	10	6.8	High
ALLIACEAE	<i>Allium triquetrum</i> L.	species	CWR	WHP	Leeks and other alliaceous vegetables	<i>Allium</i> sp. pl.	TaxonGroup	4	10	4	2	0	10	5.2	High
AMARANTHACEAE	<i>Amaranthus cruentus</i> L.	species	CWR		Amaranth, Purple	<i>Amaranthus cruentus</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Anethum graveolens</i> L.	species	CWR	WHP	Dill Seed	<i>Anethum graveolens</i> L.	TaxonGroup	1b	8	10	0	0	10	5.6	High
APIACEAE	<i>Anthriscus cerefolium</i> (L.) Hoffm.	species	CWR		Chervil	<i>Anthriscus cerefolium</i> (L.) Hoffm.	TaxonGroup	1b	10	10	0	0	10	6	High
APIACEAE	<i>Apium graveolens</i> L.	species	CWR	WHP	Celery	<i>Apium graveolens</i> L.	GenePool	1b	10	10	2	0	10	6.4	High
ERICACEAE	<i>Arbutus unedo</i> L.	species	CWR	WHP	Tree-Strawberry	<i>Arbutus unedo</i> L.	TaxonGroup	1b	10	10	2	0	10	6.4	High
ASTERACEAE	<i>Artemisia atlantica</i> Coss.	species	CWR	WHP	Tarragon	<i>Artemisia dracunculus</i> L.	TaxonGroup	4	10	4	0	10	10	6.8	High
ASTERACEAE	<i>Artemisia campestris</i> subsp. <i>cinerea</i> Le Houér.	subsp.	CWR	WHP	Tarragon	<i>Artemisia dracunculus</i> L.	TaxonGroup	4	10	4	0	10	10	6.8	High
ASTERACEAE	<i>Artemisia saharae</i> Pomel	species	CWR	WHP	Tarragon	<i>Artemisia dracunculus</i> L.	TaxonGroup	4	10	4	0	10	10	6.8	High

Table 4 continued

Family	Taxon	Rank	CWR	WHP	CROP name	CROP taxa	GenePool - TaxonGroup	Relative degree	Economic Priority	Breeding Priority	Conservation Priority	Endemic Priority	Energy Supply-ITPGRFA Priority	FPS	Priority
ASPARAGACEAE	<i>Asparagus officinalis</i> L.	species	CWR	WHP	Asparagus	<i>Asparagus officinalis</i> L.	GenePool	1b	5	10	2	0	10	5.4	High
FABACEAE	<i>Astragalus falciformis</i> Desf.	species	CWR		Milkvetch	<i>Astragalus</i> sp. pl.	TaxonGroup	4	0	4	4	10	10	5.6	High
FABACEAE	<i>Astragalus saharae</i> Pomel	species	CWR		Milkvetch	<i>Astragalus</i> sp.pl.	TaxonGroup	4	0	4	4	10	10	5.6	High
AMARANTHACEAE	<i>Atriplex halimus</i> var. <i>schweinfurthii</i> Boiss.	var.	CWR	WHP	Orach Spinach	<i>Atriplex hortensis</i> L.	TaxonGroup	4	10	4	4	0	10	5.6	High
AMARANTHACEAE	<i>Atriplex mollis</i> Desf.	species	CWR		Orach Spinach	<i>Atriplex hortensis</i> L.	TaxonGroup	4	10	4	4	10	10	7.6	High
POACEAE	<i>Avena fatua</i> L. subsp. <i>fatua</i>	subsp.	CWR		Oat	<i>Avena sativa</i> L.	GenePool	1b	5	10	2	0	10	5.4	High
POACEAE	<i>Avena sativa</i> L. subsp. <i>sativa</i>	subsp.	CWR	WHP	Oat	<i>Avena sativa</i> L.	GenePool	1b	5	10	0	0	10	5	High
POACEAE	<i>Avena sterilis</i> L. subsp. <i>sterilis</i>	subsp.	CWR		Oat	<i>Avena sativa</i> L.	GenePool	1b	5	10	2	0	10	5.4	High
POACEAE	<i>Avena sterilis</i> subsp. <i>atherantha</i> (C. Presl) H. Scholz	subsp.	CWR		Oat	<i>Avena sativa</i> L.	GenePool	1b	5	10	0	0	10	5	High
POACEAE	<i>Avena sterilis</i> subsp. <i>ludoviciana</i> (Durieu) Gillet & Magne	subsp.	CWR		Oat	<i>Avena sativa</i> L.	GenePool	1b	5	10	0	0	10	5	High
AMARANTHACEAE	<i>Beta macrocarpa</i> Guss.	species	CWR	WHP	Sugarbeet	<i>Beta vulgaris</i> L.	GenePool	1b	5	10	0	0	10	5	High
AMARANTHACEAE	<i>Beta vulgaris</i> subsp. <i>maritima</i> (L.) Arcang.	subsp.	CWR	WHP	Sugarbeet	<i>Beta vulgaris</i> L.	GenePool	1b	5	10	0	0	10	5	High
BRASSICACEAE	<i>Brassica insularis</i> Moris	species	CWR		Cabbage-Kale	<i>Brassica oleracea</i> L.	GenePool	2	10	6	4	10	10	8	High
BRASSICACEAE	<i>Brassica juncea</i> (L.) Czern.	species	CWR		Mustard	<i>Brassica juncea</i> (L.) Czern.	GenePool	1b	10	10	0	0	10	6	High
BRASSICACEAE	<i>Brassica nigra</i> (L.) W.D.J. Koch	species	CWR		Mustard-Black	<i>Brassica nigra</i> (L.) W.D.J. Koch	GenePool	1b	10	10	0	0	10	6	High
BRASSICACEAE	<i>Brassica oleracea</i> L.	species	CWR	WHP	Cabbage-Kale	<i>Brassica oleracea</i> L.	GenePool	1b	10	10	0	0	10	6	High
BRASSICACEAE	<i>Brassica rapa</i> L. subsp. <i>rapa</i>	subsp.	CWR	WHP	Turnip	<i>Brassica rapa</i> L.	GenePool	1b	10	10	0	0	10	6	High
BRASSICACEAE	<i>Brassica rapa</i> subsp. <i>campestris</i> (L.) A. R. Clapham	subsp.	CWR		Turnip	<i>Brassica rapa</i> L.	GenePool	1b	10	10	0	0	10	6	High
BRASSICACEAE	<i>Brassica tournefortii</i> Gouan	species	CWR	WHP	Cabbage-Kale	<i>Brassica oleracea</i> L.	GenePool	2	10	6	0	0	10	5.2	High
CAPPARACEAE	<i>Capparis spinosa</i> L. subsp. <i>spinosa</i>	subsp.	CWR	WHP	Capers	<i>Capparis spinosa</i> L.	TaxonGroup	1b	10	10	0	0	10	6	High
CAESALPINIACEAE	<i>Ceratonia siliqua</i> L.	species	CWR	WHP	Carob	<i>Ceratonia siliqua</i> L.	TaxonGroup	1b	5	10	4	0	10	5.8	High
FABACEAE	<i>Cicer arietinum</i> L.	species	CWR	WHP	Chickpea	<i>Cicer arietinum</i> L.	GenePool	1b	10	10	0	0	10	6	High
ASTERACEAE	<i>Cichorium intybus</i> L.	species	CWR	WHP	Chicory	<i>Cichorium intybus</i> L.	GenePool	1b	10	10	0	0	10	6	High
ASTERACEAE	<i>Cichorium pumilum</i> Jacq.	species	CWR	WHP	Endive	<i>Cichorium endivia</i> L.	GenePool	1b	10	10	0	0	10	6	High

Table 4 continued

Family	Taxon	Rank	CWR	WHP	CROP name	CROP taxa	GenePool - TaxonGroup	Relative degree	Economic Priority	Breeding Priority	Conservation Priority	Endemic Priority	Energy Supply-ITPGRFA Priority	FPS	Priority
CUCURBITACEAE	<i>Citrullus colocynthis</i> (L.) Schrad.	species	CWR	WHP	Watermelon	<i>Citrullus lanatus</i> (Thunb.) Matsum. & Nakai.	GenePool	2	10	6	0	0	10	5.2	High
APIACEAE	<i>Coriandrum sativum</i> L.	species	CWR	WHP	Coriander	<i>Coriandrum sativum</i> L.	TaxonGroup	1b	10	10	0	0	10	6	High
ROSACEAE	<i>Crataegus azarolus</i> L.	species	CWR	WHP	Azarole	<i>Crataegus azarolus</i> L.	TaxonGroup	1b	10	10	2	0	10	6.4	High
ROSACEAE	<i>Crataegus laciniata</i> Ucria	species	CWR	WHP	Azarole	<i>Crataegus azarolus</i> L.	TaxonGroup	4	10	4	2	0	10	5.2	High
ROSACEAE	<i>Crataegus monogyna</i> Jacq.	species	CWR	WHP	Azarole	<i>Crataegus azarolus</i> L.	TaxonGroup	4	10	4	2	0	10	5.2	High
CUCURBITACEAE	<i>Cucumis melo</i> L.	species	CWR	WHP	Melon	<i>Cucumis melo</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Cuminum cyminum</i> L.	species	CWR	WHP	Cumin	<i>Cuminum cyminum</i> L.	TaxonGroup	1b	10	10	0	0	10	6	High
ASTERACEAE	<i>Cynara cardunculus</i> L. subsp. <i>cardunculus</i>	subsp.	CWR	WHP	Artichoke	<i>Cynara cardunculus</i> L.	GenePool	1b	10	10	0	0	10	6	High
ASTERACEAE	<i>Cynara cardunculus</i> subsp. <i>flavescens</i> Wiklund	subsp.	CWR	WHP	Artichoke	<i>Cynara cardunculus</i> L.	GenePool	1b	10	10	0	0	10	6	High
POACEAE	<i>Dactylis glomerata</i> subsp. <i>santai</i> Stebbins & D. Zohary	subsp.	CWR	WHP	Orchard Grass	<i>Dactylis glomerata</i> L.	TaxonGroup	1b	0	10	0	10	10	6	High
APIACEAE	<i>Daucus carota</i> L. subsp. <i>carota</i>	subsp.	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Daucus carota</i> subsp. <i>drepanensis</i> (Lojac.) Heywood	subsp.	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Daucus carota</i> subsp. <i>fontanesii</i> Thell.	subsp.	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Daucus carota</i> subsp. <i>hispanicus</i> (Gouan) Thell.	subsp.	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Daucus carota</i> subsp. <i>maritimus</i> (Lam.) Batt.	subsp.	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Daucus carota</i> subsp. <i>maximus</i> (Desf.) Ball	subsp.	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Daucus carota</i> subsp. <i>sativus</i> Schübl. & G. Martens	subsp.	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Daucus durieua</i> Lange	species	CWR	WHP	Carrot	<i>Daucus carota</i> L.	TaxonGroup	4	10	4	2	0	10	5.2	High
APIACEAE	<i>Daucus reboudii</i> Coss. ex Batt.	species	CWR	WHP	Carrot	<i>Daucus carota</i> L.	TaxonGroup	4	10	4	0	10	10	6.8	High
APIACEAE	<i>Daucus rouyi</i> Spalik & Reduron	species	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	2	10	6	0	0	10	5.2	High
APIACEAE	<i>Daucus sahariensis</i> Murb.	species	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	2	10	6	2	0	10	5.6	High
APIACEAE	<i>Daucus syrticus</i> Murb.	species	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	1b	10	10	0	10	10	8	High
APIACEAE	<i>Daucus virgatus</i> (Poir.) Maire	species	CWR	WHP	Carrot	<i>Daucus carota</i> L.	GenePool	1b	10	10	0	10	10	8	High
BRASSICACEAE	<i>Diplotaxis simplex</i> (Viv.) Spreng.	species	CWR	WHP	Perennial Wall Rocket	<i>Diplotaxis tenuifolia</i> (L.) DC.	TaxonGroup	4	10	4	0	10	10	6.8	High

Table 4 continued

Family	Taxon	Rank	CWR	WHP	CROP name	CROP taxa	GenePool - TaxonGroup	Relative degree	Economic Priority	Breeding Priority	Conservation Priority	Endemic Priority	Energy Supply-ITPGRFA Priority	FPS	Priority
MORACEAE	<i>Ficus carica</i> L. subsp. <i>carica</i>	subsp.	CWR	WHP	Fig	<i>Ficus carica</i> L.	GenePool	1b	10	10	0	0	10	6	High
APIACEAE	<i>Foeniculum vulgare</i> Mill. subsp. <i>vulgare</i>	subsp.	CWR	WHP	Fennel	<i>Foeniculum vulgare</i> Mill.	TaxonGroup	1b	10	10	0	0	10	6	High
APIACEAE	<i>Foeniculum vulgare</i> subsp. <i>piperitum</i> (Ucria) Bég.	subsp.	CWR	WHP	Fennel	<i>Foeniculum vulgare</i> Mill.	TaxonGroup	1b	10	10	0	0	10	6	High
MALVACEAE	<i>Gossypium herbaceum</i> L.	species	CWR	WHP	Tree Cotton	<i>Gossypium arboreum</i> L.	GenePool	2	10	6	0	0	10	5.2	High
BRASSICACEAE	<i>Guenthera dimorpha</i> (Coss. & Durieu) Gómez-Campo	species	CWR		Rape	<i>Brassica napus</i> L.	GenePool	3	9	2	0	10	10	6.2	High
CUPRESSACEAE	<i>Juniperus oxycedrus</i> L. subsp. <i>oxycedrus</i>	subsp.	CWR		Juniper Berries	<i>Juniperus communis</i> L.	TaxonGroup	4	10	4	4	0	10	5.6	High
CUPRESSACEAE	<i>Juniperus phoenicea</i> L. subsp. <i>phoenicea</i>	subsp.	CWR	WHP	Juniper Berries	<i>Juniperus communis</i> L.	TaxonGroup	4	10	4	4	0	10	5.6	High
FABACEAE	<i>Lablab purpureus</i> (L.) Sweet	species	CWR	WHP	Hyacinth Bean	<i>Lablab purpureus</i> (L.) Sweet	GenePool	1b	10	10	0	0	10	6	High
ASTERACEAE	<i>Lactuca saligna</i> L.	species	CWR		Lettuce	<i>Lactuca sativa</i> L.	GenePool	2	10	6	0	0	10	5.2	High
ASTERACEAE	<i>Lactuca serriola</i> L.	species	CWR		Lettuce	<i>Lactuca sativa</i> L.	GenePool	1b	10	10	0	0	10	6	High
FABACEAE	<i>Lathyrus brachyodon</i> Murb.	species	CWR		Grass-Pea	<i>Lathyrus sativus</i> L.	TaxonGroup	4	0	4	4	10	10	5.6	High
LAURACEAE	<i>Laurus nobilis</i> L.	species	CWR	WHP	Laurel	<i>Laurus nobilis</i> L.	TaxonGroup	1b	8	10	2	0	10	6	High
FABACEAE	<i>Lens culinaris</i> Medik.	species	CWR	WHP	Lentil	<i>Lens culinaris</i> Medik.	GenePool	1b	8	10	0	0	10	5.6	High
BRASSICACEAE	<i>Lepidium glastifolium</i> Desf.	species	CWR		Garden Cress	<i>Lepidium sativum</i> L.	TaxonGroup	4	10	4	0	10	10	6.8	High
BRASSICACEAE	<i>Lepidium sativum</i> L. subsp. <i>sativum</i>	subsp.	CWR	WHP	Garden Cress	<i>Lepidium sativum</i> L.	GenePool	1b	10	10	0	0	10	6	High
LINACEAE	<i>Linum bienne</i> Mill.	species	CWR	WHP	Flax	<i>Linum usitatissimum</i> L.	GenePool	1b	8	10	0	0	10	5.6	High
LINACEAE	<i>Linum corymbiferum</i> subsp. <i>aristidis</i> (Batt.) Batt.	subsp.	CWR		Flax	<i>Linum usitatissimum</i> L.	TaxonGroup	4	8	4	0	10	10	6.4	High
LINACEAE	<i>Linum corymbiferum</i> subsp. <i>asperifolium</i> (Boiss. & Reut.) Martínez	subsp.	CWR		Flax	<i>Linum usitatissimum</i> L.	TaxonGroup	4	8	4	0	10	10	6.4	High
LINACEAE	<i>Linum usitatissimum</i> L.	species	CWR	WHP	Flax	<i>Linum usitatissimum</i> L.	GenePool	1b	8	10	0	0	10	5.6	High
ROSACEAE	<i>Malus pumila</i> Mill.	species	CWR	WHP	Apple	<i>Malus domestica</i> Borkh.	GenePool	2	10	6	0	0	10	5.2	High
OLEACEAE	<i>Olea europaea</i> L. subsp. <i>europaea</i>	subsp.	CWR	WHP	Olive	<i>Olea europaea</i> L.	GenePool	1b	10	10	4	0	10	6.8	High
CACTACEAE	<i>Opuntia ficus-indica</i> (L.) Mill.	species	CWR	WHP	Indian Fig	<i>Opuntia ficus-indica</i> (L.) Mill.	TaxonGroup	1b	10	10	0	0	10	6	High
APIACEAE	<i>Petroselinum crispum</i> (Mill.) Fuss subsp. <i>crispum</i>	subsp.	CWR		Parsley	<i>Petroselinum crispum</i> (Mill.) Fuss	TaxonGroup	1b	10	10	0	0	10	6	High
ARECACEAE	<i>Phoenix dactylifera</i> L.	species	CWR	WHP	Date Palm	<i>Phoenix dactylifera</i> L.	GenePool	1b	10	10	0	0	10	6	High

Table 4 continued

Family	Taxon	Rank	CWR	WHP	CROP name	CROP taxa	GenePool - TaxonGroup	Relative degree	Economic Priority	Breeding Priority	Conservation Priority	Endemic Priority	Energy Supply-ITPGRFA Priority	FPS	Priority
APIACEAE	<i>Pimpinella anisum</i> L.	species	CWR	WHP	Anise	<i>Pimpinella anisum</i> L.	TaxonGroup	1b	10	10	0	0	10	6	High
ANACARDIACEAE	<i>Pistacia atlantica</i> Desf.	species	CWR	WHP	Pistachio	<i>Pistacia vera</i> L.	GenePool	2	10	6	4	0	10	6	High
ANACARDIACEAE	<i>Pistacia lentiscus</i> L.	species	CWR	WHP	Pistachio	<i>Pistacia vera</i> L.	GenePool	2	10	6	4	0	10	6	High
ANACARDIACEAE	<i>Pistacia terebinthus</i> L.	species	CWR	WHP	Pistachio	<i>Pistacia vera</i> L.	GenePool	2	10	6	2	0	10	5.6	High
FABACEAE	<i>Pisum sativum</i> subsp. <i>elatus</i> (M. Bieb.) Asch. & Graebn.	subsp.	CWR	WHP	Pea	<i>Pisum sativum</i> L.	GenePool	1b	10	10	0	0	10	6	High
ROSACEAE	<i>Prunus xfruticans</i> Weihe	species	CWR	WHP	Plum	<i>Prunus domestica</i> L.	TaxonGroup	2	10	6	0	0	10	5.2	High
ROSACEAE	<i>Prunus avium</i> (L.) L.	species	CWR	WHP	Cherry-Sweet	<i>Prunus avium</i> (L.) L.	GenePool	1b	10	10	2	0	10	6.4	High
ROSACEAE	<i>Prunus cerasifera</i> Ehrh.	species	CWR	WHP	Plum-Myrobalan	<i>Prunus cerasifera</i> Ehrh.	GenePool	1b	10	10	0	0	10	6	High
ROSACEAE	<i>Prunus dulcis</i> (Mill.) D. A. Webb	species	CWR	WHP	Almond	<i>Prunus dulcis</i> (Mill.) D. A. Webb	GenePool	1b	10	10	0	0	10	6	High
ROSACEAE	<i>Prunus insititia</i> L.	species	CWR	WHP	Plum-European, Damson	<i>Prunus insititia</i> L.	GenePool	1b	10	10	0	0	10	6	High
ROSACEAE	<i>Prunus prostrata</i> Labill.	species	CWR	WHP	Plum-Myrobalan	<i>Prunus cerasifera</i> Ehrh.	GenePool	2	10	6	2	0	10	5.6	High
ROSACEAE	<i>Prunus spinosa</i> L.	species	CWR	WHP	Plum-European	<i>Prunus domestica</i> L.	GenePool	2	10	6	0	0	10	5.2	High
PUNICACEAE	<i>Punica granatum</i> L.	species	CWR	WHP	Pomegranate	<i>Punica granatum</i> L.	GenePool	1b	10	10	0	0	10	6	High
ROSACEAE	<i>Pyrus syriaca</i> Boiss.	species	CWR	WHP	Pear	<i>Pyrus communis</i> L.	GenePool	2	10	6	0	0	10	5.2	High
BRASSICACEAE	<i>Raphanus raphanistrum</i> L. subsp. <i>raphanistrum</i>	subsp.	CWR	WHP	Radish	<i>Raphanus sativus</i> L.	GenePool	1b	10	10	0	0	10	6	High
BRASSICACEAE	<i>Raphanus raphanistrum</i> subsp. <i>landra</i> (DC.) Bonnier & Layens	subsp.	CWR	WHP	Radish	<i>Raphanus sativus</i> L.	GenePool	1b	10	10	0	0	10	6	High
BRASSICACEAE	<i>Raphanus sativus</i> L.	species	CWR	WHP	Radish	<i>Raphanus sativus</i> L.	GenePool	1b	10	10	0	0	10	6	High
POLYGONACEAE	<i>Rumex aristidis</i> Coss.	species	CWR	WHP	Sorrel	<i>Rumex acetosa</i> L.	TaxonGroup	4	10	4	0	10	10	6.8	High
POLYGONACEAE	<i>Rumex tunetanus</i> Barratte & Murb.	species	CWR	WHP	Sorrel	<i>Rumex acetosa</i> L.	TaxonGroup	4	10	4	10	10	10	8.8	High
AMARANTHACEAE	<i>Salsola tunetana</i> Brullo	species	CWR	WHP	Saltwort	<i>Salsola</i> sp. pl.	TaxonGroup	4	0	4	4	10	10	5.6	High
CAPRIFOLIACEAE	<i>Sambucus nigra</i> L.	species	CWR	WHP	Elderberry	<i>Sambucus nigra</i> L.	TaxonGroup	1b	10	10	0	0	10	6	High
ASTERACEAE	<i>Scorzonera hispanica</i> subsp. <i>coronopifolia</i> (Desf.) Rouy	subsp.	CWR	WHP	Scorzonera	<i>Scorzonera hispanica</i> L.	TaxonGroup	1b	10	10	0	0	10	6	High
BRASSICACEAE	<i>Sinapis alba</i> subsp. <i>dissecta</i> (Lag.) Bonnier	subsp.	CWR	WHP	Mustard-White	<i>Sinapis alba</i> L.	GenePool	1b	10	10	0	0	10	6	High
BRASSICACEAE	<i>Sinapis alba</i> subsp. <i>mairei</i> (H. Lindb.) Maire	subsp.	CWR	WHP	Mustard-White	<i>Sinapis alba</i> L.	GenePool	1b	10	10	0	0	10	6	High

Table 4 continued

Family	Taxon	Rank	CWR	WHP	CROP name	CROP taxa	GenePool - TaxonGroup	Relative degree	Economic Priority	Breeding Priority	Conservation Priority	Endemic Priority	Energy Supply-ITPGRFA Priority	FPS	Priority
BRASSICACEAE	<i>Sinapis arvensis</i> L. subsp. <i>arvensis</i>	subsp.	CWR	WHP	Mustard-Black	<i>Brassica nigra</i> (L.) W.D.J. Koch	GenePool	2	10	6	0	0	10	5.2	High
BRASSICACEAE	<i>Sinapis pubescens</i> L. subsp. <i>pubescens</i>	subsp.	CWR	WHP	Radish	<i>Raphanus sativus</i> L.	GenePool	3	10	2	4	0	10	5.2	High
ROSACEAE	<i>Sorbus aria</i> (L.) Crantz	species	CWR	WHP	Service-Apple	<i>Sorbus domestica</i> L.	TaxonGroup	4	10	4	2	0	10	5.2	High
ROSACEAE	<i>Sorbus umbellata</i> (Desf.) Fritsch	species	CWR	WHP	Service-Apple	<i>Sorbus domestica</i> L.	TaxonGroup	4	10	4	2	0	10	5.2	High
AMARANTHACEAE	<i>Spinacia oleracea</i> L.	species	CWR	WHP	Spinach	<i>Spinacia oleracea</i> L.	GenePool	1b	10	10	0	0	10	6	High
LAMIACEAE	<i>Thymus algeriensis</i> Boiss. & Reut.	species	CWR	WHP	Thyme	<i>Thymus vulgaris</i> L.	TaxonGroup	4	8	4	0	10	10	6.4	High
LAMIACEAE	<i>Thymus numidicus</i> Poir.	species	CWR	WHP	Thyme	<i>Thymus vulgaris</i> L.	TaxonGroup	4	8	4	0	10	10	6.4	High
ASTERACEAE	<i>Tragopogon porrifolius</i> L. subsp. <i>porrifolius</i>	subsp.	CWR	WHP	Oyster Plant	<i>Tragopogon porrifolius</i> L.	TaxonGroup	1b	10	10	0	0	10	6	High
FABACEAE	<i>Trigonella foenum-graecum</i> L.	species	CWR	WHP	Fenugreek Seed	<i>Trigonella foenum-graecum</i> L.	TaxonGroup	1b	8	10	0	0	10	5.6	High
POACEAE	<i>Triticum dicoccum</i> Schübl.	species	CWR	WHP	Wheat-Emmer	<i>Triticum dicoccum</i> Schübl.	GenePool	1b	10	10	0	0	10	6	High
POACEAE	<i>Triticum durum</i> Desf.	species	CWR	WHP	Wheat-Durum	<i>Triticum durum</i> Desf.	GenePool	1b	10	10	0	0	10	6	High
POACEAE	<i>Triticum polonicum</i> L.	species	CWR	WHP	Wheat-Polish	<i>Triticum polonicum</i> L.	GenePool	1b	10	10	0	0	10	6	High
FABACEAE	<i>Vicia faba</i> L.	species	CWR	WHP	Faba-Bean	<i>Vicia faba</i> L.	GenePool	1b	10	10	0	0	10	6	High
FABACEAE	<i>Vicia fulgens</i> Batt.	species	CWR	WHP	Vetch-Common	<i>Vicia sativa</i> L.	TaxonGroup	4	3	4	10	10	10	7.4	High
FABACEAE	<i>Vicia monardi</i> Boiss. & Reut.	species	CWR	WHP	Broad beans	<i>Vicia</i> sp. pl.	TaxonGroup	4	10	4	0	10	10	6.8	High
FABACEAE	<i>Vicia narbonensis</i> L.	species	CWR	WHP	Vetch-Narbon	<i>Vicia narbonensis</i> L.	GenePool	1b	3	10	2	0	10	5	High
FABACEAE	<i>Vicia sativa</i> subsp. <i>amphicarpa</i> (Dorthes) Batt.	subsp.	CWR	WHP	Vetch-Common	<i>Vicia sativa</i> L.	GenePool	1b	3	10	3	0	10	5.2	High
FABACEAE	<i>Vicia sativa</i> subsp. <i>macrocarpa</i> (Moris) Arcang.	subsp.	CWR	WHP	Vetch-Common	<i>Vicia sativa</i> L.	GenePool	1b	3	10	2	0	10	5	High
FABACEAE	<i>Vicia sativa</i> subsp. <i>nigra</i> (L.) Ehrh.	subsp.	CWR	WHP	Vetch-Common	<i>Vicia sativa</i> L.	GenePool	1b	3	10	2	0	10	5	High
VITACEAE	<i>Vitis vinifera</i> L. subsp. <i>vinifera</i>	subsp.	CWR	WHP	Grape-Wine	<i>Vitis vinifera</i> L.	GenePool	1b	10	10	0	0	10	6	High
VITACEAE	<i>Vitis vinifera</i> subsp. <i>sylvestris</i> (C. C. Gmel.) Hegi	subsp.	CWR	WHP	Grape-Wine	<i>Vitis vinifera</i> L.	GenePool	1b	10	10	0	0	10	6	High

Table 5 Crops/crop groups of high importance with wild relatives in Tunisia

Crop/crop groups	Genus/Genera	No. of high priority taxa
Brassicacae	<i>Brassica</i> L.; <i>Guenthera</i> Besser; <i>Raphanus</i> L.; <i>Sinapis</i> L	15
Carrot	<i>Daucus</i> L	13
Wheat	<i>Aegilops</i> L.; <i>Triticum</i> L	11
Stonefruits	<i>Prunus</i> L	7
Broad/horse bean/Vetch	<i>Vicia</i> L	7
Leeks and other alliaceous vegetables	<i>Allium</i> L	6
Oat	<i>Avena</i> L	5
Flax	<i>Linum</i> L	4
Tarragon	<i>Artemisia</i> L	3
Azarole	<i>Crataegus</i> L	3
Pistachio	<i>Pistacia</i> L	3
Milkvetch	<i>Astragalus</i> L	2
Orach Spinach	<i>Atriplex</i> L	2
Sugarbeet	<i>Beta</i> L	2
Chicory/Endive	<i>Cichorium</i> L	2
Artichoke	<i>Cynara</i> L	2
Fennel	<i>Foeniculum</i> Mill	2
Juniper berries	<i>Juniperus</i> L	2
Lettuce	<i>Lactuca</i> L	2
Garden Cress	<i>Lepidium</i> L	2
Sorrel	<i>Rumex</i> L	2
Service-Apple	<i>Sorbus</i> L	2
Thyme	<i>Thymus</i> L	2
Grape-Wine	<i>Vitis</i> L	2
Amaranth, Purple	<i>Amaranthus</i> L	1
Dill Seed	<i>Anethum</i> L	1
Chervil	<i>Anthriscus</i> Pers	1
Celery	<i>Apium</i> L	1
Tree-Strawberry	<i>Arbutus</i> L	1
Asparagus	<i>Asparagus</i> L	1
Capers	<i>Capparis</i> L	1
Carob	<i>Ceratonia</i> L	1
Chickpea	<i>Cicer</i> L	1
Watermelon	<i>Citrullus</i> Schrad	1
Coriander	<i>Coriandrum</i> L	1
Melon	<i>Cucumis</i> L	1
Cumin	<i>Cuminum</i> L	1
Orchard Grass	<i>Dactylis</i> L	1
Perennial Wall Rocket	<i>Diplotaxis</i> DC	1
Fig	<i>Ficus</i> L	1
Tree cotton	<i>Gossypium</i> L	1
Hyacinth Bean	<i>Lablab</i> Adans	1
Grass-Pea	<i>Lathyrus</i> L	1
Laurel	<i>Laurus</i> L	1

Table 5 continued

Crop/crop groups	Genus/Genera	No. of high priority taxa
Lentil	<i>Lens</i> Mill	1
Apple	<i>Malus</i> Mill	1
Olive	<i>Olea</i> L	1
Indian Fig	<i>Opuntia</i> Mill	1
Parsley	<i>Petroselinum</i> Hill	1
date palm	<i>Phoenix</i> L	1
Anise	<i>Pimpinella</i> L	1
Pea	<i>Pisum</i> L	1
Pomegranate	<i>Punica</i> L	1
Pear	<i>Pyrus</i> L	1
Saltwort	<i>Salsola</i> L	1
Elderberry	<i>Sambucus</i> L	1
Scorzonera	<i>Scorzonera</i> L	1
Spinach	<i>Spinacia</i> L	1
Oyster plant	<i>Tragopogon</i> L	1
Fenugreek seed	<i>Trigonella</i> L	1
TOTAL		139

Maire, together with other 11 taxa of the same genus, are classified as a high priority for further conservation because of their importance for agriculture, their restricted geographical distribution and potential use in breeding for crop improvement. Other taxa, like *D. aureus* Desf., *D. crinitus* Desf., and *D. setifolius* Desf., are classified as medium priority because they are less closely related, again in agreement with Mezghani et al. (2019). However, it must be observed that floristic treatments of this genera and the subspecies variation in *D. carota* are often controversial (Mezghani et al. 2017).

Eleven CWR taxa (high priority) belonging to *Aegilops* L. (GP2) and *Triticum* L. (GP1b), and 6 tertiary gene pool taxa (medium priority) are relatives of wheat (*Triticum* spp.) and barley (*Hordeum vulgare*), respectively—the two most profitable cereal crops in Tunisia. The average wheat production in Tunisia in the period 2012–2016 was 1.2 million tonnes (FAO 2019b), but due to rainfall variations and large inter-annual fluctuations (WFP, 2011), an increasing (+ 121%) wheat import between 1984 and 2016 has been reported (Khaldi and Saaidia 2017; Sadok et al. 2019). Currently, the national production is estimated well below the yield potential of 5 T ha⁻¹ (ONAGRI 2018). Hence, to ensure yield improvement

and food security, the role of these wild relatives could be of great interest for breeding purposes. The same is true also for barley production (Lasram et al. 2017). *Citrullus colocynthis* (L.) Schrad. (high priority) is the only one CWR for watermelon (*Citrullus lanatus* (Thunb.) Matsum. and Nakai), another of the most profitable crops. High priority CWR taxa related to other significant Tunisian crops are: *Malus pumila* Mill., a secondary wild relative of apple, which represents an important economic income for the country (48,5 million US \$ per annum, over the period 2012–2016); *Brassica rapa* subsp. *campestris* (L.) A. R. Clapham, primary wild relative of turnip; thirteen *Daucus* taxa that are primary and secondary wild relatives of carrot—another economically important crop (29 million US \$ per annum, over the period 2012–2016) which contributes, together with turnip, for more than 2% to the daily energy contribution in Tunisia; *Pisum sativum* subsp. *elatius* (M. Bieb.) Asch. and Graebn., primary wild relative of pea, native to the Euro-Mediterranean region and with a potential use against biotic stress (Vincent et al. 2013); and *Allium* sp. pl. related to onion, leek, and other alliaceous crops, with 6 high and 18 medium priority wild taxa and widely used as food, spices and as medicinal plants.

It is also worth mentioning the case of olive (*Olea europaea* L. subsp. *europaea*). Tunisia is the world's second largest olive oil producer after the EU (IOC, 2021), and olive oil is the main national agricultural product in terms of value, accounting, on average, for about 480 million US \$ per annum (FAO 2019b). Olive oil is the main agricultural export product, its sector represents one of the major drivers for socio-economic development of the rural areas, and it contributes 1.6% of the dietary energy per capita per day in the region. The wild form of *O. europaea* L. (GP1b), commonly referred to as Oleaster, has been classified accordingly as high priority. It is still widely used for rootstock, especially in traditional, semi-arid areas of cultivation, and is a suitable genetic resource for crop improvement and for enlarging the basis of genetic variability for olive breeding (Hannachi et al. 2009; Rallo et al. 2018). Therefore, it should be given the highest priority for active in situ and ex situ conservation in Tunisia.

As emerged from this description of the CWR diversity of Tunisia, there are several aspects in which this prioritised plant genetic resources can be useful. At a global level, protecting the biodiversity is fundamental for safeguarding the related ecosystem services which can be beneficial for a more sustainable agriculture. These PGRs can be used to increase food security by improving yield and resistance of the crops to biotic and abiotic factors, and this is particularly true for those wild plant adapted to extreme environmental conditions. This is the case, for example, of the priority CWR related to wheat and barley that could be further investigated in breeding programs aiming at the improvement of yield stability which is strongly affected by environmental factors in the country (Ayed et al. 2021) or carrots and cabbages, which represent a valuable part of the economic income, and are represented by a wide variability of wild relatives in Tunisia.

Conclusions

Tunisia is not widely recognized as a regional hotspot of plant diversity and endemism (Médail and Quézel 1999)—however, according to several authors, a large part of the country has been included within the Mediterranean biodiversity hotspot for conservation priorities (Vavilov 1926; Myers et al. 2000; Maxted

and Vincent 2021). Our results, in agreement with Castañeda-Álvarez et al. (2016), Vincent et al. (2013) and Maxted and Vincent (2021), suggest that Tunisia can be confirmed as a hotspot of CWR and WHP diversity in the Mediterranean. The results here presented show that 85% of the Tunisian flora is potentially useful either indirectly as a source of genetic diversity for crop improvement (CWR), or directly in ethnobotanical, medicinal or food uses. Indeed, the inventory developed includes 2468 CWR and/or WHP taxa which is about 40% of the CWR reported for the North African region as a whole (Lala et al. 2018).

Mediterranean countries, including Tunisia, are considered central repositories of valuable genetic resources and are therefore responsible for their conservation (Labokas et al. 2018). Tunisia hosts several taxa adapted to extreme habitats, including salt and drought-resistant species, whose characteristics might be useful for genetic improvement of a wide range of cultivated relatives, especially in a scenario of climatic change. The prioritisation process led us to highlight 139 CWR, related to 60 crops or crop groups of socio-economic importance (Table 5), and 8 WHP high priority taxa that deserve to be included into urgent national conservation programs to meet the objectives of the global policies and legislative instruments to which Tunisia is committed.

This is, to date, the first CWR and WHP inventory for the North African region conducted at a national scale. It can offer the basis for further ecogeographic studies to evaluate in situ and ex situ status of the priority taxa and the development of more targeted synergistic conservation strategies. To this end, the integration of species-specific programs of in situ monitoring and conservation management into protected area management plans, with complementary ex situ conservation in the national genebank, is needed to decrease the risk of genetic erosion. Loss of genetic diversity is occurring in these areas without being acknowledged by monitoring teams because these socio-economically important species are not being targeted by protected area managers (Maxted et al. 2013). If these populations are not actively managed, the highest priority taxa will continue to suffer significant genetic erosion and are at risk of extinction. For ex situ conservation, the National Gene Bank of Tunisia (Banque Nationale de Gènes de Tunisie), which aims to conserve the Country's plant

genetic resources, could undoubtedly play a leading role in conservation efforts, gene banking samples from distinct CWR and WHP populations, as well as in collaborating with in situ site managers in establishing a network of sites for in situ conservation, and vitally, in enabling access to material for use by plant breeders and farmers for crop improvement. Finally, the present work clearly showed the need of appropriate research on the quantification of CWR/WHP ecosystem services to assure the sustainable management of these PGR in the Tunisian arid and semi-arid environments and/or protected areas. Taking into account the contribution that these PGR give to national income or may have for the sustainability of major crop industries, further studies should be addressed to expand knowledge on the trade-off between their usage by the rural communities and related economic return in relation to the need for their conservation.

Declarations

Conflict of interest The authors declare no conflict of interest.

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