A new list and prioritization of wild plants of socio-economic interest in Italy: towards a conservation strategy

Simona Ciancaleoni[1§], Lorenzo Raggi[1§], Giulio Barone[2§], Domizia Donnini[1], Daniela Gigante[1], Gianniantonio Domina[2], Valeria Negri[1*]

[1] Department of Agricultural, Food and Environmental Sciences, University of Perugia, Borgo XX Giugno 74, 06121 Perugia, Italy

[2] Department of Agricultural, Food and Forest Sciences, University of Palermo, Viale delle Scienze, bldg. 4, I-90128 Palermo, Italy.

[§] These authors equally contributed to the paper

Corresponding author: V. Negri, e-mail: valeria.negri@unipg.it, phone +39 075 5856218, fax +39 075 5856218

Abstract

Wild harvested plants and crop wild relatives, part of the segment of natural diversity that is collectively known as “Plant Genetic Resources”, have great socio-economic importance for humans because they are used either directly or in crop breeding. In order to lay down a solid base for constructing conservation strategies for Italy, an updated annotated list of CWR and WHP was produced for the country including information on known uses. Taxa included in the list were then prioritised using a pragmatic approach based on their value, native status and need of protection or monitoring.

Keywords: Crop Wild Relatives; Italian CWR check list; CWR taxa conservation priority; Biodiversity; Ethnobotanical use;

Introduction

It is commonly acknowledged that the inter- and intra-specific diversity, as well as the habitat diversity of wildlife is under threat of irremediable loss (Cardinale et al. 2012; Ceballos et al. 2015; Leigh et al. 2019; Chase et al. 2020). The Mediterranean basin is an important biodiversity hotspot with about 25,000 plant species (Cuttelod et al. 2008), of which about 13,000 are endemic (Myers et al. 2000). In particular, after the Iberian Peninsula and Balearic Islands, the Italian Peninsula and the main Italian Islands are the European areas where the highest number of endemic plant species can be found (Castroviejo 2010; Bilz et al. 2011; Bartolucci et al. 2018). Because of their distribution and the real and potential threats to the conservation of their populations (Bilz et al. 2011), many plant species of the Mediterranean area are considered in need of protection and/or monitoring by national and international conservation policies such as the Bern Convention (Council of Europe 1979) and the Habitats Directive 92/43/EEC (European Commission 1992). The Crop Wild Relatives, CWR (*i.e.* wild plant taxa that are relatively genetically close to cultivated plants) (Maxted et al. 2006) and the Wild Harvested Plants, WHP (*i.e.* non-cultivated species, which are collected from the wild for different uses) (Magos Brehm et al. 2008) are among these species (Bilz et al. 2011; Kell et al. 2012). Both CWR and WHP should be protected not only *per se*, as key elements of biodiversity, but also for their great and direct socio-economic importance for humans. Together with modern and obsolete cultivars, landraces and genetic stocks, CWR and WHP make up an important segment of diversity of living beings that nourish humankind and are collectively recognised as Plant Genetic Resources (PGR) (SoW1-PGRFA, 1996).

WHP are an important component of the ecosystems, are part of the local traditions linked to the use of plants, have potential uses and are under increasing pressure due to climate change, development and overexploitation (Kling 2016).

CWR, some of which are also collected in the wild for different purposes including human consumption, are widely used in specific breeding programs aimed at improving crops for productivity, quality and resistance to biotic and abiotic stress (Hajjar and Hodgkin 2007; Maxted et

al., 2010;). The most relevant economic impact of wild relatives in crop improvement is related to the introgression of disease and pest resistance traits in several crops (Goodman et al. 1987; Lenne´ and Wood 1991; Hoisington et al. 1999; Maxted and Kell, 2009). The introduction of new genes (and genetic modifications) through crossing with wild relatives, enhancing yield and biotic or abiotic resistance, can provide immense benefits to national and world economies (Nair, 2019)). For these important conservation and economic reasons, CWR deserve particular attention, especially the highly threatened ones (Maxted et al. 1997; Maxted and Kell 2009; Farmer's Pride Consortium 2019 and references therein).

Any wild plant taxon related to a crop can be defined as a CWR, but it is its genetic relatedness with a certain cultivated taxon that conditions how easily it can be used in crop breeding. Following the concept of Harlan and de Wet (1971), only taxa at least partially fertile with the crop (*i.e.* included in Gene Pool 1 and 2) are commonly considered as CWR. However, it should be pointed out that not all the interbreeding relationships of wild plants with crops have been assessed yet. For this reason, Maxted et al. (2006) proposed the concept of Taxon Group (TG) where, broadly speaking, a CWR is considered any taxa belonging to the same genus as the crop, the genus being a proxy for relatedness.

Following the Rio Conference (CBD 1992), the need for an effective PGR conservation program has been stressed on a global scale by several institutions and agreements, such as the two global plans for conservation plant genetic resources for food and agriculture (FAO 1996, 2011), the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, FAO 2001), the Global and European Strategies for Plant Conservation (CBD 2010a, 2010b; Planta Europa 2008) and the UN Sustainable Development Goals (UN 2015), particularly 2 and 15. Most recently, the European Union adopted a new strategy to halt biodiversity loss and restore ecosystems which steps up efforts to avert European biodiversity loss by establishing protected areas up to 30% of land and sea (European Commission, 2020).

In order to generate national and international PGR conservation plans, the first step is to create and maintain updated dedicated inventories of taxa. These inventories serve as the basis for an analysis of their patterns of distribution, level of threat, current conservation actions and identification of priority sites in need of conservation (Maxted et al. 2007). Based on the common CWR concept, Heywood and Zohary (1995) and Mazzola et al. (1997) compiled the first European and Italian CWR inventories. Recently, applying the CWR concept developed by Maxted et al. (2006), a comprehensive list of CWR for Europe and the Mediterranean area was produced which includes 25,687 native and exotic CWR taxa (Kell et al. 2005, 2008); 5,712 taxa are catalogued for Italy in this inventory. However, to develop precise conservation plans for a certain country, the taxa included in the catalogues need to be validated and refined, considering the regional and national floras and checklists. In addition, since not all the taxa are at risk, methods to identify those taxa most in need of protection should be developed. Several countries are creating, or already created their specific national inventories of plant genetic resources (*e.g.* Maxted *et al.*, 2007; Menezes de Sequeira *et al.*, 2012; Khoury *et al.*, 2013; Fitzgerald, 2013; Rubio Teso *et al.*, 2018).

As concerns the WHP use, a large amount of literature is available on the subject with regard to Europe (Magos Brehm et al. 2008 and refs. therein) and Italy (Bandini 1961; Barone 1963; Capasso et al. 1982; Antonone et al. 1988; Hammer et al. 1992, 1999; Pieroni and Quave 2005; Pieroni and Giusti 2009; Arcidiacono 2016; Guarrera and Savo 2016; Accogli and Medagli 2019). However, detailed lists at the national and local scales are still missing for most of the European countries. Additionally, when present, national lists are often restricted to annotated inventories and most frequently include neither the detailed distribution nor the demographic status of the considered species. That is also the case of the Italian CWR/WHP lists proposed by Landucci et al. (2014), which also include a prioritisation method applied to Italian territory. Ever since, a thorough taxonomic revision of the Italian flora has been carried out in Italy (Bartolucci et al. 2018; Galasso et al. 2018), with the serious consequence of a broad change of the geographic occurrence of taxa at the territorial level. Additionally, there has been a reassessment of their threat status as well (Rossi

et al. 2016; Orsenigo et al. 2018, 2021). As a consequence, the Italian CWR/WHP lists by Landucci et al. (2014) became obsolete and unusable.

In order to contribute to the development of solid conservation strategies for wild plants of socio-economic value in Italy, the main purposes of this study were to: i) provide revised and nomenclaturally updated CWR and WHP taxa lists, a crucial step in order to advance with the process of CWR investigation and enhancement; ii) create new updated priority lists, according to the revised taxonomic and conservation status of the Italian species, considering taxa important for food security, threat status and conservation policies at the international, national and administrative regional level; iii) analyse the changes in the number of species considered most vulnerable in the last 2 decades and iv) review different uses of WHP taxa.

Material and Methods

An updated CWR/WHP checklist for Italy

The Working Database of the Italian Vascular Flora developed by Landucci et al. (2014), available from http://vnr.unipg.it/PGRSecure, was used as starting point for this study. The updated *CWR/WHP* checklist for Italy was obtained by the following steps (please note that checklists specific for Italian peninsula, Sardinia and Sicily are all derived from this Italian checklist):

1. Recently identified taxa (e.g. Foggi et al. 2005; Conti et al. 2011; Domina et al. 2017) were added.
2. The nomenclature was revised according to the most recent Italian checklist and its updates (Bartolucci et al. 2018; Galasso et al. 2018) adding up to 10 of the most used synonyms in the Italian literature. The regional distribution was retrieved from Bartolucci et al. (2018), Galasso et al. (2018) and Pignatti et al. (2017-2019).
3. Additional information about origin (*i.e.* native or introduced, archaeophyte or neophyte status), the indication of endemic status (or not), cultivation, economic importance, uses, gene pool, and protection and/or monitoring need was provided for each taxon according to

Hammer et al. (1992, 1999), Global Crop Diversity Trust (2019), Germplasm Resources Information Network (USDA, ARS 2019) and several Italian contributions (*e.g.* Atzei et al. 1994; Atzei 2003; Leporatti et al. 1985; Leporatti and Pavesi 1989; Manzi 1999, 2003; Pieroni 2000; Pieroni and Quave 2005; Arrigoni 2006; Pieroni and Giusti 2009; Arrigoni 2010a, 2010b; La Mantia et al. 2011; Arrigoni 2013; Schicchi and Geraci 2015 Guarrera and Savo 2016; Biscotti et al. 2018; Pasta et al. 2020), also supplemented with personal knowledge of the authors.

4. Finally, the indication of the need of protection and/or monitoring at the national level was integrated following the most recent Italian Red lists (Rossi et al. 2016, Orsenigo et al. 2018, 2021) or, when taxa were not included in these lists, the IUCN Red List of Threatened Species (IUCN 2020), database available online.

The described procedure allowed to produce an updated version of the 'annotated' Italian CWR/WHP checklist. Distinct lists were then extracted for: i) the Italian Peninsula, ii) Sardinia and iii) Sicily. Lists developed for Sardinia and Sicily were based on the actual occurrence of the taxa in the regions. The two main Italian Islands, both corresponding to administrative regions (Sicily and Sardinia) and Euro+Med territories (de Jong et al. 2015) were focused since they both include large and heterogeneous territories and are characterized by a remarkably high number of endemic species (Bartolucci et al. 2018) thus constituting an emblematic example of the strong spatial and biogeographical diversity typical of Italy. The developed lists will be made available in one of the next updates of the 'Portal to the Flora of Italy' (http://dryades.units.it/floritaly/index.php).

Identifying taxa to be protected with priority for Italy

The choice of prioritization criteria followed previous experiences (*e.g.* Khoury et al. 2013; Landucci et al. 2014) and answered the specific need to address attention to the most threatened taxa since this is the pragmatic approach of the Italian conservation framework.

As a first step, the wild relative taxa of crops listed in Annex I of the ITPGRFA (FAO 2001) and/or by the Italian Institute of Statistics for cultivated areas and yield in the last five years (ISTAT 2019). The two groups together includes the most socio-economical important crops for food and agriculture for Italy and the entire European region. Then, in order to focus our attention on taxa in high need of protection, we considered the threatened taxa occurring in Red lists.

The highest priority conservation ('A', see below) was assigned to native and allochthonous taxa listed in the most recent Italian and IUCN Red List (IUCN Red List of Threatened Species 2020-; Rossi et al. 2016; Orsenigo et al. 2018, 2021) as: Critically Endangered or Possibly Extinct, (CR(PE)), Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Near Threatened (NT). Taxa characterized by a low risk level (LC) or by inadequate information (DD) were not considered.

As for priorities 'B' and 'C' (see below) assignments were as in Landucci et al. (2014) since criteria were considered to be still actual. In this process, allochthonous taxa were excluded.

As a result of the prioritisation process the taxa of interest were grouped into three distinct categories of conservation priority, 'A', 'B' and 'C', defined as follows:

- the 'A' category includes native and allochthonous taxa related to a crop of European and national importance for food and agriculture that need specific protection and/or monitoring measures; taxa in this category are present in at least one of the most recent National Red Lists (Rossi et al. 2016; Orsenigo 2018, 2021) or in the IUCN Red List (IUCN 2020).
- the 'B' category includes endemic or subendemic taxa and, although they do not necessarily require specific protection measures, they require monitoring because of their restricted distribution.
- finally, the 'C' category includes all the remaining native taxa which, on the grounds of current knowledge, do not need any specific protection measure.

Species under threat across time

In order to get insights on taxa in most need of protection, further analyses were carried out on those listed as Critically Endangered or Possibly Extinct (CR(PE)), Critically Endangered (CR) and Endangered (EN). The number of taxa belonging to these categories reported in Conti et al. (1997) was compared to numbers reported in Rossi et al. (2013) and in Rossi et al. (2016) and Orsenigo (2018, 2021).

Recording uses of WHP taxa

Following the approach of Kell et al. (2008), in the CWR/WHP checklist drafted, the status of 'CWR' was attributed to all the taxa (both cultivated and wild, native and non-native) strictly related to a cultivated species somewhere in the world (*i.e.* belonging to the same genus). The status of 'WHP' was attributed to all the taxa with one or more known direct uses, independently of the actual commercialisation of their products (Magos Brehm et al., 2008). Following Wiersema and León (1999) and Pasta and collaborators (2020), WHP species (some of which are CWR too) were categorized according to their use: generic ethnobotanical, medicinal, ornamental, food, fodder, poison, material, environmental, gene source, food additive, honey production, drink, fuel and social use.

In order to have reliable data, the analysis of WHP recorded uses was carried out at the taxonomic rank of species. The inclusion of infra-specific taxa or cultivated forms, which are obviously used, would have resulted in a biased figure. The number of taxa (WHP only or both WHP and CWR) in relation to different recorded uses, was calculated by geographical areas (Italy, Italian Peninsula, Sardinia and Sicily).

CWR/WHP checklist data analysis

Different elaborations were carried out for each of the four considered geographical areas as follows. It should be noted that when percentages are reported for the different considered geographical areas, they are calculated considering the total number of taxa present in that specific

212 area. In the ‘Rank’ column of the checklists, taxa were counted considering the occurrences of
213 codes: ‘species’ + ‘subsp.’ + ‘var.’ + ‘nothosubsp.’ while species were counted considering the
214 occurrences of codes: ‘species’ + ‘(sp.)’.
215 The following summaries were calculated.
216 • ‘Total CWR and/or WHP’: taxa that are coded as ‘CWR’ only + ‘WHP’ only + both ‘CWR’
217 and ‘WHP’ (*i.e.* recorded as both CWR and WHP in our database) (‘CWR’ and ‘WHP’
218 columns of the checklist);
219 • ‘CWR’: taxa coded as ‘CWR’ only + ‘CWR’ and ‘WHP’ at the same time (‘CWR’ and
220 ‘WHP’ columns of the checklist);
221 • ‘WHP’: taxa coded as ‘WHP’ + ‘CWR’ and ‘WHP’ at the same time (‘CWR’ and ‘WHP’
222 columns of the checklist);
223 • ‘Only WHP’: taxa coded as ‘WHP’ only;
224 • ‘Taxa/species in need of monitoring or protection’: only taxa and *species* coded as ‘A’ or
225 ‘B’ in the ‘Priority’ column;
226 • ‘Native’ (for both CWR and WHP): taxa coded as ‘N’ (native), ‘S’ (assumed to be native)
227 and ‘D’ (doubtfully native) according to Bartolucci et al. (2018) and Galasso et al. (2018) in
228 the ‘Native’ column;
229 • ‘Non native’ (for both CWR and WHP): taxa coded as ‘A’ (not native) according to
230 Bartolucci et al. (2018) and Galasso et al. (2018) in the ‘Native’ column.
231 In the manuscript, the cumulative number of species and subspecies (*i.e.* ‘taxa’) is reported
232 followed by the number of species in brackets.
233
234 **Results and discussion**
235 *An updated CWR/WHP checklist for Italy*
236

237 According to the results of our revision, 8,766 CWR/WHP taxa belonging to 7,334 species are
238 recorded in Italy. In particular, 6,839 (5,516) are CWR only, 108 (108) WHP only and 1,821
239 (1,710) CWR and WHP at the same time (*i.e.* they are related to a cultivated species and
240 characterised by having a certain use as wild plants).
241 Taxa and species are distributed as follows: 7,916 (6,641), 2,745 (2,600), 2,952 (2,738) for the
242 Italian Peninsula, Sardinia and Sicily respectively (Table 1). These numbers (8,766 total CWR
243 and/or WHP taxa belonging to 7,344 species) are lower compared to Landucci et al. (10,779 total
244 CWR and/or WHP taxa belonging to 7,128 species) (Landucci et al. 2014) when looking at the taxa,
245 but higher when considering the species. This is due to the new and different species delimitation
246 adopted in the updated checklist of Italy (Bartolucci et al. 2018; Galasso et al. 2018) and to the
247 increased knowledge of plant taxonomy in recent years (e.g. Astuti et al. 2017; Domina et al. 2017;
248 Giovino et al. 2020).
249 Most of the CWR and/or WHP taxa are native; according to the revised prioritisation, 1.8%, 1.0%,
250 1.0% and 2.4% resulted in need of protection in Italy, Italian Peninsula, Sardinia and Sicily,
251 respectively. When only native taxa that are relevant for Italian agriculture according to data from
252 ISTAT were considered, 16.4%, 8.8%, 4.6% and 15.9% resulted in need of protection for the same
253 geographical areas. According to reported data, when all taxa are considered, the need of
254 implantation of protection activities seems to be not immediately necessary. However, this scenario
255 changes quite dramatically when the attention is focused on taxa that are CWR of crop species that
256 are of socio-economic relevance for Italy. Considering that CWR are potential trait donors to crops
257 – and that taxa relevant for the improvement of the most socio-economically important crops
258 should be prioritized for conservation – the need of protecting such taxa is quite urgent in order to
259 safeguard their genetic diversity for its potential use in crop improvement programmes.
260 The 81.2% of the total CWR/WHP native taxa is CWR of some crops. Out of the recorded CWR,
261 19.0%, 19.8%, 21.0% and 17.6% are exotic (mostly neophytes) while 17.9%, 13.0%, 11.5% and
262 13.6% are endemic of Italy, Italian Peninsula, Sardinia and Sicily, respectively.

263 Regarding the WHP, 1,927(1,818) were recorded for Italy, 1,855 (1,768) for the Italian Peninsula,
264 944 (940) for Sardinia and 1,003 (974) for Sicily (Table 1). Of these, only small percentages of taxa
265 are non native (mostly neophytes): 11.7%, 11.6%, 9.6% and 9.3% for Italy, Peninsula, Sardinia and
266 Sicily, respectively. Only 108 (108), 105 (105), 62 (62), 65 (65) WHP taxa (species) cannot be
267 considered relatives of any crop for Italy and the same considered regions, respectively.
268
269 *Priority taxa to be protected in Italy*Species and subspecies (i.e. taxa) belonging to each one of the
270 three defined protection priority categories ('A', 'B' and 'C') are show in Figure 1.
271 The updated prioritization process resulted in the identification of a lower number of taxa in need of
272 protection in Italy: from 129 (124) 'A', 85 (76) 'B' and 904 (606) 'C' of Landucci et al. (2014) to
273 102 (82), 57 (50) and 735 (648) of the present study. This result is basically due to the
274 nomenclatural updating and not due to a decrease of the taxa threat levels.
275 According to our results, the taxa to be protected with highest priority in Italy ('A' category) belong
276 to 36 different genera (Table 2). Among them, *Allium* L., *Asparagus* L., *Avena* L., *Brassica* L.,
277 *Cichorium* L., *Citrullus* Schrad., *Daucus* L., *Diplotaxis* DC., *Festuca* L., *Lactuca* L., *Lathyrus* L.,
278 *Malus* Mill., *Prunus* L., *Trifolium* L., and *Vicia* L. have already been reported to be of highest
279 conservation priority, both for Italy (Landucci et al. 2014) and globally (Castaneda Alvarez et al.
280 2016). With reference to Landucci et al. (2014) the taxa to be protected with highest priority ('A'
281 category) identified in this study are quite similar with the addition of the genera *Agrostis* L.,
282 *Cynara* L., *Linum* L., *Lolium* L., *Pistacia* L., *Ribes* L., *Thinopyrum* Á.Löve and *Visnaga* Mill. and
283 the exclusion of *Atriplex* L., *Eruca* Mill., *Hedysarum* L., *Helosciadium* W.D.J.Koch, *Lens* Mill.,
284 *Lepidium* L., *Lupinus* L., *Pimpinella* L., *Rorippa* Scop., and *Vaccinium* L. This discrepancy is
285 mainly due to the different generic delimitation adopted (*e.g.* see the case of several species
286 previously attributed to *Lens* and now referred to *Vicia*).
287 As for the endemic species, different genera in the 'A' category of protection were recorded in
288 Sardinia (*Astragalus* L., *Festuca*, *Lactuca*, *Linum*, *Phleum* L. and *Ribes*) and in Sicily (*Allium*,

289 *Arrhenantherum* P.Beauv., *Astragalus*, *Brassica*, *Diplotaxis*, *Festuca*, *Linum*, *Malus*, *Prunus* and
290 *Trifolium*).
291 Since modern varieties, landraces and ecotypes of crops belonging to the 36 genera most in need of
292 protection identified in this study ('A' category) are cultivated in Italy (Negri 2003; Negri et al.
293 2013), these CWR (Table 2) emerge as precious resources for breeding. Indeed, according to
294 Dempewolf et al. 2017, several species of these genera have been already successfully used in
295 breeding programs to improve biotic and abiotic stress resistance, quality, agronomic, fertility and
296 phenological traits of the corresponding crops (Table 3).
297 It is noteworthy that *Allium* and *Brassica* are still among those with highest conservation priority as
298 already indicated by Landucci et al. (2014); considering the high economic values of crops
299 belonging to these two genera (Kell et al., 2012), it is clear that more efforts are needed to protect
300 their wild forms. It is also noteworthy that wild populations of some *Allium* and *Brassica* taxa are
301 still intensively collected in the wild and this practice might worsen the already threatened status of
302 some populations. It is the case of *B. insularis* and *B. rupestris* subsp. *hispida*, reported as Near
303 Threatened and Vulnerable in Sicily, respectively (Rossi et al. 2016; Orsenigo et al. 2018).
304 The comparison among numbers of taxa listed as CR(PE) and CR (hereafter cumulated under the
305 category CR, due to the very few numbers of the CR(PE)) and EN showed a general increase of
306 such taxa in the last 23 years: from 91 to 125 and from 110 to 227 for CR and EN, respectively
307 (Figure 2). Numbers reported in Rossi et al., 2013 are not following the general trend (Figure 2,
308 light blue), because, in this study, not all the taxa recorded in the other considered lists were
309 included. Numbers of taxa common to two lists of the considered periods (overlapping areas, Figure
310 2) show a certain variability that could be due to both changes in the risk status of a certain taxa as
311 well as to the inclusion of different taxa in different lists. However, 26 CR and 15 EN taxa have
312 been at risk in the last 23 years (central area, Figure 2); even worse, *Mandragora officinarum*,
313 *Pilularia globulifera* and *Silene linicola* have been attributed to a different risk status from CR, in
314 1997, to CR(PE) in 2013.

315 Among the 26 CR taxa, *Brassica macrocarpa* is of particular interest since it is a CWR of *B.*
316 *oleracea* (GP2) and of *B. rapa* (GP3), widely cultivated and important crops. In addition to *B.*
317 *macrocarpa*, *Ribes sardoum* and *Vicia giacominiana* are also of interest since they are mentioned
318 by ISTAT for the high value of related cultivated species. However, for these two CWR,
319 information about GP is not available and they are only recorded as belonging to the TG4 of related
320 cultivated species. In this perspective, it is important to shed light on the potential value of these
321 species to promote a more comprehensive investigation of their taxonomic interpretation. Among
322 the 15 EN taxa, it is noteworthy the presence of *Linum mulleri*, a CWR of *L. usitatissimum* with a
323 potential use as source of resistance to rust (Islam, 1992), that, according to ISTAT (ISTAT 2019),
324 is a species of high economic value for Italy. For all the above-mentioned taxa under threat we can
325 speculate that no efficient and effective protection measures have been put in place in the last 23
326 years or such measure were not sufficient to significantly increase the surviving chance of these
327 taxa; this once again calls for urgent attention to CWR.
328
329 *Ethnobotanical WHP uses*
330 The number of WHP taxa (which in some cases may also be CWR) for which a use was recorded is
331 reported in Table 4. A generic 'ethnobotanical use' was recorded for 1,308, 1,223, 623 and 649 taxa
332 in Italy, Italian Peninsula, Sardinia and Sicily respectively. It is not possible here to describe all the
333 uses in detail; however, according to the recorded cases, uses are mainly related to remedies for
334 different afflictions, food and ornamentals (Table 4).
335 A total of 608, 592, 358 and 344 taxa have a known use as medicines in Italy, Italian Peninsula,
336 Sardinia and Sicily, respectively. In the same geographical regions, 747, 718, 489, and 544 taxa are
337 used as food while 459, 443, 243, and 213 as ornamentals. It is also notable that several plants are
338 intensively collected in the wild throughout the entire country (*e.g.* many species of the genera
339 *Allium*, *Asparagus*, *Cichorium*, *Silene*, and *Sonchus*), while others are only used in some areas, due
340 to their endemic distribution and/or local traditions. For example, in Central Italy the receptacle of

Carlina acaulis (and other species of *Carlina*) is eaten fresh (Uncini Manganelli et al. 2007) or in soups (Guarrera and Savo 2016) and in Apulia the young bulbs of *Bellevalia romana* sweet are eaten cooked like onions. It is also quite common in Central Italy to harvest seeds in the wild and cultivate spontaneous species like *Bunias erucago*, *Campanula rapunculus*, *Silene vulgaris* in the home gardens (D. Donnini pers. comm.). *Brassica fruticulosa* is largely used in Sicily for the preparation of several food specialties (*i.e.* 'cavoliceddu' with sausages or with pasta, or simply boiled); in Sardinia *B. insularis* is also consumed fresh, as salad (Guarrera and Savo, 2016). *Ajuga chamaepitys* is used as a remedy for arthritis in Sardinia (Atzei, 2003). Some of the recorded plant uses are unique and locally restricted. Examples of particular uses restricted to few locations are: *Isatis tinctoria* harvested in the wild for food only in Sicily (Galletti et al. 2013), *Laurus nobilis*, whose leaves are used to store beans in vases in order to keep out bruchids only in Umbria (V. Negri pers. comm.), *Ocimum basilicum*, whose pots are put on graves as ornamentals to remember deceased people in the town of Chieti (Abruzzo) (Manzi 2003), *Asphodeline lutea* whose young shoots are fried or used for omelets in Sicily and Sardinia or *Plantago major* used in soups in Sardinia (Guarrera and Savo 2016). It should also be mentioned that for most plants, different ritual uses are recorded throughout the entire country in relationship to local religious and/or superstitious practices; however, these aspects are not specifically addressed in the present study. These traditional and local uses, often only handed down orally, are likely to be lost by the new generations.

It is also worth noting that many common species with ethnobotanical uses (such as *Ajuga chamaepitys*, *Bunias erucago*, *Agrostemma githago*) mostly growing as weeds in cultivated habitats, show a drastically decreasing presence due to intense use of herbicides (Uncini Manganelli et al. 2007). The ethnobotanical information here provided is far from being complete, since this type of knowledge is hugely scattered through literature dealing with different fields, if not totally neglected by written texts and often confined to oral tradition, thus not available at all.

Putting information into action

Following suggestions of other authors (Maxted et al., 2012; Khoury et al. 2019;), several actions should be taken to ensure that an effective and efficient conservation plan for CWR/WHP is put into action. The first step is to rely on comprehensive and updated lists, at this regard the here presented updated prioritised list emerge as a valuable tool. The second step is to increase the awareness on the critical importance of CWR and WHP as PGR and especially among public authorities in charge of drafting rules for *in situ* and *ex situ* protection and implementing such rules. In Italy, the Ministry of the Environment and the Ministry of Agricultural, Food and Forestry Policies are responsible for drafting the general rules and actions for CWR and WHP conservation, while the Administrative Regions and Autonomous Provinces are in charge of drafting and implementing concrete actions for their effective safeguard. To date, specific concern for CWR/WHP conservation is increasing in Italy also due to the signature of international agreements. For example, a recent National legislation on the collection of wild plants specifically protect WHP (D.L. 21 maggio 2018, n. 75). When occurring in Italian protected areas such as National Parks or Natura 2000 Sites, such resources already benefit some form of 'passive' *in situ* protection. Concerning CWR/WHP in protected areas, management is another issue of concern for an effective and efficient conservation plan. Direct management actions should always be implemented, including monitoring demographic trends, to assess the efficiency of protection measures and address better measures when need (Iriondo and De Hond, 2008). Further investigations in the field are needed to detect populations outside protected areas, which is also an important issue for PGR conservation, since these populations may harbour traits of interest and lack any form of protection. Genetic reserves (*i.e.* managed *in situ* conservation sites), should then be established both within existing protected areas and outside in order to cover maximum CWR/WHP diversity (Maxted et al. 2012). However, as noted by Labokas et al. (2018), this requires concerted efforts among scientists, politicians and local residents and cannot be seen other than a long-term possible achievement.

A third step is to collect and conserve prioritized taxa in *ex situ* collections, CWR/WHP for which entries are present in genebanks are better protected than the others; however, a recent survey showed that only a few Italian accessions of CWR/WHP are maintained *ex situ* (V. Negri pers. comm.). The updated prioritised lists developed in this study may represent a valuable support when setting priorities for new collections. However, since these lists are based on data recorded in literature, where geographic distribution of taxa is often given at a coarse geographic scale, precise information on actual occurrence, location and census of CWR/WHP populations need to be retrieved and/or updated. To this end, a gap analysis – a process comparing populations belonging to taxa of priority importance present in protected areas vs. those stored *ex situ* (Maxted et al. 2008; Maxted and Kell 2009; Ramírez-Villegas et al. 2010; Parra-Quijano et al. 2012a) – should be carried out to address the planning of new germplasm collections. In this context, the assessment of the ecological, morphological and genetic diversity between different CWR/WHP population occurrences would be beneficial as a proxy to estimate their inter- and intra- specific diversity (Parra-Quijano et al. 2012b) driving the collections in specific areas. For example, populations of *Brassica incana* from a small area in southern Italy were quite different, between each other, for morpho-phenological and genetic traits (Ciancaleoni et al. 2018). In this respect, populations occurring in the islands are certainly the most significant also because, occurring in particular ecological niches and being isolated, are possibly characterized by a unique genetic diversity which might result of interest for several purposes (Médail et al., 1999; Vogiatzakis et al., 2016). Finally, the increasing availability of genetic information could contribute to identify the most interesting populations for both *in situ* and *ex situ* conservation.

Conclusions and perspectives for the future

PGR are an important segment of biodiversity because they nourish humankind. The conservation of PGR is a commitment for the signatory countries of global and internationally binding agreements and biodiversity conservation programs (FAO, 2001; CBD, 1992). In spite of this, PGR

418 are still a generally neglected object of conservation (Ulian et al., 2020). Data reported in this study
419 concerning: i) taxonomy, ii) presence of taxa in Italian and European red lists and iii) conservation
420 priority for Italy and enriched by an extensive description of CWR/WHP uses, provide a valuable
421 starting point for developing *ex situ* and *in situ* conservation strategies at the country level. As also
422 emphasized by Hammer et al. (2018), the Italian approach to CWR/WHP conservation has been to
423 date characterized by fragmentation and poor coordination yet failing in inspiring a massive
424 reaction neither by policy managers nor by the institutions. Being this condition common to
425 different European countries and aiming at the establishment of a European network for in situ
426 conservation and sustainable use of both landraces and CWR, the EU recently funded the 'Farmer's
427 Pride' Project. The establishment of such a network may help in overcoming some limitations that
428 affect CWR in situ conservation in Italy as well as in other European countries (Farmer's Pride
429 Consortium 2019). Indeed this study, offers a methodological protocol for identification of
430 CWR/WHP most in need of protection that might be profitably adopted by other countries,
431 contributing towards a continental and global approach. In a scenario of changing climate and
432 progressive loss of specific and intraspecific diversity and considering that Italy is one of the
433 countries in Europe with the richest wild flora, a rational PGR conservation strategy, based on
434 widely informed priority lists, would benefit the entire human community and provide a
435 contribution to global food security.
436
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779 **Table 1.** Synoptic table of CWR and WHP for the different defined categories and geographic areas

780 areas: the number of specific and subspecific taxa is followed by the number of species in brackets

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Category	**Italy**	**Italian Peninsula**	**Sardinia**	**Sicily**
Total CWR and/or WHP	8,766 (7,334)	7,916 (6,641)	2,745 (2,600)	2,952 (2,738)
Native	7,117 (5,758)	6,367 (5,164)	2,180 (2,062)	2,431 (2,252)
Native in need of monitoring or protection (Priority A+B)	175 (148)	89 (81)	29 (27)	81 (63)
CWR	8,658 (7,222)	7,812 (6,536)	2,685 (2,544)	2,889 (2,673)
Native	7,015 (5,655)	6,268 (5,064)	2,120 (2,000)	2,380 (2,187)
Endemic	1,551 (1,155)	1,012 (733)	309 (261)	393 (314)
Non native	1,644 (1,571)	1,544 (1,472)	565 (544)	509 (486)
Neophytes	1,323 (1,295)	1,228 (1,201)	401 (394)	366 (359)
Archaeophytes	190 (148)	185 (143)	120 (107)	98 (84)
Not natives only cultivated	136 (133)	136 (133)	45 (44)	46 (44)
In need of monitoring/protection	159 (136)	79 (71)	28 (26)	72 (58)
WHP	1,927 (1,818)	1,855 (1,768)	944 (940)	1,003 (974)
Native	1,702 (1,600)	1,593 (1,519)	853 (852)	910 (884)
Endemic	163 (122)	92 (75)	43 (37)	62 (41)
Non native	225 (218)	215 (208)	91 (88)	93 (90)
Neophytes	193 (189)	184 (180)	68 (67)	74 (73)
Archaeophytes	26 (23)	25 (22)	22 (20)	18 (16)
Not natives only cultivated	7 (7)	7 (7)	2 (2)	2 (2)
In need of monitoring/protection	16 (12)	10 (10)	1 (1)	9 (5)

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784 **Table 2.** List of CWR/WHP taxa (of the identified 36 *Genera*) with the highest conservation
785 priority ("A" category) as defined in the present study. Their *Genus* current name, endemism (in
786 Italy, Sardinia and Sicily) and more details about their status [*i.e.* included in the: Italian National
787 Red Lists (Orsenigo et al. 2018, 2021; Rossi et al. 2016) and IUCN Red List (IUCN 2020) are
788 reported].
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Genus	**Taxa**	**Endemism**	**Orsenigo et al. (2021)**	**Orsenigo et al. (2018)**	**Rossi et al. (2016)**	**IUCN Red List**
Agrostis	*Agrostis canina* subsp. *aspromontana* Brullo, Scelsi & Spamp.	Italy		EN		
	Agrostis canina subsp. *monteluccii* Selvi	Italy		VU		
Allium	*Allium agrigentinum* Brullo & Pavone	Sicily		EN		
	Allium anzalonei Brullo, Pavone & Salmeri	Italy		NT		
	Allium calabrum (N.Terracc.) Brullo, Pavone & Salmeri	Italy		NT		
	Allium castellanense (Garbari, Miceli & Raimondo) Brullo, Guglielmo, Pavone & Salmeri	Sicily		EN		
	Allium diomedeum Brullo, Guglielmo, Pavone & Salmeri	Italy		NT		
	Allium franciniae Brullo & Pavone	Sicily		NT		
	*Allium garbari*i Peruzzi	Italy		NT		
	Allium garganicum Brullo, Pavone, Salmeri & Terrasi	Italy		EN		
	Allium hemisphaericum (Sommier) Brullo	Sicily		VU		
	Allium julianum Brullo, Gangale & Uzunov	Italy		EN		
	Allium lehmannii Lojac.	Sicily		NT		
	Allium lopadusanum Bartolo, Brullo & Pavone	Sicily		EN		
	Allium nebrodense Guss.	Sicily		VU		
	Allium obtusiflorum DC.	Subendemic		NT		
	Allium pelagicum Brullo, Pavone & Salmeri	Sicily		NT		
	Allium pentadactyli Brullo, Pavone & Spamp.	Italy		NT		
	Allium permixtum Guss.		VU			

	Allium savii Parl.		NT		
	Allium trifoliatum Cirillo		NT		
	Allium vernale Tineo	Sicily		VU	
Arrhenatherum	*Arrhenatherum elatius* subsp. *nebrodense* (Brullo, Miniss. & Spamp.) Giardina & Raimondo	Sicily		NT	
Asparagus	*Asparagus pastorianus* Webb & Berthel.		NT		
	Astragalus alopecurus Pall.				NT
	Astragalus aquilanus Anzal.	Italy		EN	EN
	Astragalus gennarii Bacch. & Brullo	Sardinia		CR	
	Astragalus kamarinensis C.Brullo, Brullo, Giusso, Miniss. & Sciandr.	Sardinia		EN	
	Astragalus maritimus Moris	Sardinia		CR	CR
	Astragalus nebrodensis (Guss.) Strobl	Sicily		NT	
Astragalus	*Astragalus peregrinus* Vahl subsp. *peregrinus*		CR		
	Astragalus peregrinus subsp. *warionis* (Gand.) Maire		CR		
	Astragalus raphaelis G.Ferro	Sicily		CR	
	Astragalus siculus Biv.	Sicily		NT	
	Astragalus tegulensis Bacch. & Brullo	Sardinia		CR	
	Astragalus terraccianoi Vals.	Sardinia	EN		
	Astragalus thermensis Vals.	Sardinia		EN	
	Astragalus verrucosus Moris	Sardinia		CR	CR
	Astragalus vesicarius subsp. *carniolicus* (A.Kern.) Chater		VU		
Avena	*Avena insularis* Ladiz.		NT		
Barbarea	*Barbarea sicula* C.Presl	Italy, Sicily	NT		
	Brassica baldensis (Prosser & Bertolli) Prosser & Bertolli	Italy		VU	
	Brassica glabrescens Poldini	Italy		NT	NT
	Brassica insularis Moris	Subendemic			NT
	Brassica macrocarpa Guss.	Sicily		CR	CR
	Brassica montana Pourr.		VU		
	Brassica procumbens (Poir.) O.E.Schulz		NT		
Brassica	*Brassica rupestris* subsp. *hispida* Raimondo & Mazzola	Sicily		VU	
	Brassica souliei (Batt.) Batt.subsp. *souliei*	Subendemic	NT		
	Brassica souliei subsp. *amplexicaulis* (Desf.) Greuter & Burdet	Subendemic	NT		
	Brassica trichocarpa C.	Sicily		NT	

	Brullo, Brullo, Giusso & Ilardi				
	Brassica villosa subsp. *brevisiliqua* (Raimondo & Mazzola) Raimondo & Geraci	Sicily		NT	
	Brassica villosa subsp. *drepanensis* (Caruel) Raimondo & Mazzola	Sicily		VU	
Cichorium	*Cichorium spinosum* L.		EN		
Citrullus	*Citrullus colocynthis* (L.) Schrad.		EN		
Crambe	*Crambe tataria* Sebeók				NT
Cynara	*Cynara cardunculus* subsp. *flavescens* Wiklund		VU		
Daucus	*Daucus carota* subsp. *rupestris* (Guss.) Heywood	Subendemic		EN	
	Daucus rouyi Spalik & Reduron				
Diplotaxis	*Diplotaxis scaposa* DC.	Sicily		NT	
Festuca	*Festuca alfrediana* Foggi & Signorini subsp. *alfrediana*	Sardinia	NT		
	Festuca gamisansii Kerguélen subsp. *gamisansii*	Italy		VU	
	Festuca gamisansii subsp. *aethaliae* Signorini & Foggi	Italy		VU	
	Festuca humifusa Brullo & Guarino	Sicily		NT	
	Festuca morisiana Parl. subsp. *morisiana*	Sardinia		VU	
	Festuca rivularis Boiss. subsp. *rivularis*		NT		
Ipomoea	*Ipomoea stolonifera* (Cyr.) J.F.Gmel.		CR		
Lactuca	*Lactuca longidentata* Moris	Sardinia		EN	
Lathyrus	*Lathyrus apenninus* F.Conti	Italy		NT	
	Lathyrus palustris L.		EN		
Linum	*Linum katiae* Peruzzi	Italy		VU	
	Linum mulleri Moris	Sardinia		EN	EN
	Linum punctatum C.Presl subsp. *punctatum*	Sicily		VU	
Lolium	*Lolium interruptum* subsp. *corsicum* (Hack.) Banfi, Galasso, Foggi, Kopecký & Ardenghi		CR		
Lotus	*Lotus biflorus* Desr.		NT		
	Lotus peregrinus L.		NT		
Malus	*Malus crescimannoi* Raimondo	Sicily		NT	
Medicago	*Medicago pironae* Vis.		NT		
Onobrychis	*Onobrychis alba* subsp. *echinata* (Guss.) P.W.Ball	Italy		NT	

Phalaris	*Phalaris elongata* Braun-Blanq.		NT			
	Phalaris truncata Bertol.		NT			
Phleum	*Phleum sardoum* (Hack.) Hack.	Sardinia		CR		
Pistacia	*Pistacia atlantica* Desf.					NT
	Pistacia vera L.					NT
Poa	*Poa remota* Forselles		NT			
Prunus	*Prunus mahaleb* subsp. *cupaniana* (É.Huet & A.Huet) Arcang.	Sicily		NT		
	Prunus webbii (Spach) Vierh.		VU			
Ribes	*Ribes multiflorum* subsp. *sandalioticum* Arrigoni	Sardinia		EN		
	Ribes sardoum Martelli	Sardinia		CR	CR	
Salsola	*Salsola oppositifolia* Desf.		EN			
Thinopyrum	*Thinopyrum flaccidifolium* (Boiss. & Heldr.) Moustakas		NT			
Trifolium	*Trifolium bivonae* Guss.	Sicily		NT		
	Trifolium latinum Sebast.					
	Trifolium saxatile All.				EN	
	Trifolium uniflorum L. subsp. *uniflorum*	Italy, Sicily		NT		
	Trifolium uniflorum subsp. *savianum* (Guss.) Asch. & Graebn.	Italy, Sicily		NT		
Triticum	*Triticum uniaristatum* (Vis.) K.Richt.					
Vicia	*Vicia consentina* Spreng.	Italy		NT		
	Vicia cusnae Foggi & Ricceri					
	Vicia dalmatica A.Kern.		CR			
	Vicia giacominiana Segelb.	Italy		CR		
	Vicia incisa M.Bieb.					
	Vicia serinica R.Uechtr. & Huter	Italy	EN			
	Vicia sparsiflora Ten.		NT			
	Vicia tenuifolia subsp. *elegans* (Guss.) Nyman	Italy, Sicily		NT		
Visnaga	*Visnaga crinita* (Guss.) Giardina & Raimondo	Italy, Sicily		CR(PE)		

Critically Endangered (Possibly Extinct) = CR(PE), CR = Critically Endangered, EN = Endangered, VU = Vulnerable and NT = Nearly Threatened.

794 **Table 3.** List of CWR species in most need of protection in Italy ('A' category) with a known use in

795 breeding. Modified from Dempewolf et al. 2017.

CWR scientific name	Crop common name	Use in breeding	Trait class	References
Triticum uniaristatum (Vis.) K.Richt.	Wheat	Aluminum tolerance	Abiotic Stress	Miller et al. 1997
Brassica insularis Moris	Rape	Blackleg resistance	Biotic Stress	Mithen et al. 1992
	Rape	Blackleg resistance	Biotic Stress	Mithen et al. 1988
Brassica villosa Biv.	Broccoli	Concentration of 4-methylsulphinylbutyl glucosinolate	Quality	Sarikamis et al. 2006
	Broccoli	High glucoraphanin content	Quality	Traka et al. 2013
Citrullus colocynthis (L.) Schrad.	Watermelon	Rootstock	Agronomic	USDA, ARS, National Genetic Resources Program 2019
Medicago pironae Vis.	Alfalfa	Gene transfer	Fertility	McCoy and Echt 1993
Pistacia atlantica Desf.	Pistachio	Rootstock	Agronomic	Hormaza and Wunsch 2007
	Pistachio	Rootstock	Agronomic	USDA, ARS, National Genetic Resources Program 2019
Prunus mahaleb L.	Sour cherry	Rootstock	Agronomic	Rieger 2006
	Sour cherry	Rootstock	Agronomic	USDA, ARS, National Genetic Resources Program 2019
	Sweet cherry	Rootstock	Agronomic	USDA, ARS, National Genetic Resources Program 2019
Prunus webbii (Spach) Vierh.	Almond	Rootstock	Agronomic	USDA, ARS, National Genetic Resources Program 2019
	Almond	Almond leaf spot resistance	Biotic Stress	Gradziel et al. 2001
	Almond	Self-compatibility	Fertility	Gradziel et al. 2001
Ribes multiflorum Roem. & Schult.	Blackcurrant	Currant borer resistance	Biotic Stress	Hummer and Sabitov 2004
	Redcurrant	String length	Agronomic	Brennan 2008
	Redcurrant	Yield improvement	Agronomic	Brennan 2008
	Redcurrant	Leaf spot resistance	Biotic Stress	Brennan 2008
	Redcurrant	Powdery mildew resistance	Biotic Stress	Brennan 2008
	Redcurrant	Late maturity	Phenological	Brennan 2008

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798 **Table 4.** Number of WHP by use classes. Each taxon may have more than one use.

Classes of use	Italy	Italian Peninsula	Sardinia	Sicily
All uses	2,216	2,090	1,112	1,185
Ethnobotanical (generic)	1,308	1,223	623	649
Food	747	718	489	544
Medicine	608	592	358	344
Ornamental	459	443	243	213
Fodder	191	189	127	134
Poison	191	189	122	124
Environmental	118	113	74	72
Material	110	106	72	65
Gene source	97	92	57	66
Food additive	67	65	45	42
Honey production	35	34	14	17
Drink	25	25	15	18
Fuel	11	11	8	7
Social	5	5	2	3

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Figure 1. CWR/WHP taxa, followed by species in brackets, progressively selected starting from the total CWR/WHP number: currently in need of protection and/or monitoring (A); endemic or subendemic with restricted distribution, in need of monitoring (B) and not in need of any immediate specific protection or monitoring measures (C). All taxa (species) in categories A, B and C are included in Annex 1 ITPGRFA and/or cited by ISTAT and native.

Figure 2. Venn diagram comparing number of CR+CR(PE) and EN taxa assessed: i) over 20 years ago (Conti et al. 1997) (light green); ii) seven years ago (Rossi et al., 2013) (light blue) and iii) those most recently assessed (Rossi et al. 2016; Orsenigo 2018; 2021) (light red).