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Translocations of threatened plants in the Mediterranean Basin: current status and future directions

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Abstract

The Mediterranean Basin is one of the World's plant diversity hotspots and a region prone to several anthropic pressures, besides being one of the World's areas most susceptible to climate change. In this region, which hosts a high percentage of threatened species, there has been a large increase in practical conservation actions to prevent the extinction of many plants or improve their conservation status. In this framework, plant translocations have become increasingly important. To obtain a picture of the status and to depict possible directions, data on plant translocations was collected through the available databases, national experts, and the grey literature available online. Overall, a list of 836 translocations relating to 572 plant species was found. These actions are mainly concentrated in Spain, France, and Italy (c. 87%) and, except for some pioneering actions, translocations have strongly increased starting from 2010. A subsequent in-depth bibliographic search of the scientific databases was conducted to determine how much information about plant translocations was documented in the scientific literature. This search resulted in a list of 133 peer-reviewed papers, of which only 17 describing one or more translocations and, as a whole, reporting 101 experiences carried out on 56 plant species. Our research highlighted a great discrepancy between the scarce scientific documentation in comparison to the large number of practical conservation actions carried out. The great experience gained in these translocations constitutes an enormous heritage potentially available to implement the necessary conservation actions to preserve the plant diversity of the Mediterranean Basin.

Keywords Threatened plants · Mediterranean Basin · Plant reintroduction · Plant population reinforcement · Assisted migration

Introduction

The scientific community agrees that Earth is experiencing the sixth mass extinction of living species, a consequence mainly of humans who have accelerated the rate of extinction by 100–1000 times the natural rate (Barnosky et al. 2011; Ceballos et al. 2015; Urban 2015; Pollock et al. 2020; Pyron and Pennell 2022). Global plant species diversity is under threat, and the most recent estimates indicate that c. 40% of the known plant species are at risk of extinction (Kew 2020), with the number of vascular plant species listed as threatened increasing over the past two decades (IUCN 2022). Even though the preservation of plant diversity being a well-established priority at the global level (Ceballos et al. 2015; Le Roux et al. 2019), unfortunately, the efforts of the last decades aimed at protecting plants in their natural habitats do not seem to be as effective as hoped (e.g., Araújo et al. 2007; IPBES 2019; Pollock et al. 2020; Fenu et al.

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2020; Rodríguez-Rodríguez and Sinoga 2022). Among the numerous conservation actions proposed and implemented around the World over the last two decades, plant translocations have received increased attention as a promising tool for halting and reversing species decline.

Conservation Translocation (translocation hereafter) is an umbrella term that refers to the deliberate movement of living organisms from one area to another for conservation purposes and it consists of either reinforcement plus reintroduction or introduction plans (IUCN/SSC 2013), with the goal of establishing resilient and self-sustaining populations and improving species survival in the wild over time (Menges 2008; Godefroid et al. 2011); this objective could be pursued through the augmentation of numbers of individuals in small and declining populations, the reintroduction of individuals to extinct populations, or the funding of new safe locations (e.g., Godefroid et al. 2011; Commander et al. 2018; Fenu et al. 2019). Among the implications related to this concept, plant translocation has also been proposed as a useful action to enhance the genetic parameters of a population, for example, by acting as "bridges" or "connectors" to promote gene flow between isolated populations (e.g., Lázaro-Nogal et al. 2017; Bontrager and Angert 2019; Van Rossum et al. 2022). Recently, because of the increased interest in the effects of climate change, this term also includes Assisted Migrations or Assisted colonization, aimed to actively support range shifts toward newly suitable areas as an effective climate change adaptation strategy (Thomas 2011; Hällfors et al. 2014; Casazza et al. 2021; Diallo et al. 2021). Therefore, translocations are currently considered potentially relevant conservation tools for preventing plant extinctions or decline, as well as effective tools for conserving plant species or populations threatened by the effects of climate change.

In spite of several recovery programs for threatened plants using translocations throughout the World, the effectiveness of this tool is still controversial, and the reasons are manifold (Godefroid et al. 2011; Draper et al. 2016; Fenu et al. 2016). Among these, the lack of long-term data on such experiences dominates in the face of the evidence that translocations are challenging actions showing a high risk of failure, with only a few having succeeded in establishing self-sustaining populations (Godefroid et al. 2011; CPC 2019; Ferrer Gallego et al. 2019; Fenu et al. 2020). Many studies have evaluated initial signals of reintroduction success in terms of survival rates of reintroduced individuals and rates of natural regeneration (Menges 2008; Godefroid et al. 2011; Dalrymple et al. 2012; Liu et al. 2015; Fenu et al. 2019), but our understanding of how likely and under what conditions a translocation will promote species recovery and long-term persistence is quite limited (Bell et al. 2013; Liu et al. 2015; Maschinski and Duquesnel 2007; Colas et al. 2008; Albrecht et al. 2019).

Paradoxically, even the very definition of the success of a plant translocation could be a slippery matter; to determine the translocation success, the preparation of an operational translocation protocol, adapted to the biology and ecology of the plant species under consideration is essential (Maschinski and Albrecht 2017; Commander et al. 2018; Fenu et al. 2019; Silcock et al. 2019), providing the scientific data to support on-ground actions and guide their implementation (Maslovat 2009; NSRF 2014; Abeli and Dixon 2016; Maschinski and Albrecht 2017; Commander et al. 2018; Andres et al. 2022). The estimation of the translocation success also depends on other considerations, such as the outputs of long-term demographic monitoring (e.g., IUCN/SSC 2013; Maschinski and Albrecht 2017; Commander et al. 2018) that provides feedback on recruitment, plant survival, and reproductive success (Godefroid et al. 2011; Commander et al. 2018; Albrecht et al. 2019; Fenu et al. 2019), contributing significantly to improving future translocation protocols (Albrecht et al. 2011; Jusaitis 2012; Silcock et al. 2019).

It is essential to document the translocation cases, both successful and failed, by collecting and organizing data in specific databases, and, based on this knowledge, to elaborate guidelines rooted on the best conservation practices and experimental evidence. This could also include the development of general or specific tools for improving conservation actions, including translocations.

The Mediterranean Basin, an important centre of plant diversity and a global biodiversity hotspot (Médail and Quézel 1997; Cañadas et al. 2014), faces severe threats related to several natural and anthropogenic factors that have led to a very high degree of natural habitat fragmentation. Indeed, over the last four millennia, the Mediterranean Basin has been the cradle of some of the World's greatest civilizations, resulting in soil over-exploitation and the conversion of much of the pristine vegetation into agricultural landscapes (Vogiatzakis et al. 2016). Moreover, the Mediterranean Basin is one of the most susceptible regions in the World to climate change, with a significant increase in predicted extreme weather events (Pinna et al. 2022), that will exacerbate these threats and expose the Mediterranean Basin to unique challenges (IPCC 2013, Vogiatzakis et al. 2016; Cramer et al. 2018; Vacchi et al. 2021).

Over the past few centuries and in the Mediterranean region, a decline in biodiversity has been recorded that has determined a worsening of plant diversity, which will greatly impact human society and has led to an increased focus on the effectiveness of conservation actions (e.g., Vogiatzakis et al. 2016; Fenu et al. 2020). Accordingly, in most countries around the Mediterranean Basin, there has been a large increase in practical conservation actions to prevent the extinction of many plants or to improve their conservation status, including plant translocations (e.g.,

Vicente Moreno et al. 2017; Fenu et al. 2019; Abeli et al. 2021). However, these initiatives have been promoted and financed at different levels and with various international, national, or local programs, causing a dispersion of information, not always easily accessible, on what has been done, on which target species, and with what conservation results. The need for a rigorous analysis of translocation methodologies, results, and strategies is needed to know how well it works and what factors and strategies are associated with the greatest potential success (Griffith et al. 1989; Liu et al. 2015; Silcock et al. 2019).

Thus, the need for reporting, gathering, and organizing the results of plant translocations is compelling and challenging; the results of this synthesis are strategic to determining the effectiveness of conservation measures for threatened plant species. Particularly in a biogeographical region such as that of the Mediterranean Basin, listing and documenting plant translocations requires examples and case studies to clarify aims, operating procedures, and expected reproducible protocols, making it possible to debate, define, and update common standards and methodologies to be included in (future) best practice guidelines at the biogeographical level.

The Mediterranean situation is no exception, with only a few attempts to collect and organize information on a large geographical or biogeographical scale. Broad-based analyses on this issue, both at the global level (e.g., Godefroid et al. 2011; Dalrymple et al. 2012; Beckmann and Soorae 2022) or for restricted geographic areas (i.e., country level; Liu et al. 2015; Silcock et al. 2019; Novak et al. 2021; Abeli et al. 2021) can be very important, as they allow the identification of best practices for homogeneous groups of species or biogeographical regions and provide useful information for developing a translocation policy within jurisdictions (regions, states, and countries). This article fits into this framework: to construct a picture of the current status and to depict possible future directions of plant translocations in the Mediterranean Basin. Two main issues were addressed in this study. As a first step, an attempt was made to compile how many translocations have occurred and in which geographical areas of the Mediterranean region, by consulting the available scientific literature and all other accessible sources (e.g., dedicated databases, project websites and technical reports), both official and available online, as well as by contacting via email local experts working in plant conservation (*Question 1*); then, through in-depth bibliographic research of the main scientific databases, an attempt was made to understand how many of these experiences are documented in the scientific literature to potentially support new translocations (*Question 2*). Finally, based on the results obtained and highlighting the inherent limitations of this study, an attempt was made to identify the potential prospects for plant translocations in the Mediterranean Basin.

Question 1: how many translocations (and on what plant species) have been performed in the Mediterranean Basin?

To answer this question, several sources have been used: global or national dedicated databases (both freely available online and with restricted access), websites of foundations dedicated to biodiversity conservation, international and national project information (websites, technical reports, and press releases), and available scientific literature and grey literature (mainly in English but also in Italian, Spanish, and French). For the Mediterranean region, at least two local experts working in plant conservation were consulted via email.

Each record from these searches was treated differently depending on the reliability of the source of origin; particular attention was paid to data deriving from sources that are not easily verifiable by local experts, such as those related to conservation projects (included in websites, technical reports, or press releases).

The collection of information started from the extrapolation of useful data contained in the three main databases: *TransLoc* (http://translocations.in2p3.fr/index.php), *Trans-Planta* (Vicente Moreno et al. 2017), and *IDPlanT* (Abeli et al. 2021).

The "*TransLoc*" database contains information on species of animals, plants, and fungi that have been voluntarily translocated in the Western Palearctic (i.e., in European territories and up to the Ural and Caucasus, and countries bordering the Mediterranean); the data relating to plant species were filtered and the actions carried out in the Mediterranean area were then selected; data referring to Spain and Italy were a priori excluded as they were replaced by those present in the two national databases for these countries.

The "*Trans-Planta*" database compiles information on conservation translocations carried out on flora populations in Spain; the records relating to the Canary Islands, included in the Mediterranean hotspot (Medail and Quezel 1997; Myers et al. 2000), were also maintained in the overall count. For Italy, the "*IDPlanT*" database, which contains cases collected through a survey of more than 1000 Italian botanists, conservation biologists, and practitioners (Abeli et al. 2021), was used.

Besides these main sources, the data has been enriched by consulting the online databases of the "*Rufford Foundation*" (https://www.rufford.org/projects/) and "*The Mohamed bin Zayed Species Conservation Fund*" (https://www.speciesconservation.org/case-studies-projects/case-studies), as well as the information available online on websites/technical

reports of conservation projects such as those financed by the European Life and Interreg programs or by national and regional funding. All records derived from these sources, as well as those derived from press or unofficial online sources, have been validated ad hoc by contacted local experts. Finally, local experts were interviewed online by contacting people working in the Mediterranean regions for which a lack of information was expected.

The integration of all of the collected information made it possible to take a census of 836 certified plant translocations involving 572 plant species in the Mediterranean Basin (Figs. 1 and 2). Based on the available information, it was possible to estimate that c. 80% of the plant species involved in those translocations are threatened at the national or local level.

Our research led us to identify 33 additional cases (not included in the total) in which conflicting information was recovered; this includes 15 translocations that were reported as "planned or in progress" but could not be verified, as well as another 18 actions reported in local newspapers but not confirmed or refuted by local experts. In this regard, it is important to highlight that, although some of these translocations have been declared in the final documents/reports of projects already completed, they have not been confirmed by the local experts. Similar information is not available in the literature on the other Mediterranean climate areas or other global hotspots, which makes an evaluation of the data relating to the Mediterranean Basin complicated. In general, this number is comparable to those recorded in the Australian continent, although the latter are included in a shorter time frame (1001 translocations for 376 taxa; Silcock et al. 2019).

Recorded translocations were not uniformly distributed in the Mediterranean Basin. Although it is likely that some countries have barely addressed the topic of plant conservation through translocation, despite numerous species that are probably identified as needing conservation or recovery plans, other countries are building national or international repositories/databases. Plant translocations appear to be mainly concentrated in Spain, France, and Italy, with 86.8% in total; nevertheless, this datum is clearly influenced by

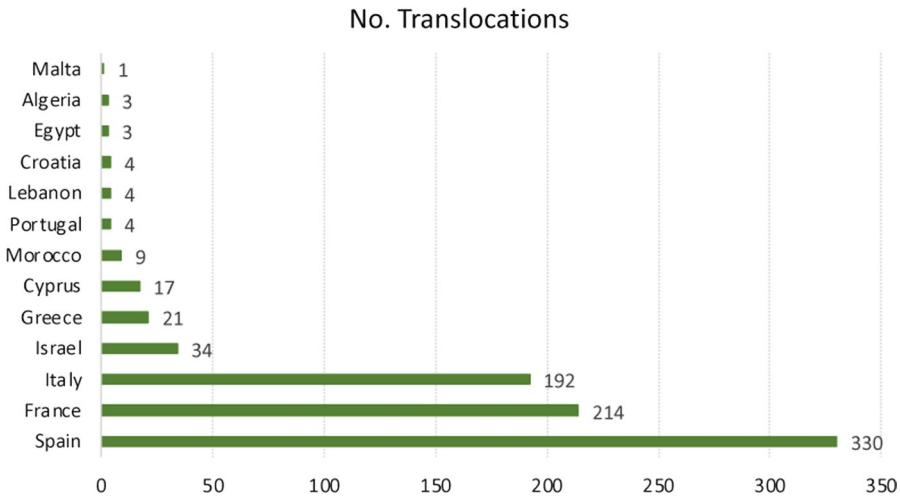

Fig. 1 Number of certified plant translocations in the countries of the Mediterranean Basin

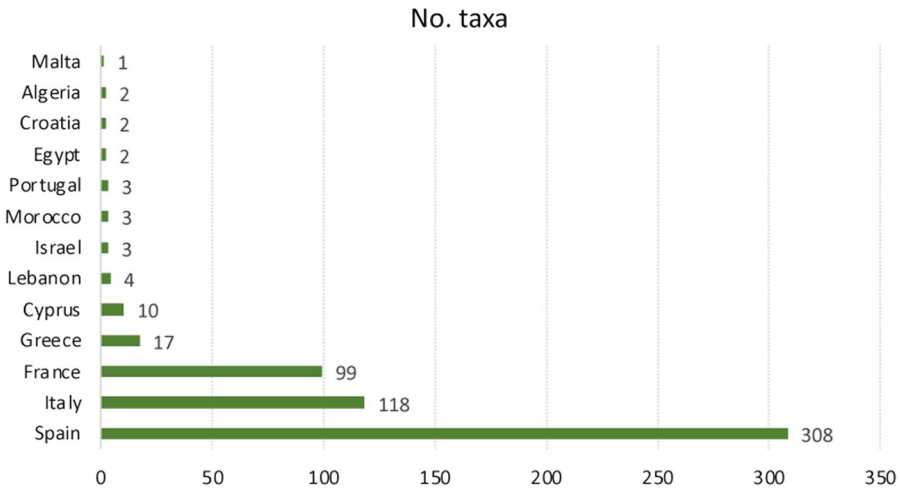

Fig. 2 Number of certified plant taxa translocated in the countries of the Mediterranean Basin

the availability of the three structured databases (Vicente Moreno et al. 2017; Abeli et al. 2021; Julien et al. 2022a). Only a few data were recorded for five countries (Algeria, Egypt, Malta, Morocco, and Portugal) with ten countries (Albania, Bosnia Herzegovina, Gibraltar, Libya, Montenegro, Palestine, Syria, Slovenia, Tunisia, and Turkey) having no information obtained from either websites or contacted experts. This scenario highlights how well-organized data could facilitate their retrieval and future actions; in such a situation it is clear that databases become essential to organize and provide information on translocation techniques and improve the underlying science (Godefroid and Vanderborght 2011; Abeli et al. 2021). In addition, national databases could provide important information on the conservation strategy and policy applied at the country level (Abeli et al. 2021). To our knowledge, the main databases are mainly managed by scientific societies and only recently there has been interest from national Governmental institutions on the topic of plant translocations. The bridge between scientific societies and national and international institutions has yet to be built. In France the National Council for the Protection of Nature is responsible for ensuring compliance with the biodiversity law; this committee requests permits and translocation reports for specific interventions involving protected species which improves the availability of data for these specific cases (Julien et al. 2022b); in addition, plant translocations are sometimes included in national action plans (*Plans Nationaux d'Action*) that aim at defining a range of actions necessary for the conservation and restoration of the most threatened species (Diallo et al. 2023). In Italy, a recently promulgated national law regulates the reintroduction and reinforcement of native policy species in Italy (D.M. 02-04-2020, n.98; Gazzetta Ufficiale 2020), though this normative does not require the establishment of a database of translocation actions (Abeli et al. 2021). Finally, in Spain, the Environmental Ministry approved a guideline with recommendations and actions to perform conservation translocations that could be used in specific conservation programs. No information was found for other Mediterranean countries.

The lack of information from several countries leads to an underestimation of the number of Mediterranean actions, presumably related to the difficulty in accessing local sources or obtaining information. The reasons for this lack of information may be numerous and difficult to identify; several translocation cases may have been published in grey literature or local reports; the lack of response from numerous local experts can then be interpreted as either a reluctance to disclose the results of ongoing experiments, which they would like to publish later on, or an unwillingness to disclose plant translocations carried out without adequate normative authorizations or adequacy.

The analysis of the sources from which the information was obtained provides indirect confirmation that there is a significant amount of covert plant translocations occurring (Fig. 3). In fact, if the consolidated data derived from the databases is excluded, it is interesting to note that 11.2% of the cases considered derive from unpublished data from local experts; this means that a total of about 95 cases are known only to the local experts who have or are carrying them out and who have decided to disclose the information only under the guarantee that no details are included in this study.

By carrying out a temporal analysis of the available data, it emerges that the first records concern pioneering interventions carried out starting from the 50 s of the last century (e.g., 1958 in Italy; Abeli et al. 2021); other experiences dating back to the same period concern *Ranunculus weyleri* Marès ex Willk. (1958) and *Lysimachia minoricensis* J. J.Rodr. (1959) in Spain and are mentioned only in papers published afterwards (e.g., Sainz-Ollero and Hernández-Bermejo 1979; Cursach et al. 2018). Since 2000, the practice

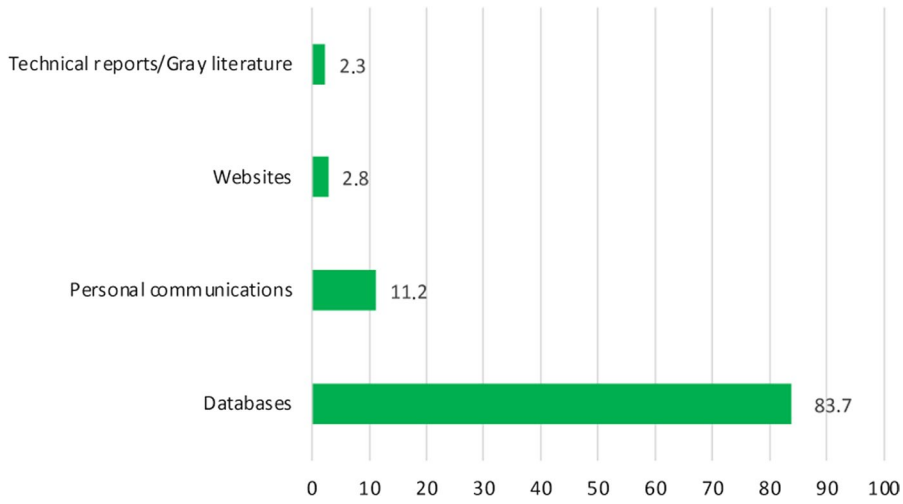

Fig. 3 Sources of information for plant translocations

of translocation has greatly expanded with most of the plant translocations documented in many countries of the Mediterranean Basin occurring since 2010. Again, the rapidly increasing trend over time showed a similar trend to that observed, for example, on the Australian continent (Silcock et al. 2019) or in other countries, such as China, where the number of translocations increased from 90 plant species in the period 2011–2015 to 206 species in 2019 (Ren et al. 2020).

Question 2: how many plant translocations are documented in the Mediterranean Basin?

An in-depth bibliographic search was conducted to obtain an exhaustive picture of the translocations carried out in the Mediterranean Basin and documented in the scientific literature. This research led to the collection of international scientific articles which have been subjected to peer-review. These documents were collected through the two main online scientific databases (Scopus and Web of Science) using different primary keywords like "Conservation translocation", "Plant Translocation", "Plant Introduction", "Plant Reintroduction" and "Plant Population reinforcement", in combination with a secondary keyword, namely "Mediterranean basin". All articles available at the time of the research (October 2022) were taken into account. The two lists were combined into one document, and after the duplicates were removed, a thorough examination was done to determine which papers addressed the topic.

The bibliographic research produced a total of 1045 scientific papers. After a careful check to understand which ones concerned the topic of interest, 912 papers (c. 87.3% of the total) did not deal with the topic of interest; in those papers, the term "translocation" was mainly used in the field of plant physiology, while "introduction" referred to the spread of alien plant species (Fig. 4). Another 116 papers correctly fit our topic, but they recommended plant translocations for a specific plant species as necessary or urgent to prevent extinction; this category of papers in peer-reviewed journals showed a relevant increase starting from 2011 (Fig. 5), following a similar trend observed in China, where the number of articles has increased from less than 5 per year in the early 1990s to more than 50 per year in 2020 (Ren et al. 2020). Among these papers, some presented experiments carried out on previously translocated populations or comparisons with natural populations, without providing information on the origin of these populations (e.g., Massó et al. 2016; Majone et al. 2016). However, it should be highlighted that, because database research looks for keywords in specific sections of scientific papers (in particular, the title, abstract, and keywords), this amount is probably underestimated. Finally, only 17 papers described, often with only a few details, plant translocations carried out in the Mediterranean Basin (Fig. 4; see Table S1 for details). It is interesting to observe the great discrepancy between these last two categories: while numerous authors suggest the implementation of translocations, only a few of these have been disclosed to the scientific community. In addition, analyzing the temporal trend of these papers (Fig. 5), it can be observed that scientists started recommending plant translocations (in a broad sense) long before we had documented experiences of this type of conservation action. This confirms what has already been stated above regarding the tendency not to disclose the outputs of this type of conservation action by numerous local experts; where it was possible to collect detailed data, such as in Spain, more than half of the documented translocations were not published in the scientific literature (García-Fernández et al. 2017). Other reasons for the high proportion of unpublished translocations were that they have been unsuccessful, as previously reported (Godefroid et al. 2011).

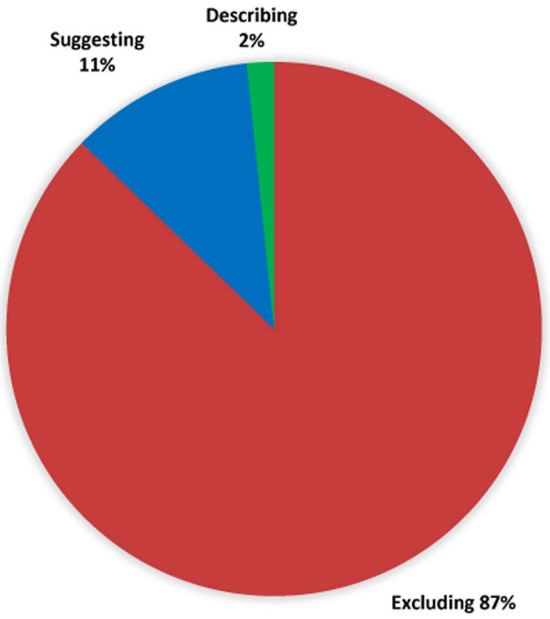

Fig. 4 Percentage of papers for each category: excluding; suggesting and describing

Further in-depth analysis of these articles gives us a rather poor picture of the information available and potentially usable as a basis for future conservation actions. Overall, 101 translocations involving 56 plants were reported, with the information generally being so heterogeneous as to not allow a comparison (see Table S1 for details). The most common information, which is not always present, concerns the origin of the material, the type of multiplication, and the season in

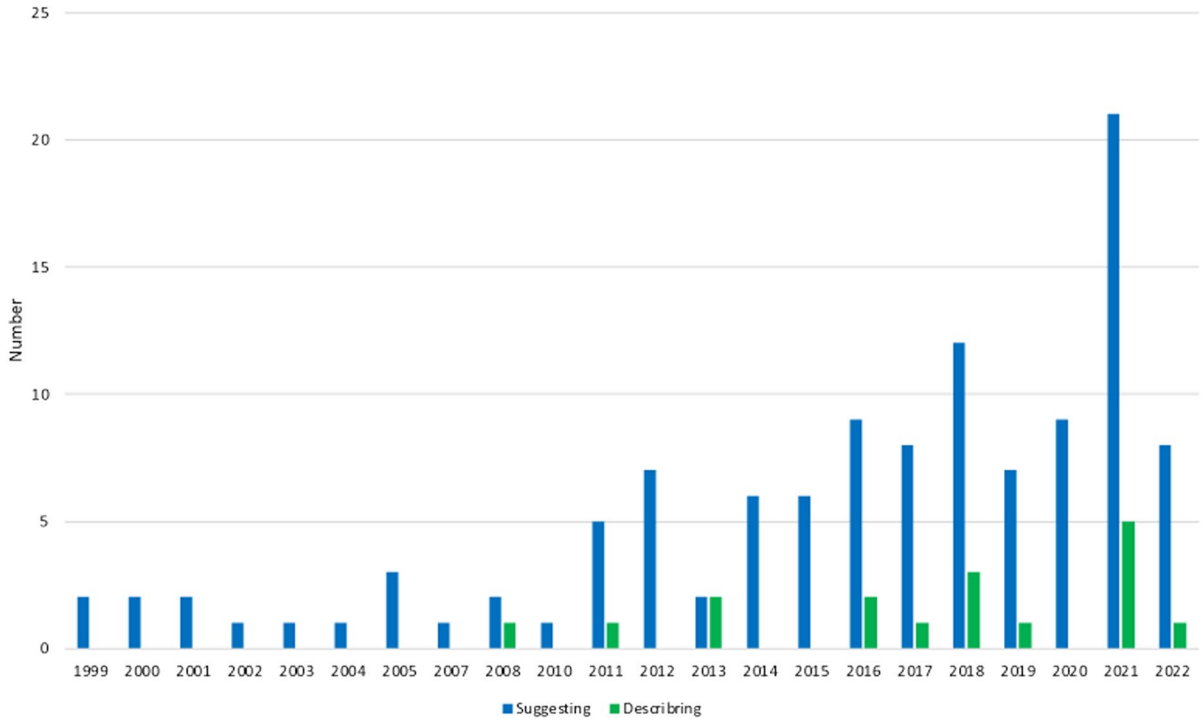

Fig. 5 Temporal trend of scientific papers dealing with plant translocations

which the release in the field was carried out. Where present, only brief information concerning the site selection methodology and the after-care actions was available.

Almost all the papers reported results relative to a short post release period which is a poor indicator of the success in reversing the extinction trend of a population/species; in fact, monitoring generally covers only a short post-intervention period (< 5 years). The exceptions are not numerous; among these are several examples in Spain, like those for *Silene cambessedesii* Boiss. & Reut. (Navarro et al. 2015) or *Cistus heterophyllus* Desf. (Ferrer Gallego et al. 2018), the case of *Narcissus cavanillesii* A. Barra & G. López in Portugal (Draper et al. 2016), and the translocation of *Iris atrofusca* Baker in Israel (Volis and Blecher 2022), for which long-term monitoring data (> 10 years) are available. For few additional plant species, integrating the information contained in numerous articles, it is possible to obtain a medium-term picture of the results of translocation, such as in the case of *Dianthus morisianus* Vals. in Sardinia (Cogoni et al. 2013; Fenu et al. 2016, 2019, 2020), which represents one of the most documented experiences in the Mediterranean Basin.

Promoting long-term monitoring would allow better assessment of the success of a translocation so that valuable insights can be made regarding plant response to climate change (e.g., Fenu et al. 2020; Diallo et al. 2021; Dalrymple et al. 2021; Julien et al. 2022b). At the same time, although numerous cases are known nationally or internationally, none of the papers described a failed translocation. However, there are likely vast volumes of unpublished data to which translocation practitioners cannot access; the development and advancement of this scientific field are dependent on the documentation of previous translocation activity, procedures, and outcomes (e.g., Silcock et al. 2019; Novak et al. 2021; Beckmann and Soorae 2022). Reviews that, as in this instance, draw both from published papers and unpublished sources and data can only partially make up for the absence of documentation, which remains a severe limitation.

Another interesting aspect concerns the fact that translocation actions have often been considered and documented for single localized endemic plants (e.g., Cogoni et al. 2013; Laguna et al. 2016; Abdel Samad et al. 2016, 2021; Ferrer Gallego et al. 2019; Omar and Elgamal 2021), while there are only a few papers that address the issue with a more general approach, including pools of different plant species in comparable territorial contexts, such as the Mediterranean island environments (Fenu et al. 2019, 2020).

Current status and potential future directions

Our study allows us to reconstruct a picture of the plant translocations carried out in the Mediterranean Basin, characterized by low scientific production in the face of a considerable number of translocations, some of which are

long-standing and could be very important as representative examples. In general, and especially during the interaction with local experts (made up largely of practitioners, conservationists, and citizens), the term "translocation" is not yet unanimously used; this situation could be related to the fact that the term lends itself to many meanings. This is also supported by bibliographic research which has produced a large proportion of articles far from our topic. There is a strong tendency to use the consolidated terms, with a great predilection towards "plant reintroduction", because it distinguishes among reintroduction, introduction, and population reinforcement, which are conceptually distinct actions and not attributable to a single wording.

Excluding this conceptual difficulty, linked to the young age of translocation science, which can be overcome in time, the current situation in the Mediterranean shows some positive aspects. Given the discrepancy between the scarce scientific documentation available and a large number of practical conservation actions, it is easily conceivable that there is a significant difference between the numbers presented and the real situation in the field; this is due to both the scarcity or lack of data for many Mediterranean countries as well as citizens' traditional customs of carrying out plant translocations independently, often without any scientific support or outside legislative framework, as evidenced by the cases of *Gentiana lutea* L., *Ribes sardoum* Martelli and *Silene velutina* Pourr. ex Loisel. in Sardinia (e.g., Bacchetta et al. 2008; Ruggero 2022).

It is noteworthy to highlight the great difficulty in gathering and validating information on plant translocation activities as well as the lack of communication among the existing national databases (e.g., the same action is reported differently depending on the local taxonomy).

All of these major issues make it difficult to obtain a complete picture of the situation in the Mediterranean Basin; however, based on the information available in the literature, two main indications can be highlighted: the first relates to the plant materials and indicates that transplants multiplicated from fresh seeds have higher survival rates than those produced from seeds germinated in the laboratory; in addition, seedlings cultivated *in loco* (nurseries located near the natural populations or in ecologically similar sites) perform better when released into the wild; the second concerns the selection of optimal sites which, despite the availability of highly advanced IT tools, is mainly made using an expert-based criterion (e.g., Cogoni et al. 2013; Draper et al. 2019; Fenu et al. 2019). However, the lack of experience with long-term monitoring and the few cases of failed actions and the reason(s) for those failures made it complicated, and often impossible, to establish if a translocation was successful (in reversing the negative trend of a threatened population/plant) or not.

What has been mentioned emphasizes that there is still much to be done, but the knowledge collected thus far represents a vast heritage that may be made available to carry out the conservation measures required to maintain plant diversity in the Mediterranean Basin. A first step to frame the topic at the biogeographical region or hotspot level could be to create and compile a Mediterranean plant translocation catalogue, with a primary focus on endangered and endemic plants, highlighting the methodologies used and the success/failure of conservation actions; to do this, as demonstrated by this research, national or regional data repositories for plant translocation actively involving scientists, conservationists, citizens and enthusiasts can play a decisive role. Therefore, the need for national or regional databases as already suggested (Abeli et al. 2021), is still highlighted, as is the need to establish a standardized plant taxonomy at the Mediterranean Basin level to improve communication between these tools. Such a database could support the definition of guidelines and best practices to perform plant translocation at the Mediterranean level and, perhaps, guide the development of effective national and regional regulations.

From a broader perspective, plant translocations will require a significantly greater investment of time, experience, and resources in the future and result in general and effective conservation practices. Plant translocations, despite all the critical issues that remain unresolved, could be fundamental for the development of new conservation strategies that are emerging, such as IUCN Green Status of Species (Grace et al. 2021a, b; Cogoni et al. 2022), which are based on the ability to quantify the effects of conservation actions in situ.

Limitations of this research

Some relevant limitations are intrinsic to this study and must be taken into due consideration. Firstly, this research focused on the Mediterranean Basin and the Mediterranean hotspot (sensu Medail and Quezel 1997) but the exact delimitation of this region is extremely complex to achieve. Consequently, the results obtained suffer from this inaccuracy; this means that the numerical results must be treated with care and represent only a numerical scale useful for setting up a biogeographical analysis (that remains extremely complex and, surely, not exhaustive).

A second limiting factor concerns the language used in the search; although four widely diffused idioms were used, it was not possible to use other widespread languages, especially those from the southern and eastern parts of the Mediterranean (e.g., Arabic, Turkish, etc.). This aspect could have had a significant impact on the possibility of using the grey literature written in these languages and, to a lesser extent, on the exchange of information with local experts.

Two other aspects that are no less important in carrying out large-scale research should be considered: on the one hand, the lack of a botanic taxonomy common to the whole biogeographical region; on the other hand, the difficulty in collecting often basic information on conservation actions as well as of involving local experts. Coordination is necessary, not only between conservationists but also between taxonomists and politicians.

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Author contributions GF, DC and GC conceived the idea; All authors collected data; GF, DC and GC analyzed the data; GF, DC and GC drafted the manuscript; All authors revised and approved the final version of the manuscript.

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Declarations

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