Article

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Management actions to achieve Favourable Conservation Status for the priority plant species of the Habitats Directive *Androcymbium rechingeri* (*Colchicaceae*) in Greece

Abstract

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Androcymbium rechingeri Greuter is a range restricted geophyte. It occurs only on sandy beaches and coastal areas in West Crete, Greece: Elafonisi islet, Elafonisi coast, Falasarna and Imeri Gramvousa islet and it has also been reported in coastal areas of Libya. *A. rechingeri* has been categorized as Endangered according to the IUCN Red List and the Red Data Book of Greece (1995). It is listed as priority species in Annex II of the Habitats Directive and is protected by the Greek Presidential Decree 67/81 and the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention). Management actions are currently in progress with the aim to achieve Favourable Conservation Status for the species. The actions include fencing and designation of pathways in the highly touristic areas of Elafonisi and Falasarna, re-establishment of the plant population at part of Elafonisi, seed collection from all subpopulations for *ex situ* conservation, planning for long-term monitoring of the *in situ* conservation actions, and raising awareness of the residents and visitors. This work presents the results from population reinforcement of *A. rechingeri* started during 2016-2019, in the framework of the CARE-MEDIFLORA project at the Elafonisi coast, and continued to this day with the monitoring of the results. Moreover, the results from the germination and viability tests of the seeds samples collected from the various subpopulations of the species are presented. Finally, the various management actions that have been implemented for species conservation are described.

Key words: threatened plant species, West Crete, conservation actions, *in situ*, reinforcement protocol, *ex situ*, germination.

Introduction

Life form & distribution - *Androcymbium rechingeri* Greuter (*Colchicaceae*) is a geophyte which is range restricted in Europe, occurring only on sandy beaches and coastal areas

in West Crete, Greece (Elafonisi islet, Elafonisi, Falasarna and Imeri Gramvousa islet) (Kypriotakis & al. 1998; Fournaraki & al. 2005). Elsewhere, it has been reported in N Libya (WCSP 2022) and in coastal areas of N Africa from Tunisia to NW Egypt (Strid 2016).

Legal status - *A. rechingeri* is listed as priority species in Annex II of the Habitats Directive (Council Directive 92/43/EEC). It is included in Appendix I of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) and it is protected by the Greek Presidential Decree 67/81. Most of the subpopulations in West Crete are included in NATURA 2000 sites (GR4340002, GR4340001 and GR4340015).

Conservation status - The conservation status of *A. rechingeri* has been assessed as Endangered under the IUCN Red List criteria B1ab(iii)+2ab(iii) (Delipetrou 2011) and it is included in the Red Data Book of Greece as Endangered (Phitos & Kypriotakis 1995).

According to the last national report under Article 17 of the Habitats Directive (Council Directive 92/43 EEC), for the 6-year period 2013-2018 (EIONET 2022), the Conservation Status of the range and of the total population of the species *A. rechingeri* are assessed as Favourable, due to the recent discovery of some new, small subpopulations along the west coast of Crete. However, the Conservation Status of its habitat and its future prospects are assessed as Unfavourable-Inadequate due to severe pressures and threats. Consequently, the overall assessment of its Conservation Status is found Unfavourable-Inadequate.

Pressures and Threats - In Greece, the habitat of *A. rechingeri* is adequately protected at the locations on the islets. However, there is continuous degradation at Elafonisi coast and Falasarna due to recreational activities and tourism, overgrazing, agricultural activities, and construction of roads, parking areas and other facilities. In particular, both Elafonisi coast and Falasarna are highly touristic, attracting thousands of visitors every year, and there is extensive use of vehicles and trampling all over the areas due to recreational activities such as swimming, sunbathing, water sports and hiking. Umbrellas and sunbeds are established on the beach, the surroundings are extensively used as parking lots and camping grounds, and toilets, snack bars and boats are found all around. In addition, both areas and their surroundings are subjected to seasonal grazing by the local shepherds and in the vicinity of Falasarna there is a considerable number of agricultural installations (i.e. greenhouses) occupying and polluting the habitat.

Conservation actions – A first assessment of the whole population of *A. rechingeri* in West Crete was conducted by the CIHEAM Mediterranean Agronomic Institute of Chania (MAICh) during 1995-1998 with the project LIFE Western Crete 95/GR/A22/GR/01143/KRI (Kypriotakis & al. 1998). Conservation actions were initiated in 2004 with the project "CRETAPLANT: A Pilot Network of Plant Micro-Reserves in Western Crete" of the EU LIFE-NATURE-2004 Programme (Thanos 2007). The outputs of CRETAPLANT included a detailed inventory of the *A. rechingeri* populations (Fournaraki & al. 2005), *ex situ* conservation of all the subpopulations in W Crete, development of seed storage, germination, growth and outplanting protocols (Fournaraki & al. 2007), and the establishment of a Plant Micro-Reserve for *A. rechingeri* at Elafonisi islet.

In the past the local municipalities had placed fencing at Elafonisi coast to protect the priority habitat "Coastal dunes with *Juniperus* spp." (Code: 2250 *). The purpose of this action was the limitation of trampling and parking of cars beneath the *Juniperus macrocarpa* trees. This was very effective in restoring dunes and generally the natural vegetation of the area and among others for the conservation of the natural population of *A. rechingeri*

in this particular area. Moreover, other endemic and endangered species of flora that are recorded within the habitat of *A. rechingeri* are also protected. Specifically on the beach of Elafonisi the following species are found: *Bellevalia brevipedicellata* Turrill, *Limonium elafonisicum* Alf. Mayer, *Viola scorpiuroides* Coss., *Centaurea pumilio* L. etc. (Kypriotakis & al. 1998). In the same area, part of the subpopulation is located within the priority habitat '2250* Coastal dunes with juniper species (*Juniperus* sp. pl.)'.

During the implementation of the CARE-MEDIFLORA international project (http://care-mediflora.eu/) (2016-2019), this species fulfilled the criteria for selection as 'target species' for conservation (Fenu & al. 2019a, Fenu & al. 2019b) and the following actions have been carried out: *ex situ* conservation at the seed bank of MAICh with five seed collections in the wild from respective natural subpopulations, germination experiments for plant production purposes, and *in situ* conservation at the Elafonisi area (setting up fences and information signs, and experimentation with different methods for the reinforcement of the species population); but so far only preliminary results have been published (Fenu & al. 2020).

In the work here described, results of conservation actions are presented, which are implemented in the framework of a national project for the conservation of *A. rechingeri* (2020-2022), funded by the Green Fund of the Greek Ministry of Environment & Energy, with the aim to contribute to the achievement of an overall Favourable Conservation Status for *A. rechingeri*, particularly with regard to its habitat and Future Prospects in the areas of Elafonisi and Falasarna. In addition, the results of the past reinforcement of the Elafonisi coast population, which was initiated with CARE-MEDIFLORA project, are given after a monitoring period of five years.

Main threats addressed - The threats that are mainly addressed involve the impact of tourism and recreation areas, the severe recreational activities and the nomadic grazing activities on the populations of Elafonisi and Falasarna.

Materials and methods

All field works and plant material collections of *Androcymbium rechingeri* have been implemented in the areas of Elafonisi, Falasarna and Imeri Gramvousa islet in West Crete (Fig. 1). The actions have been carried out by the Mediterranean Plant Conservation Unit of MAICh in close collaboration with the Decentralised Administration of Crete - Forest Directorate of Chania and the Management Unit of Samaria National Park and the Protected Areas of Western Crete of the Natural Environment and Climate Change Agency (N.E.C.C.A.). Research permits were obtained from the Greek Ministry of Environment & Energy.

Ex situ *conservation*

For *ex situ* conservation, seed collections were made from all known populations of *A. rechingeri* in West Crete. The collections were implemented in the periods May or June from 2020 until 2021 (Table 1). The seed collections were curated and stored using the GENMEDA (Bacchetta & al. 2006) and ENSCONET protocols (ENSCONET 2009a & 2009b). After cleaning, the seeds were placed in open containers in the Dry Room (temperature: 15-20 °C, relative humidity: 15-20%). The seeds remained in the Dry Room until packaged and stored in the Cold

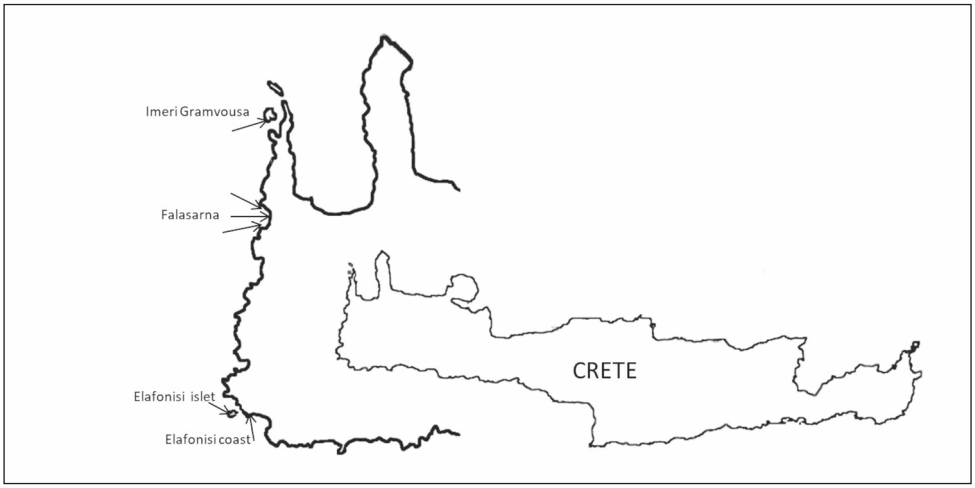

Fig. 1. Map of Crete showing the locations of various subpopulations of *Androcymbium rechingeri.*

Room (temperature: minus 18-20 °C). For safety reasons, part of the collections was duplicated at the Seed Bank of the National & Kapodistrian University of Athens.

Germination and viability tests were implemented for all the 2020-2021 accessions 4-12 months after their collection and during the Dry Room phase. The germination protocol of *A. rechingeri* was determined in previous experiments (Pretreatment: Seed scarification, Temperature: 15 °C, Photoperiod: 12 h light/12 h dark, Substrate: 2% agar) (Fournaraki 2010). The seed viability was estimated from the results of the germination tests and the cut

Table 1. *Androcymbium rechingeri* seed collections 2020-2021.

Sub-population locality	**Date of seed collection**	**No of seeds stored in MAICh Seed Bank**	**No of seeds duplicated**
Falasarna, mid	19/5/2020	7960	2000
Falasarna, south	20/5/2020	8620	2000
Falasarna, north	20/5/2020	6448	2000
Elafonisi coast	15/6/2021	5009	1000
Elafonisi islet	15/6/2021	2773	500
Imeri Gramvousa islet	24/6/2021	3270	500

tests which were performed on the non-germinated seeds after the end of the germination tests. To determine the germination rate, the parameter T50 was used (GENMEDA 2006).

In situ *conservation*

Population reinforcement. Experimentation on population reinforcement of *A. rechingeri* started in the framework of the CARE-MEDIFLORA project, during 2016-2019, at the Elafonisi coast (Fenu & al. 2019a, Fenu & al. 2019b, Fenu & al. 2020) and continues up to date with the monitoring of the results. During the national conservation project, further population reinforcement of *A. rechingeri* was implemented at the Elafonisi coast on 12 January 2021: a total of 1400 seeds were directly sown in the soil of a fenced area, within 14 grids fixed to the ground. In each metal grid, 100 seeds were sown, in 50 separate cells. The seeds used were from the seed collection from Elafonisi on 19/5/2016 which was stored in the Seed Bank of MAICh. All planting locations were recorded with GPS and mapped in order to be easily identified for the long-term monitoring. The place selected for population reinforcement was a fenced area at Elafonisi coast from where the species had almost disappeared due to the severe and continuous degradation of the habitat due to trampling by the thousands of summer visitors, parking of cars and other activities.

Fence erection. After relevant studies and permissions, two fences were established on the coast of Elafonisi and walking pathways were marked in the highly touristic areas of Falasarna beaches. The above interventions were carried out in collaboration with the competent management authorities (Decentralised Administration of Crete/Forest Directorate of Chania and the Management Unit of Samaria National Park and the Protected Areas of Western Crete) and after consultation with the Municipalities and land-owners.

Results & Discussion

Ex situ *conservation*

A total of 6 seed collections, one from each of the known sub-populations of *Androcymbium rechingeri*, were made in May 2020 and June 2021 (Table 1). In the June collections most of the capsules had opened and shed their seeds and therefore the collections were smaller in number of seeds.

In Figures 2 & 3, results of germination experiments and seed viability tests are presented. Final germination rates for the various seed samples range between 66-97%. Seed germination was faster (T_{50} = 17-19 days) for the sub-populations in the SW (Elafonisi area) compared to the sub-populations in the NW (Falasarna and Imeri Gramvousa) (T_{50} = 23-26 days) (Fig. 2). Various factors that affect the seed germination behavior of a population have been identified, among which are: 1) the time of collection, 2) storage of seeds in the dry room and in the laboratory (Fournaraki 2010). The small differences observed in the germination behavior of the different seed collections may be due to the above factors. Moreover, these differences have been observed in the same subpopulation of *A. rechingeri* in collections of different years (Unpublished data from the Seed Bank of MAICh).

Seed viability was over 70% for all sub-populations except from the area of ‘Falasarna mid’ which was slightly under 50% (Fig. 3). The low seed viability of this subpopulation (Falasarna mid) requires further investigation.

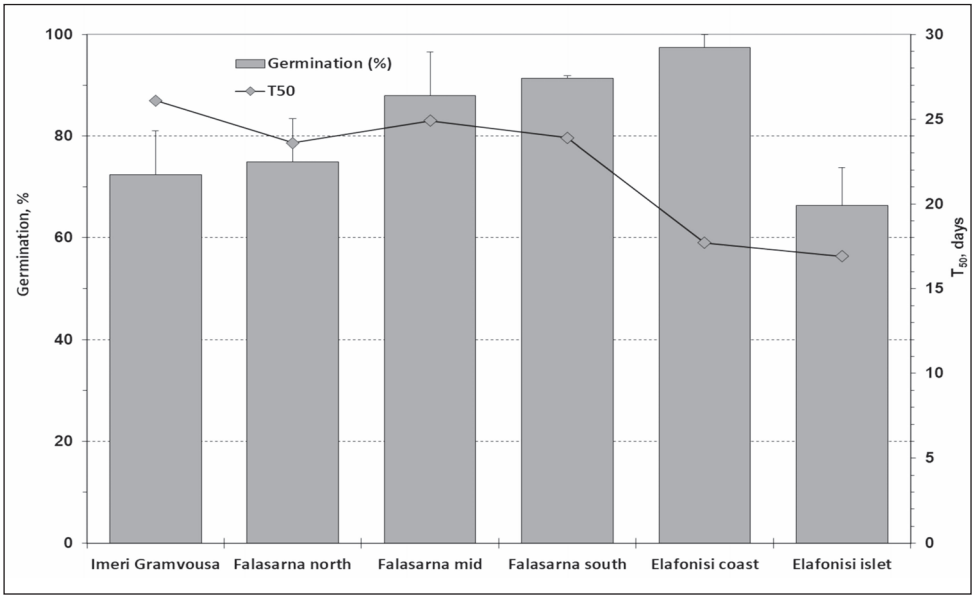

Fig. 2. Final germination percentage and germination rate (T_{50}) of the different sub-populations of *Androcymbium rechingeri* at a constant temperature of 15 °C and photoperiod 12 h light/12 h dark. Pretreatment: Seeds scarified. The vertical lines above the columns represent the standard error.

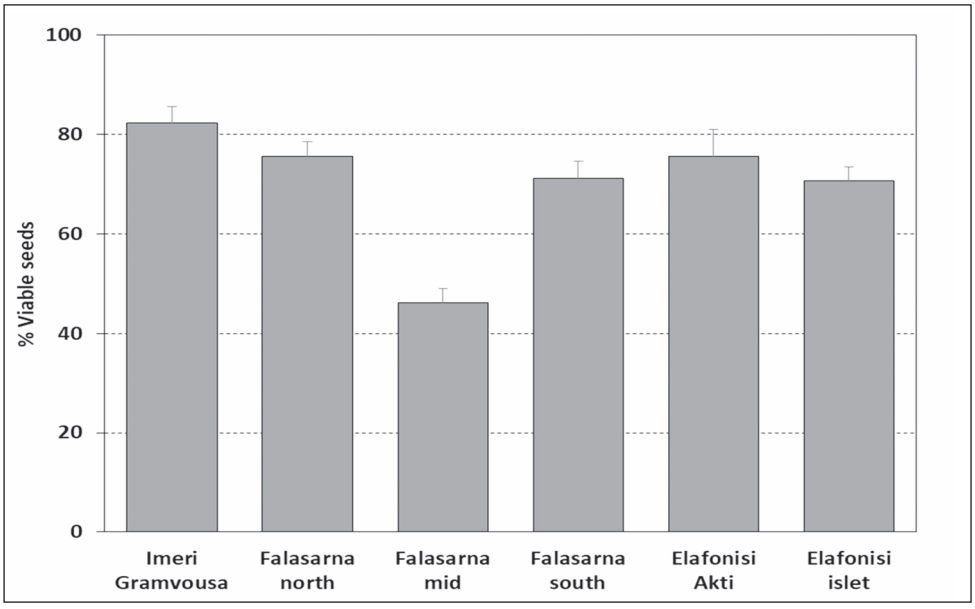

Fig. 3. Seed viability of the different sub-populations of *Androcymbium rechingeri* collected in 2020-2021. The vertical lines above the columns represent the standard error.

In situ *conservation*

Elaboration of optimum protocol for population reinforcement – Results from 5 years of monitoring of population reinforcement of *A. rechingeri* are presented in Fig. 4. Overall, the results can be summarised as follows:

- There is no significant difference in the successful establishment of *A. rechingeri* when sowing seeds directly in the field or planting seedlings during the winter period (December). In both cases the survival rate in fenced areas after 5 years is approximately 40% (Fig. 4).
- The establishment of new plants is successful when the locations are fenced in order to prevent grazing and trampling. After 5 years, the survival rate outside fenced areas is only about 10%.

Monitoring of plant establishment in the 1st year may show incorrect low survival rate (Fig. 4), due to non-distinguishable seedlings in the field because of their tiny size.

In addition, it was noted that plants established from seeds started to flower after 4 years from sowing and plants established from seedlings started to flower 3 years after planting.

Although there is no significant difference in the successful establishment of *A. rechingeri* plants when sowing seeds directly in the field or planting seedlings, sowing seeds is preferred as possible losses during plant production in the nursery are avoided and there is no risk of accidentally introducing alien species or other harmful organisms in the wild by transferring them with the plant substrate. Overall, sowing seeds directly in a fenced area is also a faster and less expensive method in terms of resources needed.

Therefore, the optimum reinforcement protocol for the *A. rechingeri* population is the direct sowing of seeds in the early winter period (December or January) provided that the pressure on the habitat of the species by tourism activities has been reduced.

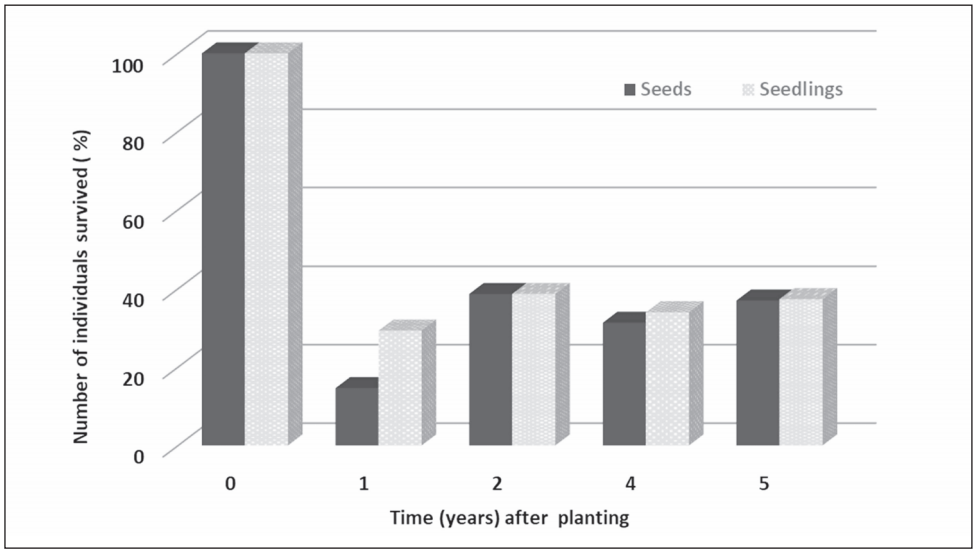

Fig. 4. Monitoring of *Androcymbium rechingeri* population reinforcement. Success rate when sowing seeds directly in the field (seeds) or planting seedlings (seedlings) inside a fenced area.

With regard to the last reinforcement action, the first monitoring of results, after 1 year, in January 2022, has shown that only 29 plants were established from the 1400 seeds sown. However, as mentioned above, the 1st year monitoring results are not indicative of the success of the action.

Fencing: Two fenced areas were constructed in Elafonisi coast (7,700 m² and 9,600 m²) and two pathways were demarcated in Falasarna (550 m in total). The locations specified for the fenced areas and pathways are those where the highest degradation of the sub-populations and the habitat was observed mainly due to the construction of roads, parking of vehicles and trampling by the thousands of tourists visiting Elafonisi and Falasarna.

Information signs providing information about the project and indicating the threatened species were placed in prominent positions at the entrance of the demarcated pathways and the fenced areas. Leaflets about *A. rechingeri* and the current project were prepared in English and Greek in order to be distributed to visitors. Until the end of the national project (2020-2022) it is anticipated to hold information days at the Municipalities of Kantanos-Selino and Kissamos. T-shirts with drawings of *A. rechingeri* have been prepared for distribution to students and residents participating in the information campaign. In addition, it is anticipated to hold a training seminar in order to inform the staff of the competent authorities (Forest Directorate, Management Unit, Municipalities, etc.) about issues related to the long term monitoring of the *in situ* conservation actions and the maintenance needs of the infrastructure of the project.

Conclusions

Ex situ conservation of all the subpopulations of *Androcymbium rechingeri* in Crete has been secured at the Seed Bank of MAICh. The observed variation in seed viability among subpopulations of *A. rechingeri* needs further investigation. The optimum reinforcement protocol for the *A. rechingeri* population is the direct sowing of seeds in the early winter period (December or January) provided that the pressure on the habitat of the species by tourism activities has been reduced. The survival rate in the fenced areas after 5 years was approximately 40%, while in unprotected areas, the survival rate was only about 10%.

The long-term development of scientific knowledge on the biology of the species, the population distribution and estimation, the conservation status of the subpopulations and the long-term monitoring of reinforcement actions have contributed to the implementation of an effective management plan for improving the species conservation status. Also, the above measures can improve the conservation status of other endangered species and habitats. The management of protected areas where there are intensive tourism activities requires multifaceted actions and approaches to be effective. It requires the close cooperation of all management bodies as well as great awareness of the inhabitants and visitors of Crete.

Finally, both areas, Elafonisi and Falasarna are popular tourist destinations and receive a large number of visitors annually. Therefore, the interventions can be an opportunity for demonstration projects aimed at informing and raising awareness on issues of sustainable tourism development in ecologically sensitive areas.

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