Rehabilitation of disturbed areas by mining activities in high floristic diversity areas: the case of Mt Giona

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ABSTRACT

Mt Giona situated in the floristic hot-spot of southern-central Greece has an especially rich flora that counts more than 1000 native vascular plant taxa (species and subspecies) and an important plant endemism that is estimated to be about 10% of the native flora. The danger of population reduction of rare and endemic plant species and the opportunity to use rare native species in rehabilitation projects are two different aspects of rehabilitation planning in Mt Giona.

In this study, an inventory of rare and endemic species of the area, their classification into IUCN threatened categories and an estimation of their habitats vulnerability are provided. The results emphasize the necessity to develop a monitoring program to analyze population viability of certain threatened plant species. The creation of artificial micro-reserves on calcareous spoils derived from bauxite mining for the conservation of water-stress tolerant rare and endemic plants is also proposed. An inventory of the species that have colonized the mining spoils was also undertaken. Twelve of them are endemics. Seven native species, because of their biological and ecological features, were selected for rehabilitation purposes of disturbed areas by mining activities. Seed germination, aspects of their reproductive biology and seedling emergence after sowing in pots under field conditions were studied. The seed germination study in the laboratory led to the identification of the optimum germination conditions and the creation of germination protocol for each species. Seedling emergence depends on the sowing season and the mulching. The use of the above species is recommended for rehabilitation purposes. The creation of artificial micro-reserves on calcareous spoils derived from bauxite mining for the conservation of water-stress tolerant rare and endemic plants is also proposed.

1. INTRODUCTION

The conservation of biodiversity is a major challenge for the 21st century and a wide array of approaches will be necessary to address it. The co-existence of high floristic richness and intensive human impacts in an area is an ideal case study for detecting the potentials to conserve plant species richness and simultaneously to give an impulse to sustainable economic development.

Mt Giona situated in one of the ten hot-spots for the plant species diversity in the Mediterranean Basin (Médail and Quézel, 1999) has an especially rich flora and it is also an area rich in minerals. The recording of the flora and the evaluation of the conservation status of endemic, rare and threatened plant species, as well as, the use of native plant species for the rehabilitation of disturbed areas by mining activities in Mt Giona is the subject of a project currently in progress. In this paper we present the first results of this project, regarding the sensitive group of the endemic species, their classification into IUCN categories and the assignment of their habitats vulnerability in order to identify the most threatened species and habitat types. We also detect the life strategies of the endemics in order to evaluate their suitability for use in

rehabilitation projects and/or to be planted in artificial micro-reserves on calcareous spoils derived from bauxite mining. The extension of this study in the whole flora of Mt Giona is in our future purposes.

Observations in disturbed areas, however, have shown that certain native species colonize the old mining spoils and deposits, presenting satisfactory vegetation cover, depending on the quality of soil substrate. In some publications (Brofas, 1979, 1997) referring to the problems presented in the revegetation of calcareous spoils following the exploitations of bauxite in Giona-Parnassos region in central Greece several species have been recorded, (notably: *Centranthus ruber, Epilobium dodonaei, Nepeta spruneri, Scrophularia canina, Melica ciliata, Vincetoxicum hirudinaria* subsp. *nivale* and *Rhus coriaria*), which have been established in the mining spoils of these exploitations. These species can play an important role in the revegetation, since the advantages of the native species are widely recognized. They were selected for their rich above-ground plant parts, effective soil cover, good radical system, effective soil stabilization, establishment ability in soil poor in nutrients and because they are perennial.

2. MATERIAL AND METHODS

Based on field studies, studies of herbarium specimens and analysis of the existing bibliography, a still unpublished plant list that consists of c. 1000 vascular plant taxa known from Mt Giona has been formed. The list contains species and subspecies, but the term 'species' will be used throughout the paper in reference to vascular plant overall richness for simplicity. The nomenclature follows Flora Hellenica (Strid and Tan, 1997, 2002) and Mountain flora of Greece (Strid, 1986; Strid and Tan, 1991).

As endemic species in this study we count these ones that fulfill the following criteria: 1) they are endemic to Greece, 2) they occur in Mt Giona. The endemic plants of Mt Giona were classified in threatened categories using the IUCN Red List Categories and Criteria (IUCN, 2001). The established categories for a species are: extinct (EX); extinct in the wild (EW); critically endangered (CR); endangered (EN); vulnerable (VU); near threatened (NT); least concern (LC); and data deficient (DD). The classification of the endemic species was based to our own estimations, supplemented with data from IUCN (1982), Phitos et al., (1995) and Constantinidis (1997).

A simplified list of 14 habitat types occupied by the endemics of Mt Giona was created. The habitat types were classified into three levels of vulnerability according to Médail and Verlaque (1997), depending on the percentage of threatened species in each habitat type (0-25% of threatened species in the corresponding habitat: low vulnerability; 26-50%: medium vulnerability; 51-100%: high vulnerability). To identify the vulnerability level of each habitat type, except from the number of threatened species, the number of near threatened species divided by two has been used. The data deficient (DD) species have been rejected from the analysis.

CSR model described by Grime (1977) gives the relationships between species traits and their relative abundance. A triangle of species and habitats was described, in which the extremes are 'competitors' exploiting conditions of low stress and low disturbance, the 'stress tolerators' associated with high stress and low disturbance, and the 'ruderals' characteristic of low stress and high disturbance. There are other combinations of plant characters suited to exploit various intermediate conditions corresponding to particular equilibria between stress, disturbance and competition factors in the environment. Following this scheme, the life strategies of the endemic species of Mt Giona were identified and a CSR triangle for the endemics was created, in order to evaluate the suitability of the endemics to be used in rehabilitation projects.

An inventory of plant species growing on the surfaces of mining exploitations was realized according to Braun-Blanquet (1964). Data from Brofas (1979, 1997) were also included. As a result, seven native species suitable for rehabilitation of disturbed areas by mining activities were selected.

Seed germination study in the laboratory was performed for the selected plants in temperature and light controlled chambers (Model BK 5060 EL, W.C. Heraeus GmbH, W. Germany) by using Petri dishes and 2 sheets of filter paper with addition of water or appropriate solution.

The seedling emergence in the field was in-

Table 1: Habitat classification and vulnerability of the endemic plants of Mt Giona.

	Habitat type	Number of endemic plants			Vulnerability
		Total	Threatened	Near Threatened	
1	*Sclerophyllus* scrubs	6	0	0	Low
2	*Abies cephalonica* woodlands	2	0	0	Low
3	Low altitude forest edges and glades	5	0	0	Low
4	Mid and high altitude forest edges and glades	14	0	2	Low
5	Mid-altitude cliffs and rocks	8	0	1	Low
6	High altitude cliffs and rocks	46	5	11	Medium
7	Calcareous rocky grasslands at mid-altitudes	13	0	1	Low
8	Calcareous rocky grasslands at high altitudes	58	3	15	Low
9	Screes	25	2	6	Medium
10	Moist sub-alpine pastures	15	0	3	Low
11	Fallows, roadsides	11	0	1	Low
12	Ravines, springs and rivulets	6	1	2	Medium

vestigated after sowing in pots of 25 cm diameter in the Gravia area (altitude 430 m) in the area of mining exploitations (Giona-Parnassos), with filling material of barren calcareous materials from bauxite exploitations. These materials are mine spoil deposits composed of fractured limestone overlying bauxite of different sizes mixed with small quantities of surface soil. The fine soil material (fraction <2mm) is approximately 20-30% and is characterized as sand-clay. The pH ranges from 7 to 8.5. The percentage of free $CaCO_3$ varies and it can reach up to 90-95%. Organic matter appears in very small quantities (<0.5%), and N, P, and K elements in very low concentrations (Brofas, 1979, 1992).

The sowing in the pots was done during 2 seasons (spring 2001 and autumn 2002) with 4 treatments: i) in barren materials, ii) in barren materials with covering with soil, iii) in barren materials with straw mulching and iv) in barren materials with covering with soil and straw mulching. One hundred seeds were sown in each pot for each species.

3. RESULTS AND DISCUSSION

Studies on rarity patterns of the endemic flora of Greece are still scarce, since only fragmentary data of the exact distribution and population status for many endemic species are available. This is a first effort to classify the endemic plants of Mt Giona in threatened categories according to IUCN Red List Categories and Criteria (IUCN, 2001).

The endemic flora of Mt Giona consists of 101 species. Two species have a distribution range restricted to Mt Giona (*Arenaria gionae*, *Potentilla kionaea*) and 99 species have a wider distribution in the neighbouring mountains of Sterea Ellas and/or the mountains of Peloponnese and central-northern Greece. Seven species are classified as VU (*Allium parnassicum*, *Alyssum taygeteum*, *Aquilegia ottonis* ssp. *ottonis*, *Arenaria gionae*, *Campanula aizoon* ssp. *aizoon*, *Potentilla kionaea*, *Silene barbeyana*), 25 as NT, 53 as LC and 16 as DD.

Threat is strongly clumped across habitats in Mt Giona, a characteristic that enable us to identify several habitat types with significantly more threatened species than expected. The endemic plants of Mt Giona are distributed in 12 habitat types (Table 1). The majority of the endemics are located in habitats with high stress level. High altitude cliffs and rocks (habitat 6), calcareous rocky grasslands at high altitudes (habitat 8) and screes (habitat 9) are exceptionally rich in endemic elements. Habitat types with a dense plant cover and high competition, like forests and sclerophyllus scrubs seem to be unfavorable for the endemics.

The classification of the habitat type's vulnerability in accordance with the proportion of threatened and near threatened species that they contain has extracted interesting results (Table 1). None of the habitats types occupied by the endemics in Mt Giona has been classified as

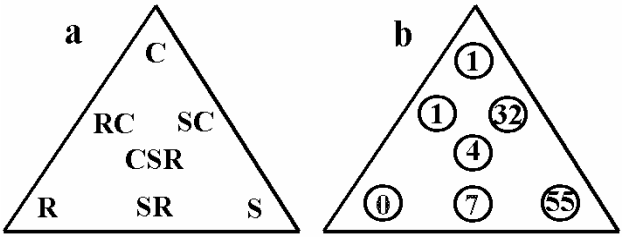

Figure 1: Grime's CSR plant strategies (a) and percentage of life strategies of endemic plants from Mt Giona (b).

highly vulnerable. High altitudes cliffs and rocks (habitat 6), screes (habitat 9) and ravines, springs and rivulets (habitat 12) are classified as medium vulnerable. The first two habitat types are rich in endemic species, while the latter includes only six species of damp places with a usually dense plant cover and high interspecific competition. All other habitat types occupied by the endemics in Mt Giona are classified as low vulnerable.

Classification of the 101 endemic plants of Mt Giona according to their life strategies was done and the corresponding CSR triangle of life strategies (Fig. 1) emphasizes the importance of stress-tolerant endemics for the whole endemic flora. About 55% of the endemics belong to this category. Three categories (S, SC, SR) are predominant in the endemic flora including 94% of the endemics. All other categories are underrepresented in CSR triangle.

Low competition and specialized habitats with high stress level are the main factors correlated to the abundance of the endemics, as it is indicated by the dominance of stress-tolerators in the endemic flora (Fig. 1) and the habitat types they inhabit (Table 1). Reduced competitive ability followed by specialization is an important characteristic of the endemic flora of Mt Giona and probably the same pattern expands to many other Greek mountains.

The SR life strategy category includes stress-tolerant plant species able to colonize disturbed habitats. This category includes seven endemics (*Bupleurum capillare*, *Centaurea affinis* ssp. *pallidior*, *Cirsium hypopsilum*, *Lysimachia serpyllifolia*, *Nigella arvensis* ssp. *aristata*, *Odontites linkii* ssp. *linkii*, *Plantago atrata* ssp. *graeca*) suitable for rehabilitation of disturbed areas by mining activities, mainly for conservation purposes. Moreover, 63 S and SR endemic species (amongst them the 7 VU and 18 NT endemics of Mt Giona) are potentially suitable to be planted in artificial micro-reserves on calcareous spoils derived from bauxite mining.

The inventory of the plants growing naturally on the surfaces of the mining exploitations resulted to the recognition of 295 plant species. Seven of them have been selected for rehabilitation of disturbed areas by mining activities. Their seed germination, aspects of their reproductive biology in the laboratory and seedling emergence after sowing in pots under field conditions were studied. The germination of non-dormant species at various temperatures in the laboratory, specifically *Melica ciliata*, *Vincetoxicum hirundinaria* subsp. *nivale* and *Centranthus ruber* is shown in Table 2 with the optimum germination temperatures for each species. Gibberelic acid used as pre-treatment of dormant seeds of the species *Nepeta spruneri*, *Scrophularia canina*, and *Epilobium dodonaei* promoted the germination. Boiling water promoted the germination of *Rhus coriaria* seeds, as also in Doussi (1999). The results are shown in Table 3. The seedling emergence in the pots with soil from barren materials of excavations is presented in Tables 4 and 5.

Table 2: Seed germination (G, %) in various temperatures (T, ^{o}C) of non-dormant species.

T, ^{o}C	*Melica ciliata*		*Vincetoxicum hirundinaria ssp. nivale*		*Centranthus ruber*	
	G, %	T_{50}, days	G, %	T_{50}, days	G, %	T_{50}, days
5	-	-	6±1	112.3	16±2	15.6
10	100	14.3	8±1	58.0	41±3	4.5
15	100	2.7	63±3	31.5	72±3	4.5
20	100	1.5	94±3	12.8	81±4	1.0
25	100	0.7	94±2	4.3	52±3	1.0
30	80±5	2.4	84±3	4.6	44±3	5.7
35	-	-	33±2	2.9	-	-

Table 3: Germination promotion by gibberelic acid ([GA_3]) pre-treatment of dormant species.

GA_3	*Scrophularia canina*		*Epilobium dodonaei*		*Nepeta spruneri*	
	G, %	T_{50}, days	G, %	T_{50}, days	G, %	T_{50}, days
0	4±1	13.7	26±3	21.0	0	0.0
1	8±4	12. 6	28±2	12.5	-	-
10	6±1	5.5	42±1	8.3	-	-
100	34±3	6.8	44±1	5.8	-	-
500	41±3	4.7	63±6	4.4	10±1	12.9
1000	36±3	4.4	46±5	4.7	-	-

Table 4: Seedling emergence (%) in pots with Barren material and straw mulching (B-SM), Barren material (B), Barren material with surface soil and straw mulching (B-SS-SM) and Barren material with surface soil (B-SS) of non-dormant species.

	Sowing season	B-SM	B	B-SS-SM	B-SS
Vincetoxicum hirudinaria ssp. *nivale*	autumn	22.5	5.5	15.5	7.5
	spring	79.5	40.0	91.0	52.0
Centranthus ruber	autumn	37.0	17.5	15.5	16.5
	spring	46.0	33.0	37.0	25.5
Melica ciliata	autumn	6.2	26.2	22.7	8.0
	spring	24.0	10.5	33.2	26.2

Table 5: Seedling emergence (%) in pots with Barren material and straw mulching (B-SM), Barren material (B), Barren material with surface soil and straw mulching (B-SS-SM) and Barren material with surface soil (B-SS) of pre-treated dormant species.

	Sowing season	B-SM	B	B-SS-SM	B-SS
Scrophularia canina (+GA_3)	autumn	4.2	18.7	10.2	6.2
	spring	37.7	9.0	34.5	16.5
Epilobium dodonaei (+GA_3)	autumn	19.2	8.5	8.5	2.5
	spring	6.0	4.5	10.0	7.0
Nepeta spruneri (+GA_3)	autumn	8.5	11.0	8.5	3.5
	spring	2.5	0.0	4.7	0.0
Rhus coriaria (boiled 100 ^oC water)	autumn	8.0	0.5	17.5	0.0
	spring	27.5	18.0	9.0	9.0

Seedling emergence in pots with barren material is not efficient for most of the species. The spring sowing seems to favor the seedling emergence compared with autumn sowing, in most cases, but not for all species and treatments. Similar results are also reported by Brofas and Karetsos (2002). The use of surface soil filling in the barren materials does not appear to improve the emergence of seedlings in all cases, compared to the barren materials. Probably this result can be connected with the quality of the used soil, which comes from deeper layers and is poor in nutritious components. The creation of crust observed appears to be a more suppressive factor in the success of sowing.

On the contrary the straw mulching or the covering with surface soil, of the barren materials, increases considerably the seedling emergence in almost all species. This favorable effect of mulching appears to be connected with the prevention of the appearance of extreme temperatures, specifically the high temperatures that are created on the ground surface, and improve the soil moisture conditions (Unger, 1978). According to Barkley et al., (1965) these factors can allow germination and maximize it. These advantages and mainly the improvement of the soil moisture are important for the survival and the vegetation establishment in the conditions created of the barren materials after the quarries excavations, where the soil moisture is the limiting factor (Packer, 1974).

It is worth mentioning that among the species that have colonized the mining spoils 12 endemics are also included such as *Bupleurum capillare*, *Cerastium candidissimum, Lysimachia serpyllifolia, Marrubium velutinum ssp. velutinum, Astragalus sempervirens ssp. cephalonicus*, etc. Some of them such as *Cerastium candidissimum, Marrubium velutinum ssp. velutinum, Astragalus sempervirens ssp. cephalonicus,* are potentially suitable to use for rehabilitation purposes. Seeds of these species have already been collected in order to study their reproductive biology and to produce plants that will be used in rehabilitation projects.

4. CONCLUSIONS

Certain actions must be taken for the conservation of the endemic flora of Mt Giona. Monitoring programs should be developed to analyze population viability of the seven vulnerable (VU) endemics. Further studies are necessary to identify the conservation status of the 16 data deficient (DD) endemics, and protective actions for the conservation of the three medium vulnerable habitat types of the endemics (Table 1) should be taken. Seven SR endemics could be used for rehabilitation of disturbed areas by mining activities, mainly for conservation purposes. The creation of artificial micro-reserves on calcareous spoils derived from bauxite mining would be promoting effective conservation, as the majority of the endemics seem to be suitable for planting in this environment. Further studies to identify the status of the whole flora of Mt Giona are strongly recommended, and studies on reproductive biology and rehabilitation capability of the endemic plants naturally growing on mining spoils, are also proposed.

Melica ciliata, *Vincetoxicum hirundinaria* subsp. *nivale* and *Centranthus ruber* are non-dormant and no germination pre-treatment is necessary. The dormant seeds of *Epilobium dodonaei*, *Nepeta spruneri*, *Scrophularia canina* require gibberelic acid (GA_3) for germination promotion. The dormant seeds of *Rhus coriaria* require a treatment in boiled water (100^{o}C, 1 min), to break dormancy in order to produce in the nursery, seedlings for outplanting. The sowing in the barren material is not suggested, while plant production in the nursery and transplantation in the disturbed areas is suggested. Of the seven native species selected for rehabilitation of disturbed areas by mining activities, no species can be suggested for direct sowing in the soil substrate.

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