

***Andryala integrifolia* L. (Asteraceae), a new alien species for the Island of Madeira (Portugal)**

Introduction

Madeira is an archipelago from Macaronesia comprising Porto Santo Island (11-14 Ma) and Madeira and Desertas Islands which constitute a volcanic complex with 0-6 Myrs. (GELDMACHER *et al.*, 2006). In Madeira Island, the more recent volcanic activity occurred 6,000-7,000 years ago (GELDMACHER *et al.*, 2000). This island is situated between 32°38' and 32°52'N and 16°39' and 17°16'W, at approximately 600 km northwest of the Western African coast.

Andryala L. is represented in Macaronesia by at least 8 endemic taxa distributed in different archipelagos: 5 taxa in the Canary Islands (ACEBES-GINOVÉS *et al.*, 2010) and 3 in the archipelago of Madeira (JARDIM and MENEZES DE SEQUEIRA, 2008). The vascular flora of the archipelagos of Madeira and Selvagens comprises 1,204 taxa. Of these, 12.8% are endemic to the archipelagos of Madeira and Selvagens, and 6.1% are Macaronesian endemics (JARDIM and MENEZES DE SEQUEIRA, 2008).

Andryala integrifolia was described by LINNAEUS (1753) in his "Species Plantarum". SELL (1976) and TALAVERA (1987) assigned this species for SW Europe, the Mediterranean Region and Macaronesia. It can also be found in North Africa: Tunisia (POIRRET-ALAPETIT, 1981), Algeria (BATTANDIER and TRABUT, 1899) and Morocco (NÈGRE, 1962).

In what concerns Macaronesia, KUNKEL (1978) assigned *A. integrifolia* to

the Canary Islands of El Hierro and Gran Canaria, and emphasized its Mediterranean origin. However, more recently ACEBES-GINOVÉS *et al.* (2010) referred *A. integrifolia* as a "probable native" species of these two islands. It also occurs in the Azores (SELL, 1976), namely in the islands of S. Jorge and Faial (FRANCO, 1984; HANSEN and SUNDING, 1993). SILVA *et al.* (2005) considered *A. integrifolia* as introduced in these Azorean islands. Recently SILVA *et al.* (2010) included St. Maria Island in the Azorean distribution, regarding *A. integrifolia* as naturalized.

Andryala integrifolia L. was recently found by us for the first time as a fully naturalized species in Madeira Island. Its morphological characters are clearly distinct from the endemics *Andryala glandulosa* Lam. and *Andryala crithmifolia* Aiton. A diagnostic key is provided and detailed images of the diagnostic characters are presented. The consequences of the introduction of *A. integrifolia* in Madeira Island are discussed.

Material and methods

Most of the observations were made upon herbarium specimens from the herbaria MA, LISU and TFC. Specimens collected during 2005-2010 in Madeira and in the Canary Islands were also revised. The macroscopic analysis was performed using a binocular microscope Zeiss model SV 11 APO. Micro characters were photographed using a Scanning Microscope (JEOL-TSM T330A). The distribution map is based on geographic coordinates of localities for the studied specimens and was plotted with the application QUIKMAP for Windows Version 1.02.

Results

During field work, plants with a contrasting morphology when compared with the Madeiran *Andryala* species (*Andryala glandulosa* Lam. and *Andryala crithmifolia* Aiton) were detected. Following various floras [Flora de Portugal (COUTINHO, 1939); Flora Europaea Vol. IV (SELL, 1976); Nova Flora de Portugal (FRANCO, 1984) and Flora Vascular de Andalucía Occidental (TALAVERA, 1987)] these plants correspond to *A. integrifolia*. The morphology of the vegetative and reproductive structures of this species differs from those recognized for the archipelago of Madeira (Figure 1). A key to Madeira archipelago *Andryala* L. is presented:

KEY TO MADEIRA ARCHIPELAGO *ANDRYALA* L. SPECIES

1. Lower leaves 1-2-pinnatissect with segments up to 3 mm in width; peduncles with short glandular hairs, ligules stellate-hairy at the apex of all the teeth.....*A. crithmifolia*
Lower leaves subentire to pinnatipartite; peduncles with long glandular hairs, ligules not stellate-hairy or rarely so at the apex of a few teeth2
2. Stem with numerous long glandular hairs, all along the stem or at least on the superior part; involucre bracts involute, enfolding a floret; florets golden yellow, external ones rarely with a reddish stripe on the outer face.....*A. glandulosa*
Stem sometimes with few glandular hairs on the superior part; involucre bracts flat, not enfolding a floret; external florets pale yellow,

frequently with a reddish stripe on the outer face.*A. integrifolia*

A. integrifolia has a very restrict distribution in Madeira (Figure 2). In 2009 it was found at Prazeres, Fajã da Ovelha and Paul da Serra, but more recently (2010) it was seen in abundance at Ponta do Pargo, the most far western locality of the island, co-existing with *Andryala glandulosa* Lam. subsp. *glandulosa* and *Andryala glandulosa* Lam. subsp. *cheiranthifolia* (L'Hér.) Greuter. *A. integrifolia* has been reported to grow on sandy, rocky or sterile terrains, uncultivated lands and stone walls (COUTINHO, 1939; FRANCO, 1984). In Madeira Island it grows on rocky road slopes (Figure 3) and uncultivated lands nearby roads, at altitudes between 539 m (road to Prazeres) and 1500 m (Paul da Serra) above sea level.

Studied material (*Andryala integrifolia* L.)

PORTUGAL. Madeira: Paul da Serra, talude rochoso junto à Estrada, 24.VII.2009, M. Sequeira, A. Pupo Correia, A. Figueiredo, Z. Ferreira (MA 801896); Madeira: Estrada para os Prazeres, Alt. 590, 29.VII.2009, Z. Ferreira, M. Benedito & M. Sequeira (MA 801898); Madeira: Estrada para os Prazeres, no talude da via rápida, 29.VII.2009, Z. Ferreira, M. Benedito & M. Sequeira (MA 801897); Beira Baixa: Barca d'Alva, taludes do caminho de ferro, VI.1915, R. Palhinha e F. Mendes (LISU 40310); Beira Litoral: Lousã, Quinta da Alfocheira, R.F. Palhinha (LISU 40284); Estremadura: Setúbal, Arrábida, Casais da Serra, erva anual, com cerca de 50 cm, folhas onduladas, 06.VI.1979, João Paulo Lopes (LISU 139690); Ribatejo: Pancas, a sudoeste do Espanadal, linha de água

que termina no Mosqueteiro, sebe ao longo da linha de água, na periferia, erva anual com ca. de 80 cm, capítulos amarelos, 22.VII.1982, M. Correia & J.

Cardoso (LISU 150967); Trás-os-Montes: Nantes, Serra da Brunheira, VI.1910, Dr. R. Palhinha, H. Navel e F. Mendes (LISU 40337)

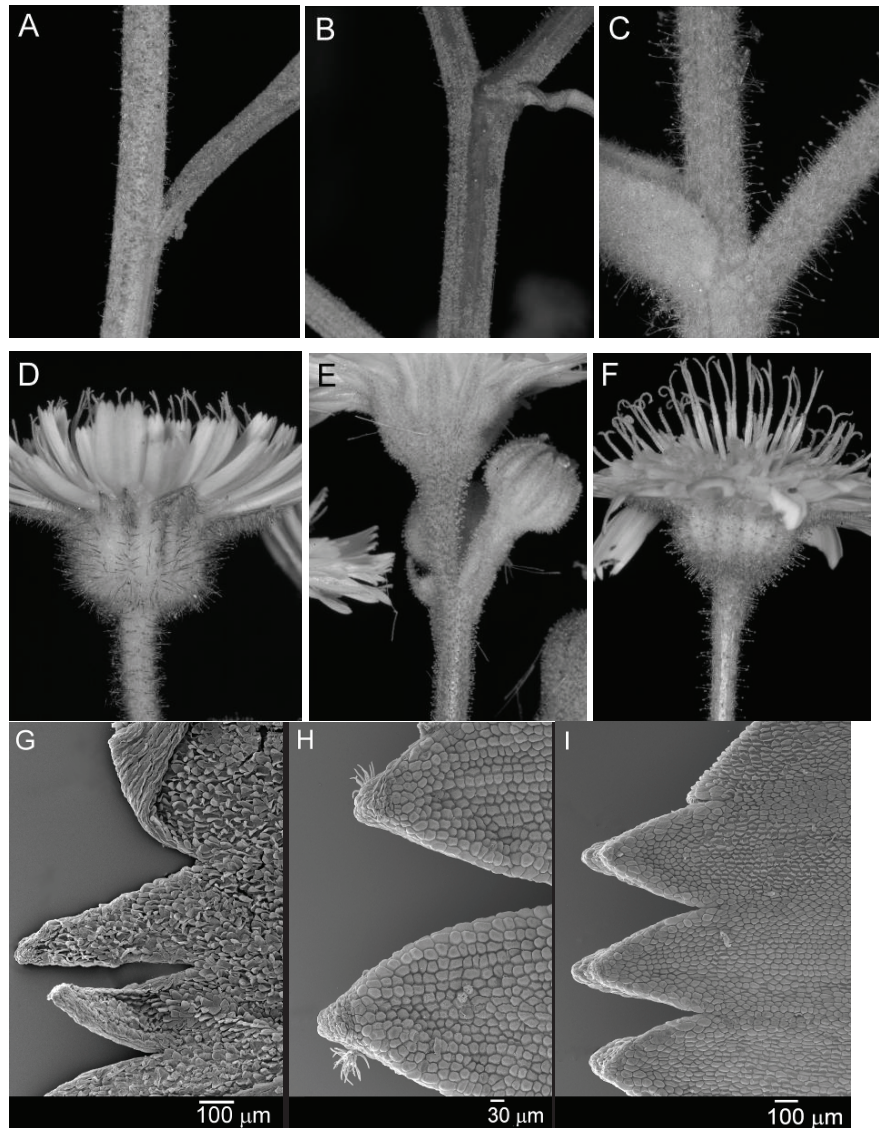


Figure 1 - Stem: A - *A. integrifolia*; B - *A. crithmifolia*; C - *A. glandulosa*
 Peduncle: D - *A. integrifolia*; E - *A. crithmifolia*; F - *A. glandulosa*
 Teeth of the ligules: G - *A. integrifolia*; H - *A. crithmifolia*; I - *A. glandulosa*

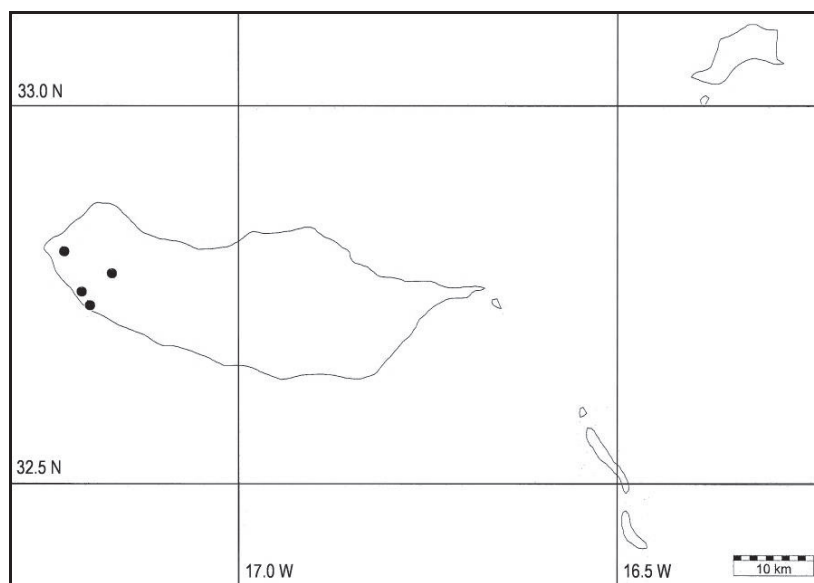


Figure 2 - Distribution area of *Andryala integrifolia* in Madeira



Figure 3 - *A. integrifolia* (to the left), *A. glandulosa* (to the right)

SPAIN. Canary Islands: San Andrés, El Pinar (El Hierro), borde carretera, 28.III.2004, Miguel António Padrón Mederos (TFC 45089); Canárias: Vega de S. Mateo, Matazano (Gran Canária), en eriales de cultivos abandonados y zonas de pastoreo de las medianías altas, 23.V.1999, A. Marrero (MA 632723); Burgos: cercanías de Huidobro, paramera caliza, 22.VII.1984, Galán Cela & A. Martín (MA 639931); Cantabria: Valderredible, Ruijas, cuneta, 780 m, 29.VI.2000, M. Pardo de Santayana (MA 726270); Madrid: Sierra de Guadarrama, Collado Mediano, 26.VI.1995, M.A. Carrasco & S. Pajarón (MA582315).

Discussion

AITON (1789) assigned *A. integrifolia* to South Europe and considered two *Andryala* species for Madeira, both endemic: *A. crithmifolia* Aiton and *Andryala cheiranthifolia* L'Hér. (presently included in *A. glandulosa*). Likewise, no references to the presence of *A. integrifolia* in the Madeira archipelago are found on the basic floras by LOWE (1868), MENEZES (1914), PRESS & SHORT (1994) and VIEIRA (2002), neither do JARDIM and MENEZES DE SEQUEIRA (2008) make any allusion. Thus, *A. integrifolia* can be considered a new alien species in Madeira.

According to DAISIE [Delivering Alien Invasive Species Inventories for Europe (<http://www.europe-aliens.org/>)], *A. integrifolia* is considered an alien species in Austria (not established) and the Azores (established). Alien plants are those whose presence in a given area is due to human involvement, or which have arrived there without people's intervention from an area in which they

are alien (PYŠEK *et al.*, 2004). These can become naturalized if they sustain self-replacing populations for at least 10 years without direct intervention by people (or in spite of human intervention) by recruitment from seed or ramets capable of independent growth. Naturalized plant species acquire an invasive status when producing reproductive offspring, often in very large numbers, at considerable distances from the parent plants, thus exhibiting potential to spread over a large area (PYŠEK *et al.*, op cit.).

Invasive species can alter the evolutionary pathway of native species by niche displacement, competitive exclusion, hybridization, introgression, and ultimately extinction (MOONEY and CLELAND, 2001). Invasive plants can displace native species through propagation abilities, soil chemistry alteration, allelopathic effects, competition for nutrients, water, etc (GLEADOW and ASHTON, 1981; D'ANTONIO and MAHALL, 1991; BAARS and KELLY, 1996; CLEVERLY *et al.*, 1997; FOGARTY and FACELLI, 1999; CORDEIRO and SILVA, 2003; VAN DEN BOSCH *et al.*, 2004; ASNER and VITOUSEK, 2005; BOLAND, 2006; REASER, 2007; NIU, 2007; SILVA *et al.*, 2008; GALLO *et al.*, 2008; BOWMAN, 2008; CONSER and CONNOR, 2009).

Natural hybridization can increase genetic diversity at both the population and species level, and new species can be derived through this process (GALLEZ *et al.*, 1982; RIESEBERG, 1991a; ARNOLD, 1993; WANG *et al.*, 1994; MENEZES DE SEQUEIRA and CASTROVIEJO, 2007; SHERMAN and BURKE, 2009). However, hybridization due to the introduction of non-native species can threaten the

genetic integrity and persistence of native species (KRAHULCOVÁ *et al.*, 1996; GALLAGHER *et al.*, 1997; ANTTILA *et al.*, 1998; HUXEL, 1999; VILÀ *et al.*, 2000; ABBOTT *et al.*, 2003).

There is increasing evidence that invasive alien species have become the most significant driver of population declines and species extinction in island ecosystems (VITOUSEK *et al.*, 1987; SMITH and TUNISON, 1992; REASER, 2007). The fairly recent, deliberate introduction of alien plants in Macaronesia has unfortunately meant considerable changes to the landscape during the 20th century and in some cases also meant a threat to the very survival of native types of vegetation (SJÖGREN, 2000). In the Canary Archipelago, the total of alien vascular plants species is about 701, of which 82 are invasive (ACEBES GINOVÉS *et al.*, 2010). While in the Azores no less than 60% of the vascular plant taxa is non-indigenous (SILVA and SMITH, 2004), in the archipelagos of Madeira and Selvagens about 33.3% of the vascular flora is introduced (JARDIM and MENEZES DE SEQUEIRA, 2008).

The introduction of new plant species in Madeira seems to continue at a strong rhythm, and, apart from *A. integrifolia*, *Solidago chilensis* Meyen (GONÇALVES SILVA *et al.*, 2008) and *Viburnum tinus* L. (SILVA *et al.*, 2009) were recently detected. The introduction of *A. integrifolia* will certainly not have the same impact as some phanerophytes (e.g. *Acacia mearnsii* De Wild) have in the Madeiran landscape and ecosystems. Although the ecological impacts are expected to be negligible, the possible hybridization with endemics (*A. crithmifolia* and *A. glandulosa*) could lead to a biodiversity loss. The fact that there are several records of hybridization

within *Andryala*, with *A. integrifolia* as one of the parental species, contributes to raise concerns in this matter. For instance, KUNKEL (1978) described the hybrid *x Andryala christii* Kunkel (= *A. integrifolia* L. x *A. pinnatifida* Aiton) for Gran Canaria. MAIRE (1926) described an algerian hybrid, *x Andryala faurei* Maire (= *Andryala arenaria* Boiss. et Reut. x *A. integrifolia* L.), considering it closer to *A. integrifolia*, which indicates that breeding probably resulted from pollination by this parental species. Later MAIRE (1937) described a new hybrid for Algeria: *x Andryala dichroa* Maire (= *A. integrifolia* L. x *A. laxiflora* Salzm.), which is closer to *A. laxiflora*, although the male parent is again *A. integrifolia*. Besides, *A. glandulosa* and *A. integrifolia* are both diploids with $2n=18$ (DALGAARD, 1985; IZUZQUIZA, 1988), and therefore hybridization is quite possible. Hybridization is even more feasible at Ponta do Pargo, where *A. integrifolia* co-exists with both subspecies of *A. glandulosa*.

Hybridization and subsequent introgression between abundant exotic taxa and rare native congeners can promote extinction of the latter (RHYMER and SIMBERLOFF, 1996; LEVIN *et al.*, 1996; WOLF, 2001). Small insular populations are particularly vulnerable to extinction by hybridization (RIESEBERG, 1991b; LEVIN *et al.*, 1996; MOONEY and CLELAND, 2001). In Madeira the populations of *A. crithmifolia* occur only in a few sites and are numerically small. Hence, the probability of extinction of this critically endangered endemism may be increased by hybridization with *A. integrifolia*, encase this congener becomes a widespread species invading areas where populations of *A. crithmifolia* occur.

All the well-documented examples of invasive alien plants around the world, and especially on islands, clearly show that most of them constitute a serious conservation issue. Alien species may stay at a fairly low population size for years and then explode at some later date. This so-called lag effect may simply be the result of the normal increase in size and distribution of a population (MOONEY and CLELAND, 2001; e.g. *Lantana camara* L. in Galapagos Archipelago, TYE, 2001). *A. integrifolia* is fully naturalized in Madeira, and may become a conservation problem in a near future. It is currently growing in western localities of Madeira Island, but it may be going through a time-lag effect and the possibility of it becoming invasive must not be discarded. The fact that *A. integrifolia* was recently found on another Azorean island shows that its spreading ability should not be underestimated.

In order to implement efficient control methods, it is essential to understand how alien plants affect native vegetation. Relatively to *A. integrifolia* in Madeira, the impacts may seem insignificant when compared to other alien plants, but the strong possibility that two endemic *Andryala* species can be threatened by the presence of *A. integrifolia*, justifies the need of constant monitoring, since naturalized species can reach an invasive status replacing even endemisms. An early eradication at the sites where it co-habits with *A. glandulosa* could help prevent hybridization and inherent consequences.

Globalization facilitates the spread of invasive alien species as international commerce develops new trade routes, markets, and products (MEYERSON and MOONEY, 2007). By trade, transport,

travel and tourism, invasive alien species are introduced through various pathways, which can be intentional or unintentional (BURGIEL *et al.*, 2006). Some major pathways of introduction for alien plants are forestry, seed contaminant, feral crop, horticulture, hitchhikers, and ornamental (HULME *et al.*, 2008). The introduction of *A. integrifolia* L. in Madeira was most likely unintentional as a by-product of trade either as seed contaminants or accidental hitchhikers attached to vehicles or machinery. The increasing global rate of road construction is leading to a parallel increase of areas of degraded soil conditions and steep slopes that need revegetation. Hydro seeding with commercial seeds of fast-growing grasses and legumes is a common practice in revegetation of motorway slopes (MATESANZ *et al.*, 2006). In Madeira *A. integrifolia* grows on roadsides, and since road construction and road use are disturbed habitats related to weed proliferation (FORCELLA and HARVEY, 1983), another plausible explanation for the introduction of *A. integrifolia* is the hydro seeding of the roadsides with seed mixtures including alien species. Hydro seeding is a good method of revegetation as long as local species are used instead of the available commercial species (TORMO *et al.*, 2007). To impede further introductions of *A. integrifolia* in Madeira, a special attention should be given to seed and plant trade, bearing in mind that the success of restoration by hydro seeding dwells in the selection of native species from the local flora that are more able to overcome the specific limitations of the disturbed area to be restored (BOCHET *et al.*, 2009).

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