Journal für Kulturpflanzen, 62 (10). S. XXX–XXX, 2010, ISSN 0027-7479 Verlag Eugen Ulmer KG, Stuttgart

Originalarbeit

Miguel A.A. Pinheiro de Carvalho[1], Humberto Nóbrega[1], Lothar Frese[3], Gregório Freitas[1], Uriel Abreu[2], Graça Costa[1], Susana Fontinha[2]

Distribution and abundance of *Beta patula* Aiton and other crop wild relatives of cultivated beets on Madeira

Verbreitung und Abundanz von *Beta patula* Aiton und anderen mit Kulturrüben verwandten Wildarten auf Madeira

Abstract

In the Archipelago of Madeira four crop wild relatives of beets are native: *Beta patula*, *Beta vulgaris* subsp. *maritima*, *Patellifolia procumbens*, and *Patellifolia patellaris*. All species are valuable genetic resources for the sugar beet breeding. Only in the very eastern part of the Madeira Island on the islet Ilhéu do Desembarcadouro and Ilhéu Chão the endemic species *Beta patula* can be found. On both islets the plant number of this very rare species, and of the two widely distributed species *B. vulgaris* subsp. *maritima* and *P. procumbens* was established and the habitat described. The results of the species census are presented. The establishment of a genetic reserve for *Beta patula* is suggested in this paper with the objective to protect this species more effectively.

Key words: Archipelago of Madeira, Crop Wild Relative, *Beta patula*, *Patellifolia*, distribution, genetic resource, beet breeding, genetic reserve, in situ conservation

Zusammenfassung

Auf Madeira und benachbarten Inseln sind vier mit Kulturrüben verwandte Wildarten heimisch: *Beta patula*, *Beta vulgaris* subsp. *maritima*, *Patellifolia procumbens*, und *Patellifolia patellaris*. Alle Arten sind wertvolle genetische Ressourcen für die Zuckerrübenzüchtung. Die endemische Art *Beta patula* kommt nur im östlichen Teil von Madeira auf den Schären Ilhéu do Desembarcadouro und Ilhéu Chão vor. Auf beiden Schären wurde die Anzahl der Individuen dieser sehr seltenen Art sowie von zwei weiter verbreiteten Arten, *B. vulgaris* subsp. *maritima* und *P. procumbens*, ermittelt und ihr Lebensraum beschrieben. Die Einrichtung eines genetischen Schutzgebietes für *Beta patula* wird in diesem Beitrag vorgeschlagen, um diese Art effektiver schützen zu können.

Stichwörter: Madeira, *Beta patula*, *Patellifolia*, Wildarten, Verbreitung, genetische Ressourcen, Rübenzüchtung, genetisches Schutzgebiet

Introduction

Crop wild relatives (CWR) are considered a very important component of plant biodiversity due to their role as genetic resource for plant breeding. According to Maxted et al. (2006) "*A Crop Wild Relative is a plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop; this relationship is defined in terms of the Crop Wild Relative belonging to gene pools 1 or 2, or taxon groups 1 to 4 of the crop.*" In the past crop wild relatives have neither been in the focus of the nature conservation community nor sufficiently considered by the plant genetic resources for food and agriculture conservation sector and tended therefore to fall through the cracks (Maxted, 2000) of biodiversity and agrobiodiversity conservation programmes.

Institute
ISOPlexis Germplasm Bank, Biotechnology and Genetic Resources Group, Funchal, Portugal[1]
Biodiversity and Environmental Group, CEM, University of Madeira 9000-390 Funchal, Portugal[2]
Julius Kühn Institute – Federal Research Centre for Cultivated Plants, Quedlinburg, Germany[3]

Correspondence
Dr. Lothar Frese, Julius Kühn Institute – Federal Research Centre for Cultivated Plants, Erwin-Baur-Str. 27, 06484 Quedlinburg, Germany. E-Mail: lothar.frese@jki.bund.de

Accepted
January 2010

Within the framework of the European Cooperative Programme for Plant Genetic Resource (ECPGR) a task force addressed this fact (Laliberté et al., 2000) and initiated the EU research project PGR Forum. The project team developed *in situ* conservation methodologies, techniques and tools to further the *in situ* conservation of crop wild relatives in Europe (Maxted et al., 2006). Jain (1975) stressed the need for conservation of wild relatives of domesticated species in genetic reserves. However, until recently only few countries have specifically allocated area to secure CWR in situ. A widely known exception is the Amiad nature reserve dedicated to the in situ conservation of wild emmer wheat (Kaplan, 2008). It took about 20 years from the launching of a specific conservation strategy by Jain until the development of the genetic reserve conservation concept by Maxted et al. (1997) who defined genetic reserve conservation as "*... the location, management and monitoring of genetic diversity in natural wild populations within defined areas designated for active, long-term conservation*". This conservation technique is described in detail by Iriondo et al. (2008) and forms an important element of the *in situ* conservation strategy nowadays.

The project "An integrated European in situ management work plan: implementing genetic reserves and on farm concepts (AEGRO)" is a follow-up of the PGR Forum project. The genus *Beta* including its former section *Procumbentes*, now named genus *Patellifolia*, is one of the four model taxa used by the AEGRO team to test the genetic reserve concept in practice. *Beta patula*, an endemic species of the flora of Madeira, was selected as model species (Fig. 1).

The Portuguese archipelago of Madeira is located in the Atlantic Ocean, 630 km West of North Africa and 900 km southwest of the Iberian Peninsula. The region of Ponta de São Lourenço with its islet Ilhéu do Desembarcadouro (Fig. 2a and b) forms the eastern part of the main island. The Desertas Islands consist of three islets, Ilhéu Chão (Fig. 3), Deserta Grande and Bugio. These are located at approximately 25 km southwest of Madeira. The Selvagens Islands located 280 km south of the main island complete the archipelago.

Ponta de São Lourenço and the Desertas Islands have similar ecological conditions. According to historical and geological data both ecosystems have appeared after the Würm glacial periods between 75,000 and 10,000 years ago (Goodfriend et al., 1996; Klügel et al., 2009). The archipelago of Madeira harbours a vascular flora composed of more than 1800 species, including native and introduced taxa as well as crop species. The vegetation of the Ilhéu do Desembarcadouro and the Ilhéu Chão islet is adapted to semi-arid conditions characterized by a high deficiency in precipitation. Rainfall occurs mostly between October and December while the summer is dry.

Ponta de São Lourenço is a straight and deeply eroded peninsula, being the result of intense marine erosion, in particular along the north eastern coast. In a geological context, it is characterized by a predominating distribution of basaltic pyroclastic deposits, from Strombolian and phreatomagmatic eruptions, lava flows, and intensively dike swarm (Klügel et al., 2009) oriented with the island's east western rift zone. According to Zbyszewski et

Fig. 1. *Beta patula* Aiton: green plants on the photo.

Fig. 2a and b. View of the Desembarcadouro islet, a protected area of the Natural Park of Madeira and a site of Natura 2000 Network where the majority of *B. patula* plants occur. Fig. 2a depicts the rocky relief.

Fig. 3. View of Ilhéu Chão, one of the three Desertas Islands, a nature reserve and a site of Natura 2000 Network where one of the two known *B. patula* occurrences grow. On the left part Ponta de São Lourenço is visible at the horizon.

al. (1975) and Goodfriend et al. (1996), observed sediments are interpreted as Quaternary eolian sand dunes of 40 m magnitude whose materials were deposited during the Würm glacial period. Klügel et al. (2009) also noted that the Ilhéu do Desembarcadouro is consisting of lapilly tuff with subordinate spatter and spindle bombs. A predominance of lava flows with a low percentage (3–5%) of titaniferous augite phenocrysts and 10 to 15% of olivine with a few dikes was observed.

Crop species and their crop wild relatives are frequently found side by side on the archipelago territory. Among them are the cultivated *B. vulgaris* L. subsp. *vulgaris* Leaf Beet Group, the closely related wild beets *B. vulgaris* L. subsp. *maritima* (L.) Arcang., *B. patula* Aiton, and the very distantly related *Patellifolia procumbens* (C.Sm. ex Hornem) A.J. Scott, B.V. Ford-Lloyd & J.T. Williams as well as *P. patellaris* (Moq.) A.J. Scott, B.V. Ford-Lloyd & J.T. Williams (Press, 1994; Jardim and Sequeira, 2008). Madeira and the genus *Beta* were chosen as model for four reasons. Firstly, the very few *B. patula* accessions maintained in gene banks probably originate from collections made by Coons in 1935 (Coons, 1975) and were received by the United States National Plant Germplasm System in October 1937. Most of them are no longer available (http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1810058, queried on 03-Aug-2009). Secondly, one accession of *B. patula* (BETA548, IPK Genebank, Gatersleben, former BGRC35290) was screened for Beet Mild Yellowing Virus resistance within the framework of the EU project GENRES CT95 42 (Council Regulation 1467/94) and described as resistant by Luterbacher et al. (2004). Thirdly, the exact distribution of the species and its conservation status was unknown. Fourthly, working with a species endemic to Madeira would allow the straightforward identification of a site suited to establish a genetic reserve. Hence, there were good reasons to select *B. patula* as a model species and, consequently, the archipelago of Madeira as one of the AEGRO model regions.

On the main island of Madeira, *B. patula* is confined to Ilhéu do Desembarcadouro at the Ponta de São Lourenço. Ilhéu do Desembarcadouro is an uninhabited islet with a length of 1.95 km and a width of 0.43 km in its largest and 0.06 km in narrowest part. In the Desertas Islands, the species is confined to the islet Ilhéu Chão, also an uninhabited area of approximately 0.5 km^2. The access to this table-like shaped islet, raising about 80 m above sea-level, is difficult. It is the most northern and the smallest of the Desertas Islands, located about 11 nautical miles southwest from Ponta de São Lourenço with its islet Ilhéu do Desembarcadouro. In both islets the vegetation is largely made up of annual and biennial herbaceous plants, which are joined by a sparse cover of bushes. The plant cover of Ilhéu Chão can be described as grassland on coastline (Anonymous, 2008) and includes habitats such as cliffs with endemic Macaronesian coastal flora. Low *Euphorbiaceae* formations can be encountered on cliffs (Anonymous, 1992; Fontinha and Carvalho, 1995).

In its natural habitat *B. patula* behaves as biennial plant with stems reaching up to 30 cm, branching freely from the base, the branches spreading or ascending. The species is self-fertilising but out crossing is easily possible (Letschert, 1993). The glomerules are composed of seven flowers on average. At seed maturity the seed balls of *B. patula* contain the highest number of seeds compared to all *Beta* species (Letschert, 1993).

For Ilhéu do Desembarcadouro as well as for the entire Ponta de São Lourenço peninsula, there are historical records of human attempts of colonization during the last five centuries (Silva and Meneses, 1984). However, the human use seemed to be sporadically and discontinuously. More recently, in 1982, the Desembarcadouro islet and later in 1995 the Desertas Islands obtained protection status as nature reserves. Thus, *B. patula* has a good legal protection status since its distribution area coincides within the area of the Madeira Natural Park. The areas of Desembarcadouro and Chão islets belong to the Natura 2000 Network and have nature reserve protection status. Nevertheless, the knowledge about its exact distribution pattern and population structure is limited.

The genetic variability within the species has never been investigated with original material. Since the collection of the material by Coons in the 1930 s, it has been regenerated at least several times, and small quantities of seeds were exchanged as research material between germplasm collections in Europe and the USA during the past decades. Letschert (1993) used 10 allozymes to investigate the genetic diversity within *Beta* section *Beta* species. At that time the only available ex situ accession of *B. patula* was IDBB6963 (parallel numbers are BGRC56782, BETA866, WB96) which was used to determine the infraspecific diversity. The genetic diversity (H_e) of *B. patula* turned out to be very low (H_e = 0.01) compared to *B. vulgaris* subsp. *maritima* (H_e = 0.28). However, in general, the genetic diversity between accessions of a self-fertilizing species is higher than the within accession diversity. Hence, the species *B. patula* as such, may contain more genetic diversity than found by

Letschert (1993). The low level of genetic diversity within IDBB6963 can be explained by a genetic bottleneck caused by a low number of plants sampled during collecting mission or by low effective population sizes during seed regeneration causing genetic drift. Research is needed to determine the genetic diversity present within the species. Therefore, during the inventory of the species leaf samples were harvested with the objective to investigate the spatial pattern of genetic diversity of *B. patula* at a later stage of the research work.

The paper presented here describes the results of the first census of *B. patula* and its allied species *B. vulgaris* subsp. *maritima* and *P. procumbens* on two sites on Madeira. A set of field trips were undertaken to determine the species' geographic distribution pattern and plant number by taxon and site. The establishment of a genetic reserve for *B. patula* is our ultimate aim.

Methods

The geographic and biological terms used in this publication are defined as follows:

- Region. A larger area such as Madeira
- Area. A fraction of a region
- Site. A fraction of an area where a target species is growing
- Plot. A defined surface within a site
- Distribution area. Total area where the species is known to exist.
- Patch. Group of individuals spatially separated from another group of the same species
- Sampling plot. Marked, fixed place where the species is growing.

From November 2007 to May 2008 there were around 16 field trips to Ilhéu do Desembarcadouro. The first objective was to describe the geographic distribution pattern for *B. patula*, *Beta vulgaris* subsp. *maritima* and *P. procumbens*. In a first round the distribution of each species was approximately established along transects. As the occurrence of *Beta* species proved to be discontinuously, areas with a significantly large number of plants were marked. Every area has a small barrier or discontinuity that separates it from the adjacent.

Whenever plants of a given species were found, the approximate location was marked on a military map. In a second round leaf samples were collected for genetic studies. At a later stage, our concern was to determine the ecological conditions, soil parameters, such as moisture, organic matter and pH-value of each of the areas. To do so the islet was divided in six areas (A1 to A6) based on species distribution, relief variation and soil distribution according to the soil map. Mean annual precipitation and temperature data were collected from the Meteorological Institute and cartographic data bases (Anonymous, 2007).

On Ilhéu do Desembarcadouro the preliminary survey was conducted along four parallel linear transects, which crossed the islet from east to west, to describe the distribution of *Beta* species and the location of plant patches. These linear transects were separated by about 75 m breadthwises of the islet and less than 40 m lengthwise with a total length of about 1.95 km.

Inside the areas where *B. patula*, *B. vulgaris* subsp. *maritima* and *P. procumbens* were growing, sampling plots with a size of 4 m^2 have been set up, at a minimum distance between them of approximately 40 m, and used for plants census and sampling. For pragmatic reasons, this work was performed on Ilhéu do Desembarcadouro, only. The plant counting was made twice across the area; the counting results were recorded and compared. If both counts were significantly different a re-count was made. Final specimen counts represent the average results of two separate counts per site. Each sampling plot was also marked with a coloured steel rod and a geographic coordinate was taken with the help of a Geographic Positioning System (GPS) to facilitate the identification and retrieval of the plots for future monitoring.

Soil samples were taken after the establishment of the plant distribution and plant counting. Soil samples were collected from the 20 cm top soil layer as part of a standard procedure of the ISOPlexis gene bank. The areas for soil sampling were defined independently of plant patches. Areas A1 to A6 are defined based on soil structure and relief. Within these areas the soil samples were taken from various places (on average of 10 to 20 sampling places) within the limits of a given area. Small soil samples of approximately 100 gr were taken every 30 meters and assembled and blended.

As far as possible all field data including the species census, plant and soil samples have been georeferenced for mapping and GIS (Geographical Information System) analysis.

Leaves of individual *Beta/Patellifolia* plants were sampled to gather DNA probes for genetic analysis with SSR markers. This work was done by three collectors to speed the sampling process, since locating plants in the field having sufficient leaves mass sometimes proved very difficult. Therefore most of the sampled individual plants lack geographic coordinates as only a single GPS was available to the team. To facilitate management, data treatment and their representation in view of maps using the ESRI software (ArcINFO 9.2) was deployed. A database has been created with the purpose of supporting the data documentation, retrieval, analysis and graphical presentation of results. The database collects vector data from (Anonymous, 2003), namely for soil type, precipitation, temperature and altimetry (Anonymous, 2007), raster data from DRIGOT (Remote Sensing Images – Orthophoto – 1:17.000) and from the Military Geographic Institute (Military Based-model Cartography – 1:25.000). Additionally, to analyse and determine the geographical zonation/distribution and the correlation between the soil samples and soil covered areas, we have vectorized the data from Madeira Island Soil Map (1:50.000) (Ricardo et al., 1992). This project applies the soil classification system established by FAO/UNESCO (1988).

Results

The first field mission confirmed that three wild beet species occurred on the Desembarcadouro and the Chão islet (Tab. 1 and 2). *B. patula* was not found on Ponta de São Lourenço and Ilhéu do Foral which are very close to the Desembarcadouro islet. Since Ilhéu Chão proved to be very difficult to access, further field work was focussed on the Desembarcadouro islet. Seeds collected during these field missions have been included in the ISOPlexis germplasm collection and can be used for future evaluation work and genetic studies.

Ilhéu Chão has a unique landscape compared to the other Desertas islands. It is a flat plateau, rising from 65 to 99 meters above sea level, without relief barriers which could shape the spatial distribution pattern of *B. patula*. Nevertheless, *Beta patula* and *P. procumbens* have been found on a single site only, where all three species, i.e. *B. patula*, *B. vulgaris* subsp. *maritima* and *P. procumbens* were growing. Sometimes plants of different species were found a few centimetres apart. The map (Fig. 4) illustrates the site on the Chão islet. The number of individuals of all species was found to be low with *B. patula* being the most abundant one.

The highest number of wild beet plants was detected in the Desembarcadouro islet (Tab. 2). Compared to Ilhéu Chão the relief in the Desembarcadouro islet is more variable ranging from 0 to 104 m asl in the highest place.

Tab. 1. Results of the field work on Ilhéu Chão. Number of plants counted and sampled

Species	Location	Site	Census counts	Sampled individuals
Beta patula	Ilhéu Chão	Site 1	134	134
Beta vulgaris subsp. *maritima*	Ilhéu Chão	Site 1	42	42
Patellifolia procumbens	Ilhéu Chão	Site 1	22	22

Tab. 2. Results of field work on the Desembarcadouro islet. Number of plants counted and leaf probes sampled

Species		*B. patula*	*B. vulgaris* subsp. *maritima*	*P. procumbens*
Location	Census Site	Counts and samples		
Desembarcadouro islet	A1	3	23	29
	A2	19	63	38
	A3	68	47	24
	A4	223	30	38
	A5	64	30	28
	A6	38	–	–

The mean annual temperature is higher than 18°C; the annual maximal rainfall is less than 800 mm (Fig. 5), with a mean annual rainfall estimated at ca. 400 mm, an average monthly temperature of 16 to 18°C, dry weather, with a high percentage of relative air humidity (60–70%) and a strong influence of salinity. Clay is the prevailing soil type, the soil is rocky, poor in organic matter, of low soil moisture, the pH-value near to neutral and the salinity is high. (Tab. 3).

The Desembarcadouro islet can be roughly divided in three different soil units: Haplic calcisoils, Eutric accident soils, and Eutric rocky soils (FAO, 1988). Based on collected information the islet can be segmented in six areas as displayed in Fig. 6.

The distribution pattern of *B. patula* was identified by searching for plant patches along linear transects. Plants have been encountered in six major areas across the Desembarcadouro islet. In these areas the wild beet taxa showed a patchy distribution pattern. The size of the areas containing *B. patula* plants is shown in Tab. 3 and displayed in Fig. 7a. The abundance of *B. patula* is shown in Fig. 7b.

B. patula occurred in the sites Bp-A1 to Bp-A3 which are characterized by the haplic calcisoil type. Within the sites Bp-A2 and Bp-A3 *B. patula* is distributed continuously. The remaining *B. patula* patches were found on Eutric accident soil and Eutric rocky soil units, respectively. The Bp-A4 site showed the highest species diversity, merged with Bp-A3 in the east side and with Bp-A5 in the west side. However, in site Bp-A4 *B. patula* showed a fragmented distribution, presumably as a result of the relief and vegetation barriers. The Bp-A1 and Bp-A6 are very well separated *B. patula* patches localized in both ends of the Desembarcadouro islet.

Fig. 4. Map of the Ilhéu Chão showing sites where *B. patula* and other *Beta/Patellifolia* species are growing.

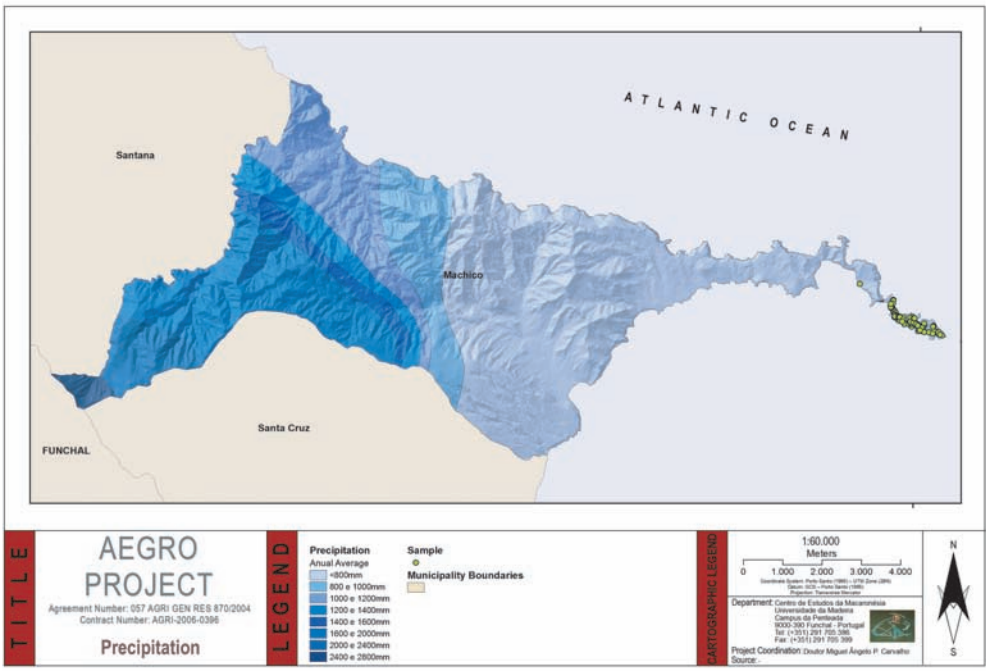

Fig. 5. Precipitation map of the very eastern part of Madeira including the Desembarcadouro islet and sampling sites of wild relatives of cultivated beets.

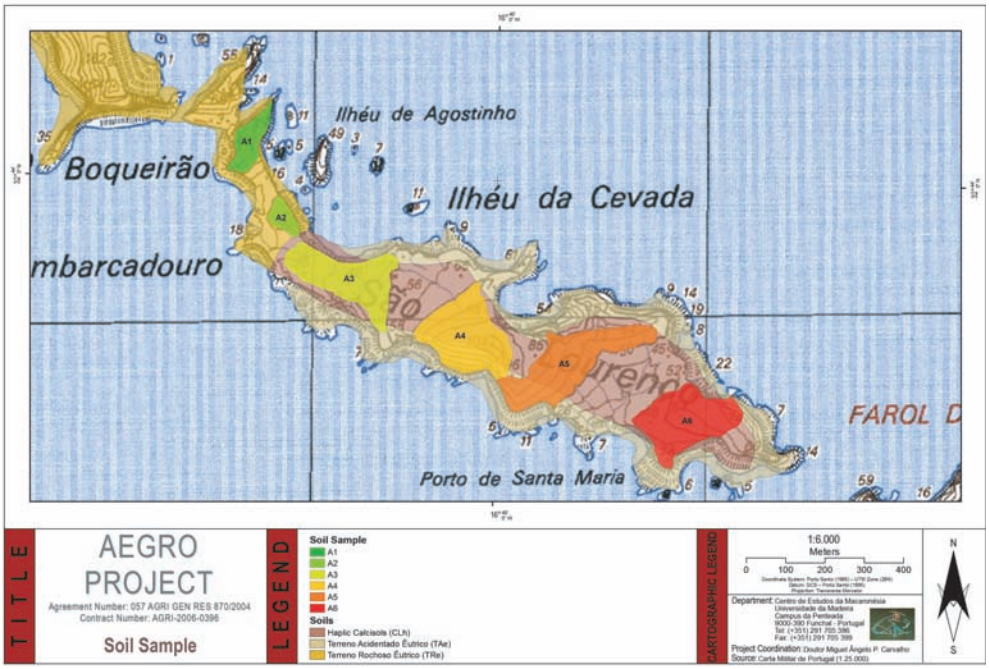

Fig. 6. Soil map of the Desembarcadouro islet showing the 3 major soil types, according to FAO classification and the six areas (A1 to A6) of soil sampling.

In several of these areas *B. patula* shares the habitat with other wild beet taxa. Fig. 8 shows the results of the species' census and illustrates the relative frequency of wild beet taxa in each site.

Discussion

The project has stimulated the interest of the regional nature conservation agency in the genetic reserve concept. The planned establishment of a genetic reserve for *B. patula* coincides with the local policies promoted by Madeiran nature conservation agencies to protect local and endemic resources. A genetic reserve of *B. patula* will be established which is a major result of the project.

Inventory and distribution of wild beet species on Madeira

For the first time the exact distribution of *B. patula* species has been determined and published. This is the second significant output of the project closing a knowledge gap. In addition, an inventory of *B. vulgaris* subsp. *maritima* and *P. procumbens* occurrences on the Archipelago of Madeira was produced which is also new.

Tab. 3. The table presents the observed area with *B. patula* patches. The pH and Aluminium content on soil were sampled for each of the area. The pH values were obtained through the KCl method, and Aluminium determination was made using the Morgan reagent or KCl as extractants

Site designation	Area, m^2	pH	Al^{3+}, $cmol.kg^{-1}$	Al^{3+}, $cmol.kg^{-1}$
A1	235.0	7.49	0.28	0.005
A2	921.0	7.18	0.52	0.018
A3	4,554.0	5.88	0.11	0.003
A4	46,298.0	5.93	0.13	0.003
A4'	396.0	–	–	–
A4''	18,747.0	–	–	–
A5	31,135.0	7.10	0.30	0.009
A6	2,143.0	6.93	0.19	0.026

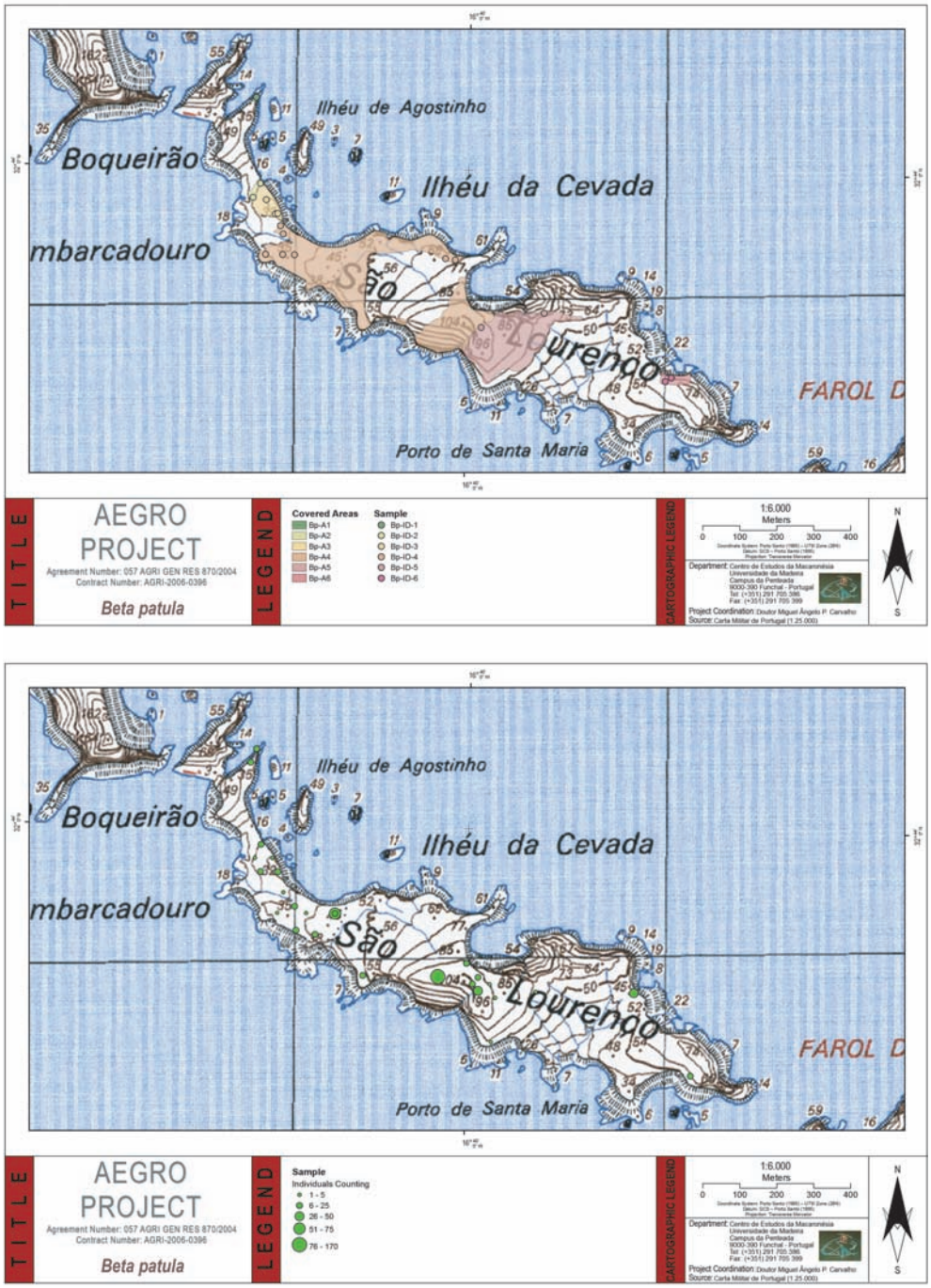

Fig. 7a and b. Maps of the Desembarcadouro islet showing the distribution area of *B. patula* (Bp-A1 to Bp-A6) (7a) and number of *B. patula* plants at the sites (7b).

Fig. 8. Map of the Desembarcadouro islet showing the spatial distribution and relative frequency of wild relatives of cultivated beets.

These missions have shown that three out of four beet taxa vaguely known to occur on the Archipelago of Madeira are indeed present on the Desembarcadouro as well as the Chão islet; the exception is *P. patellaris*, which occurs only in the Selvagens Islands (Press, 1994). On the Chão islet, *B. patula* occurs on a single site, geographically isolated from the majority of plants growing on the Desembarcadouro islet (see Fig. 4).

Towards the establishment of a genetic reserve for Beta patula

Isolation by distance shapes genetic diversity in the wind pollinating *B. vulgaris* subsp. *maritima*, the widely distributed sea beet, which is closely related to *B. patula*. In contrast to the latter inbreeding is effectively prevented by three genetic systems: self-incompatibility, genetic male sterility and cytoplasmic male sterility. Transmission of pollen by wind over long distances and the distribution of seeds via sea currents contribute to gene flow between groups of plants within the distribution area (Fievet et al., 2007). These authors detected genetic boundaries at distances of more than 40 km between plant groups. In addition, gene flow is determined by the type of habitat and genetic marker system used as noted by Raybould et al. (1997) who observed stronger isolation by distance in cliff top plant groups as compared to drift line plant groups.

The biology and ecology of *B. patula* is different from the sea beet. Since *B. patula* is an inbreeding species, transmission of pollen between spatially separated plant groups may not play a significant role in gene flow compared to the sea beet. As it is not known how *B. patula* seeds are dispersed over longer distances the seed mediated gene flow between patches of this wild species cannot be assessed. However, considering the fact that the group of *B. patula* plants on Ilhéu Chão occurs on an islet which is a cliff with 80 m high almost gapless brims it seems unlikely that seeds are transported by sea currents from Desembarcadouro up to the plain level of Ilhéu Chão. Although genetic analyses still need to be performed, there are good reasons to assume that the plant group located on the Chão islet can be called a population in the sense of Kleinschmit et al. (2004). According to these authors, a group of individuals which differs spatiogenetically from other groups and forms a reproductive coherent group adapted to the environmental conditions of its growing site can be called a "population". If the population is used as a donor of seeds, in forestry one would call it a provenance.

For pragmatic reasons we will not suggest the establishment of a genetic reserve for *B. patula* on the Chão islet. According to Maxted et al. (2006) a plant species is actively managed within a genetic reserve. Since an active management of *B. patula* on the Chão islet would be difficult to perform, a genetic reserve has to be delineated on the Desembarcadouro islet. Here, the species shows a patchy distribution. Since the genetic relationships between patches are not yet established the best possible location of a genetic reserve cannot be determined at this stage of the project. For the time being, as working hypothesis, we consider plant groups Bp-A1, Bp-A2/A3, Bp-A4, Bp-A5, and Bp-A6 as populations.

After having determined the sites(s) harbouring the highest amount of infraspecific variability of *B. patula*, the target species, a site will be selected that also contains *P. procumbens*. Within this location the maximum level of in situ conservation of wild beet genetic diversity on Madeira could be obtained. The data recorded during the *B. patula* census indicate that the central area of the

Desembarcadouro islet, coinciding with the sampled sites Bp-ID-4 and Bp-ID-5, may prove to be the best place to establish a genetic reserve for this group of crop wild relatives. Our conclusion is supported by the total number of *B. patula* individuals counted in each site (Fig. 8) which is highest in the central part of the islet. The size of the area is approximately 200 m × 200 m.

Quality aspects of genetic reserve management

The quite recently launched genetic reserve expert concept is being tested by the AEGRO team during the projects' lifetime (2007–2010). No experiences are available concerning the users' expectations and the quality standards to be defined for the genetic reserve management. By definition, the active management of a genetic reserve would include the collection and distribution of plant material or seeds on request of germplasm users. The sample distribution would be similar to the sending of ex situ gene bank accessions to users who expect to receive more or less identical research material upon repeated orders at larger time intervals. If we consider a species' population within a genetic reserve similar to the provenance in forestry the maintenance of a reproductively coherent, spatiogenetically distinct group of individuals required to maintain a population with a defined set of traits over time would be an aim of the genetic reserve management, and the realization of this aim a quality feature of the genetic reserve management.

An element of the management quality is the maintenance of the genetic integrity of a *B. patula* population by preventing introgression of genes from related species including the crop types. Whether a multi-species genetic reserve can be established in the centre of the Desembarcadouro islet depends on the risk of gene flow between the target species and the associated *B. vulgaris* subsp. *maritima*. In that context *P. procumbens* needs not to be considered, as strong crossing barriers between *Beta* and *Patellifolia* prevent gene flow. The risk of gene flow between *B. vulgaris* subsp. *maritima* and *B. patula* will depend on the effectiveness of the isolation mechanism which has separated both wild beet taxa in the past. On the Portuguese mainland and Spain, *B. vulgaris* subsp. *maritima* and *B. macrocarpa* Guss. grow sympatrically and are likely isolated by flowering time (Frese et al., 1990). Further investigations are required to learn if this mechanism effectively prevents gene flow between *B. patula* and *B. vulgaris* subsp. *maritima* on Madeira.

Acknowledgements

We would like to thank the PNM (Parque Natural da Madeira), Dra. Rosa Pires, the Nature Wardens of PNM (Claudio Alves, Gil Pereira, João Paulo Mendes, Nelson Santos, Isamberto Silva and Filipe Viveiros), Paulo Costa, as well as the Portuguese Navy for the safety navigation to "Ilhéu Chão" and back to the Madeira Island. We would also like to thank DRIGOT for providing us with all the necessary maps. This work is part of Workpage 6, case study *Beta*, of the EU project "An integrated European in situ management work plan: implementing genetic reserves and on farm concepts", AGRI GENRES 057, coordinated by the Julius Kühn-Institute and co-funded by the EU Commission, DG AGRI within the framework of council regulation 870/2004.

References

Anonymous, 1992: Habitats Directive (92/43/CEE Annex I).

Anonymous, 2003: Plano Regional da Água da Madeira. Secretaria Regional do Ambiente e Recursos Naturais. Funchal. 328 pp.

Anonymous, 2007: Atlas do Ambiente. Ministério das Cidades, Ordenamento do Território e Ambiente. APA, Agência Portuguesa do Ambiente. http://www.iambiente.pt/atlas/est/index.jsp?zona=madeira&grupo=madeira.m0&tema=madeira.m0. Last visit: 2009/05/28.

Anonymous, 2008: IUCN Habitats Classification Scheme. IUCN: Habitats Authority File [http://intranet.iucn.org/webfiles/doc/SSC/RedList/AuthorityF/habitats.rtf].

Coons, H.G., 1975: Interspecific hybrids between *Beta vulgaris* L. and the wild species of *Beta*. Journal of the A.S.S.B.T. **18**, 281-306.

FAO/UNESCO, 1988: Soil Map of the World. Revised Legend. World Soil Resources Report 60. Food and Agriculture Organization of the United Nations, Rome.

Fievet, V., P. Touzet, J.-F. Arnaud, J. Cuguen, 2007: Spatial analysis of nuclear and cytoplasmic DNA diversity in wild sea beet (*Beta vulgaris* ssp. *maritima*) populations: do marine currents shape the genetic structure? Molecular Ecology **16**, 1847-1864.

Fontinha, S., J.A. Carvalho, 1995: Evaluation of the Vascular Flora of Madeira's Extreme East; Boletim do Museu Municipal do Funchal, sup. **4**, 263-275.

Frese, L., E. de Meijer, J.P.W. Letschert, 1990: New wild beet genetic resources from Portugal and Spain. Zuckerind. **115** (11), 950-955.

Goodfriend, G., R. Cameron, L. Cook, M.-A. Courty, N. Fedoroff, E. Livett, J. Tallis, 1996: The Quaternary eolian sequence of Madeira: stratigraphy, chronology, and peleoenviromental interpretation. Paleogeography, Paleoenvironmental, Palaeoecology **120**, 195-234.

Heywood, V., A. Casas, B. Ford-Floyd, S. Kell, N. Maxted, 2007: Conservation and sustainable use of crop wild relatives. Agriculture, Ecosystems and Environment **121**, 245-255.

Iriondo, J.M., N. Maxted, M.E. Dulloo, 2008: Conserving Plant Genetic Diversity in Protected areas. CAB International, 212 pp.

Jain, S.K., 1975: Genetic Reserves. in: Frankel, O.H., J.G. Hawkes (eds.). Crop genetic resources for today and tomorrow. International Biological Programme 2. Cambridge, University Press, 379-396.

Jardim, R., M.M. Sequeira, 2008: List of vascular plants (*Pteridophyta* and *Spermatophyta*). in: Borges, P.A.V., C. Abreu, A.M.F. Aguiar, P. Carvalho, R. Jardim, I. Melo, P. Oliveira, C. Sérgio, A.R.M. Serrano, P. Vieira (eds.). A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens archipelagos Direcção Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Angra do Heroísmo, 13-25.

Kaplan, D., 2008: A Designated Nature Reserve for In Situ Conservation of Wild Emmer Wheat (*Triticum dicoccoides* (Körn.) Aaronsohn) in Northern Israel. In: Maxted, N., B.V. Ford-Loyd, S.P. Kell, J.M. Iriondo, M.E. Dulloo, J. Turok (eds.): Crop Wild Relative Conservation and Use. CAB International 2008, 389-393.

Kleinschmit, J.R.G., D. Kownatzki, H.-R. Gregorius, 2004: Adaptational characteristics of autochthonous populations-consequences for provenance delineation. Forest Ecology and Management **197**, 213-224.

Klügel, A., S. Schwarz, P.V.D. Bogaard, K. Hoernle, C. Wohlgemuth-Ueberwasser, J. Köster, 2009: Structure and evolution of the volcanic rift zone at Ponta de São Lourenço, eastern Madeira. Springer-Verlag, DOI 10.1007/s00445-008-0253-7.

Laliberté, B., N. Maxted, V. Negri (comp.), 2000: Report of a joint meeting of a Task Force on wild species conservation in genetic reserves and a Task Force on On-farm conservation and Management, 18–20 May 2000, Isola Polvese, Italy. Laliberté, B., N. Maxted, V. Negri (comp.). Bioversity International, Rome, Italy, pp. 80.

Letschert, J.P.W., 1993: *Beta* section *Beta*: biogeographical patterns of variation and taxonomy. Wageningen Agricultural University Papers, 93-1.

Maxted, N., B.V. Ford-Loyd, J.G. Hawkes, 1997: Complementary conservation strategies. In: Plant genetic conservation: the in situ approach, Maxted, N., B.V. Ford-Loyd, J.G. Hawkes (eds). London, Chapmann & Hall, 20-55.

Maxted, N., 2000: Genetic reserve conservation of PGRFA in Europe. in: In situ and On farm conservation network. Report of a joint meeting of a Task Force on wild species conservation in genetic reserves and a Task Force on On-farm conservation and Management, 18–20 May 2000, Isola Polvese, Italy, Laliberté, B., N. Maxted, V. Negri (comp.). Bioversity International, Rome, Italy, 10-13.

Maxted, N., B.V. Ford-Loyd, S.L. Jury, S.P. Kell, M.A. Scholten, 2006: Towards a definition of a crop wild relative. Biodiversity and Conservation **15** (8), 2673-2685.

Press, J.R., 1994: Chenopodiaceae. In: Press, M.J., M.J. Short (eds.): Flora of Madeira. London, HMSO, 68-74.

Raybould, A.F., R.J. Mogg, C.J. Gliddon, 1997: The genetic structure of *Beta vulgaris* ssp. *maritima* (sea beet) populations: II. Differences in gene flow estimated from RFLP and isozyme loci are habitat-specific. Heredity **78**, 532-538.

Ricardo, R.P., E.M. Silva da Câmara, M.A. Melo Fereira, 1992: Carta de Solos da Ilha da Madeira. Lisboa, Governo Regional da RAM.

Stewart, D., M.K. Roane, 1980: George Herbert Coons 1885–1980. **70** (12) 1123.

Stolton, S., N. Maxted, B. Ford-Lloyd, Sh. Kell, N. Dudley, 2006: Arguments for Protection. Food Stores: Using Protected Areas to Secure Crop Genetic Diversity. Birmingham, UK, WWF – World Wide Fund for Nature.