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Seed ecology of Mediterranean hind dune wildflowers

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ABSTRACT

There is an increasing need for the landscape conservation of the threatened biodiversity of coastal ecosystems. This work studies the seed ecology (germination, dormancy, self-burial, seedlings emergence and seed bank disposition) of various Mediterranean hind dune wildflowers in a perspective of landscape protection and restoration. The deep dormancy of most species (overall Fabaceae, Brassicaceae and *Calystegia soldanella*) was eliminated or reduced after some seed treatments selected to simulate some natural events (washing, cold stratification, scarification, *etc*). "*In situ*" seed bank analysis was carried out by collecting sand samples in different dune ecosystems of Tuscany and Sardinia.

Indeed the seed vertical distribution plays a crucial role in the germination dynamics on buried seeds. The vertical distribution of the seed bank of 20 selected species was confined to the upper 0–12 cm layer of sand dune. Their burial depth was found to be inversely related to the 1000 seed weight of the different species ranging by 0.01 g of *Centaurium maritimum* to 47.58 of *C. soldanella*. Roughly 80% of the seed bank is accumulated in the shallowest sand layer (0–3 cm) and the only very little seeds of *C. maritimum* and *Silene colorata* were capable to reach the deeper layer of 9–12 cm. Seedling emergence from increasing burial depth has been studied in pots "*ex situ*". In spite of the respective seed dormancy-breaking treatments, their germination was progressively inhibited by burial depth increasing in the sand matrix. Calculation of the depth able to halve emergence established an inverse relationship between seed weight and depth-mediated inhibition. In addition, the *ex situ* capacity for self-burial (mediated by winter rains), ranging between 1 and 3.5 cm, showed a similar, but inverse, relationship between seed weight and self-burial performance. Seed bank of herbaceous perennial species appears to be a good indicator of an ecosystem's health and the perspective of environmental restoration, by using native wildflowers, should be carried out by sowing treated seeds, with a light burial, behind the natural or artificial foredunes.

1. Introduction

Coastal dune systems are characterized by strong environmental gradients which determine the coexistence of different plant communities in a relatively small area (Wilson and Gitay, 1995). Unfortunately, many species in this highly biodiverse environment (Grootjans et al., 2004), are threatened by both the reduction of these particular habitats and their anthropogenic alteration (Brown and McLachlan, 2002; Defeo et al., 2009).

Bare sand and semi-fixed dunes are ideal conditions for successional young slack habitats that support rare species of coastal dune flora (Lucas et al., 2002). Open patches of these microhabitats generally have the greatest richness, diversity, and productivity of species (Yu et al., 2008). In such coastal environments setting up successful biodiversity conservation programs entails conserving "biologically rich hotspots" and also including species-poor habitats where there are endangered species or which are unique in some way (Acosta et al., 2009).

In addition to this *habitat* conservation policy, several restoration programs of dune ecosystems have been planned (Grootjans et al., 2002; Lithgow et al., 2013), sometimes carried out as natural engineering projects (Hanley et al., 2014). Non- or minimal intervention as well as totally management systems such as intensive single-species management and habitat re-creation is required when attempting to reach certain objectives in terms of conservation (Rhind and Jones, 2009).

In both cases (conservation or restoration) the study of the biology and ecology of dune species plays a crucial role. Primary importance has been given to studies on the species typically facilitate the consolidation of dunes as a consequence of their indisputable importance as stabilizers (Hanley et al., 2014). In contrast much less importance has been given to the hind dune

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Table 1
Botanical characteristics and germplasm collection site of the dune wildflowers selected for the experiments.

Species	Botanic family	Life form	Locality of seed collection	Geographical coordinates
Anchusa crispa Viv.	Boraginaceae	Hemicryptophyte	Vignola (OT)	41°13′ N, 9°11′ E
Anthemis maritima L.	Asteraceae	Hemicryptophyte	Torre Mozza (LI)	42°09′ N, 10°67′ E
Anthemis mixta L.	Asteraceae	Therophyte	Tirrenia (PI)	43°56′ N, 10°24′ E
Armeria pungens (Link) Hoff. et Lk	Plumbaginaceae	Chamaephyte	Vignola (OT)	41°13′ N, 9°11′ E
Cakile maritima Scop.	Brassicaceae	Therophyte	Castiglione della Pescaia (LI)	42°76′ N, 10°87′ E
Calystegia soldanella (L.) Roem. Et Schult	Convolvulaceae	Geophyte	Viareggio (LU)	43°86′ N, 10°25′ E
Centaurea aplolepa Moretti	Asteraceae	Hemicryptophyte	S. Vincenzo (LI)	43°11′ N, 10°54′ E
Centaurium maritimum L.	Gentianaceae	Therophyte	Vada (LI)	43°35′ N, 10°45′ E
Dorycnium hirsutum L.	Fabaceae	Chamaephyte	Marina di Vecchiano (PI)	43°80′ N, 10°26′ E
Echium arenarium Guss.	Boraginaceae	Hemicryptophyte	Capo Mannu (OR)	40°03′ N, 8°39′ E
Glaucium flavum Crantz	Papaveraceae	Hemicryptophyte	Vignola (OT)	41°13′ N, 9°11′ E
Matthiola tricuspidata L.	Brassicaceae	Therophyte	Marina di Cecina (LI)	43°27′ N, 10°50′ E
Medicago marina L.	Fabaceae	Chamaephyte	Marina di Grosseto (GR)	42°72′ N, 10°96′ E
Ononis variegata L.	Fabaceae	Therophyte	Marina di Vecchiano (PI)	43°80′ N, 10°26′ E
Pancratium maritimum L.	Amaryllidaceae	Geophyte	Follonica (GR)	42°09′ N, 10°76′ E
Scabiosa maritima L.	Dipsacaceae	Hemicryptophyte	Marina di Grosseto (GR)	42°72′ N, 10°96′ E
Scabiosa rutifolia Vahl	Dipsacaceae	Therophyte	Capo Mannu (OR)	40°03′ N, 8°39′ E
Silene colorata Poiret	Caryophyllaceae	Therophyte	Vada (LI)	43°35′ N, 10°45′ E
Silene conica L.	Caryophyllaceae	Therophyte	Castiglione della Pescaia (GR)	42°76′ N, 10°87′ E
Solidago litoralis Savi	Asteraceae	Hemicryptophyte	Marina di Vecchiano (PI)	43°80′ N, 10°26′ E

environment (immediately back to the fore dunes) in spite of its high, and often rare biodiversity. This biodiversity strongly depends on the vegetation of the foredune, since they serve as ecosystem engineers in this coastal environment, with an influence on multiple levels of biological organization (Cushman et al., 2010).

The wind is not able to carry large amounts of sand particles since the sand is protected by the shrubs, which enables the particular flora evolved to tolerate abiotic stresses (wind, drought, salinity) without the need for robust rooting which instead is required in the foredune in front of the sea (García-Mora et al., 1999).

This partially protected environment is the ecological niche of herbaceous species including many fixed dune wildflowers (O'Rourke et al., 2014). Many of these species have mutualism with insect pollinators (Junker and Blüthgen, 2010) thanks to the availability of pollen and nectar (Goulson, 1999) and are sometimes indispensable for the survival of rare butterfly and/or solitary bees (Pyle et al., 1981; Petanidou et al., 1998). Consequently, flower-pollinator mutualism increases the biodiversity level of these areas even more with the flora-micro-fauna threat of disappearance. In addition the landscaping impact (Provoost et al., 2011) of these beautiful hind dune wildflowers is important due to their typical chromatically eye-catching flowers.

Since these herbaceous species entrust the survival dynamics to their seeds, it follows that knowledge of their seed ecology plays a crucial role for both conservation and/or restoration. Indeed the survival dynamics of these species, in such erratic environments, strongly depends on their ability to retain, in the sand matrix, viable seeds able to re-colonize them in space and time. In this background plays a crucial role both seed dormancy and their burial capacity. This last, allow even to not dormant seeds, to acquire a "forced dormancy" (Baskin and Baskin, 2004) mediated by hypoxia (Benvenuti and Macchia, 1995). This burial-dependent germination inhibition often implies seed longevity (Thompson et al., 2003) and consequently makes less vulnerable the survival dynamics of the dune species. In this background the self-burial capacity and velocity, of each species, support a seed bank accumulation in the shallowest sand layers making the dune ecosystem capable to a dynamic re-colonization after natural and/or anthropic ecological disturbance. Despite the complexity of experimental studies dedicated to the dune environment there are few studies focused to wildflowers. Indeed the important role that many wildflowers dune take in terms of biodiversity and landscape suggested to explore even their seed ecology in both perspectives: conservation and restoration.

The aim of this work was to investigate: (i) the amount of the wildflower's seed bank and its vertical arrangement *in situ* in various hind dunes of Mediterranean ecosystems; and (ii) the seed ecology in terms of dormancy, germination, self-burial capacity, and emergence from increasing sand depths.

2. Materials and methods

2.1. Plant material and dune environments

Personal observations since 2000 on coastal flora have identified several Mediterranean dune ecosystems (in Tuscany and Sardinia) characterized by a high floristic biodiversity.

In these environments plant community surveys were conducted in order to identify species that can be defined as wildflowers. The selection criterion was to choose herbaceous wild species, common in the above cited dune environments roughly defined as "*Crucianellion maritimae*" (Del Vecchio et al., 2012), is characterized by chromatically eye-catching flowers that have evolved towards entomophilous pollination (Benelli et al., 2014). Table 1 shows the 20 selected species (nomenclature follows Pignatti, 1982) in the various areas of hind dunes. Between 2012 and 2013 (in the summer and autumn) seeds from each species were collected in the respective dune environments as shown in Fig. 1. The seeds were extracted from the senescent fruits in the

Fig. 1. Landscape of the dune environment (left hindune and right foredune) of a Sardinian site (near Vignola, OT) where sand samples for seed bank analysis were collected.