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ORIGINAL PAPER

The impact of *Pinus halepensis* afforestation on Mediterranean spontaneous vegetation: do soil treatment and canopy cover matter?

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Abstract: We investigated central Mediterranean *Pinus halepensis* plantations under semi-arid climate in order to evaluate the combined effect of soil treatment and afforestation practices on spontaneous plant species composition, richness and evenness, and on the trend and speed of vegetation dynamics. Phytosociological relevés of three different plot typologies, i.e. (1) soil-treatment and plantation, (2) only soil-treatment, (3) no soil-treatment and no plantation, were compared by (a) multivariate analysis and (b) with reference to species richness and evenness. Moreover, in order to compare vegetation dynamics within the plantations with those ones ongoing in semi-natural garrigue communities, we compared life form and syntaxonomic spectra between phytosociological relevés taken at 8 years of distance. DCA showed that floristic species composition and similarity are influenced by the canopy cover of Pine trees as well as by soil-treatment practices. Although species richness and evenness are not clearly related to neither soil treatment nor Pine afforestation, canopy cover clearly plays a major role: in fact, the highest *Ph* cover rates correspond to the lowest values of understory species richness. This is true also if only species of biogeographical/conservation interest are considered. Regarding vegetation dynamics, sites with dense Pine canopy cover evolve much slower than the adjacent garrigue communities. The same factors invoqued to explain the patterns of floristic composition and similarity (i.e. allelopathy and competition for light, water and nutrients) may also explain the lowering of diversity of therophytes and the strong decline of the cover perfomed by both therophytes and hemicryptophytes underneath the canopy of dense *Ph* plantations. Thus, in sites where *Ph* cover exceeds about 80%, thinning is recommended not only in order to accelerate succession, but also to give a natural 'shape' to afforestations.

Keywords: plant diversity; understory; vegetation dynamics; plantation

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Introduction

In the 20th century, large surfaces of the Mediterranean arid and semi-arid areas of the world have been afforested with *Pinus halepensis* Mill. (hereinafter *Ph*). These plantations were designed to fulfill a multiplicity of objectives like habitat protection, increase of forest cover, etc. (Ne'eman and Trabaud, 2000). In fact, *Ph* afforestations have been considered very effective against the deterioration of grasslands and garrigues, so they were mainly carried out in strongly disturbed and/or degraded sites where spontaneous progressive succession appeared to be very slow (Alrababah et al. 2007).

In this context, a crucial point with *Ph* afforestations is if they are able to evolve towards 'final' Mediterranean communities or not by favouring the shrubs and trees typical to the final steps of succession. Despite the opinion of some authors (e.g. Gil and Aránzazu Prada, 1993), indeed *Ph* plantations do not always show a positive or neutral role in that regard. As for the short to the medium term (i.e. within 3-15 years after planting), several recent studies suggest that *Ph* afforestations may significantly improve the environmental quality of degraded areas when substituting very scattered herbaceous or subshrub communities (Le Houérou, 2000). For example, positive trends concerning various indicators (e.g. number of plant species, total plant cover, perennial species density, soil evolution, etc.) have been recorded by Grünzweig et al. (2007) and by Jeddi and Chaieb (2010).

But if we consider longer time lapses the results are not so univocal. Several studies in the western Mediterranean Basin (e.g. Chiarucci and De Dominicis, 1995; Andrés and Ojeda, 2002) have shown that planted pine woodlands have a negative impact on the diversity of the local flora. For example, Alrababah et al. (2007) found a lower number of species with increasing *Ph* cover in a semi-arid Mediterranean area.

In addition to tree cover, also soil treatments (such as subsoiling and terracing) and silvicultural treatments (such as removal of native shrubby vegetation) could have effects on the biodiversity within *Ph* plantations, but up to now only few relevant studies have been published on the impacts of these treatments on plant diversity (e.g. Chirino et al. 2006; Fernández et al. 2010; Prévosto et al. 2011).

On the other hand, elsewhere in central Mediterranean (Liguria: Moreno et al. 1993; central Sardinia: Bianchi et al. 2002) it has been observed that artificial pine woods may enhance both succession and biodiversity if (1) they are not too dense, (2) the autochthonous species typical to the last stages of succession are favoured by shading (e.g.: *Quercus ilex*), and (3) local climatic conditions are more humid (i.e. mesomediterranean or supramediterranean).

Nowadays plantation forestry practice is under profound review worldwide (Harrington, 1999). In fact, developing the ideas of some pioneer papers on this topic (e.g. Noy-Meir, 1989), recent forest planning and management policies are ecologically-oriented. Such new addresses are even more important within semi-arid contexts (e.g. Israel: Ginsberg, 2006) and they represent a trial to apply European-wide recommendations to the Mediterranean environment (FAO, 2006; Fabbio et al. 2003).

In Italy, only recently attention has been paid on the need of re-addressing *Ph* plantations management according to modern sustainable silviculture practices, especially within protected areas. Although their effectiveness is still under lively debate, in Italy the removal of native shrubby vegetation, the mechanical terracing before strip planting or subsoiling still represent the most common soil-treatment steps preceding afforestation (Garfì et al. 2002). Instead of applying the same soil treatment as a standard, modern afforestation should use variable soil treatment practices, selected in agreement with local pedo-climatic conditions, past land use and afforestation purposes (Corona et al. 2009).

In addition to the former issues, the conservation of biodiversity of open semi-natural ecosystems is one of the priority goals of the EU environmental policy because of their high rates of species richness and species of biogeographic/conservation interest (Peco et al. 1983). Therefore, considering the need to preserve Mediterranean open semi-natural ecosystems and the ongoing debate on pre-afforestation soil treatments, our paper aims at answering the first research question: (1) do soil treatment practices and tree cover of *Ph* afforestations affect species composition and plant diversity patterns (species richness and evenness) of Mediterranean semi-natural communities?

Moreover, in order to verify if and to what extent *Ph* plantations could affect the restoring of natural semi-arid woody ecosystems by counteracting degradation, in the present paper we compared the vegetation dynamics of *Ph* plantations and garrigues. Our hypothesis was that *Ph* plantations are in a steady state and that without any silvicultural intervention (e.g. thinning) they stop local progressive succession process which should lead to its gradual substitution by autochthonous woody communities. So, our second research question is: (2) which are the vegetation dynamics within *Ph* afforestations as compared to semi-natural (garrigue) communities?

The answers to these two questions may help resource managers and decision makers to outline effective plans to better conserve, manage and restore semi-natural Mediterranean ecosystems under semi-arid bioclimatic conditions.

Materials and methods

Site description

Geography, geo-pedology and climate

Data sampling was done in the central Mediterranean island of Lampedusa (Fig. 1), which is part of the Pelagie Archipelago and is located in Sicily Strait (35°30' N; 12°36' E; ca. 20 Km^2 surface). It is characterized by gentle slopes interrupted by narrow canyons; its maximum height is 133 m a.s.l. The most common rock outcrops are limestones and marls (Grasso and Pedley, 1988).

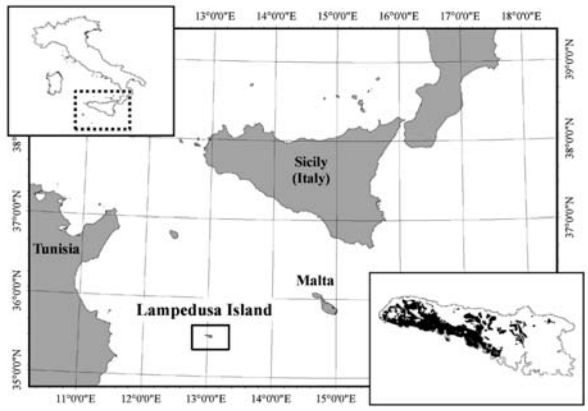

Fig. 1 Location of Lampedusa within central Mediterranean area. Upper left corner: position of Sicily within Italian territory; lower right corner: distribution of afforested areas (black) and garrigues (grey) on the island.

Local soils are characterised by the association *Lithic Xerorthents - Rock outcrop - Typic e/o Lithic Haploxerepts*. These poorly evolved soils show an 'A-R' profile, whose upper horizon is only slightly differentiated. The horizon A is rather thin (average depth c. 15 cm) with abundant skeleton and low organic matter content.

Local climate is classified as inframediterranean upper-semiarid according to that of Rivas-Martínez (2008). Average yearly temperature is about 19°C, the coldest month is February (9−14°C, never under 2°C), while the hottest one is August (24-30°C, sometimes nearly 35°C). Although extremely irregular, precipitations show a typically Mediterranean regime: in fact, they are mostly concentrated between october and march. During the last 150 years mean annual rainfall decreased from 500 mm to 300 mm; moreover, present average monthly values rarely exceed 60 mm, while drought period may last more than six months (La Mantia et al. 2011). Besides rain and overnight dew accumulation, wind regime is the third driving force of local climate. In fact, windy days are 80% per year (Chamard et al. 1998).

Vascular flora and vegetation

Because of their exceptional interest, local vascular flora and vegetation have been thoroughly and regularly investigated since Gussone (1839) till recent times (La Mantia et al. 2009): Lampedusa hosts 11 strictly endemic plants and the only Italian populations of many species with S Mediterranean, Mediterranean-Saharian and Mediterranean-Irano-Turanian distribution, which testify the repeated connections of the island with N Africa during Pleistocene. Many of these noteworthy taxa are threatened at national and regional level (Conti et al. 1997).

The history of Lampedusa's landscape is emblematic of the disruptive effect of human pressure on Mediterranean island ecosystems. In fact, during the last 170 years pre-forest and forest communities - once covering most part of the island - have been erased (Pasta and La Mantia, 2004), and today native pine communities with Aleppo pine have totally disappeared; very few and scattered spots of thermophilous maquis (alliance *Oleo-Ceratonion siliquae*) have survived and even local garrigue communities (alliance *Cisto-Ericion multiflorae*) are degraded and species-poor with respect to past times. The extreme rarity of pre-forest and forest vegetation spots heavily biases local progressive succession processes, which since about two decades are in progress in many parts of the island due to the strong reduction of grazing activities. In fact, the results of 12 years of floristic and structural investigations carried out in a permanent plot within a garrigue undergoing post-grazing succession testify the low speed of local progressive succession.

At present the most widespread woody plant community is a species-poor garrigue assemblage with *Thymbra capitata*, *Jasonia lopadusana*, *Lotus cytisoides*, *Phagnalon rupestre*, etc.. Rather common are also perennial grasslands dominated by *Hyparrhenia* and/or *Piptatherum* spp. (all. *Hyparrhenion hirtae*) and ephemeral annual prairies ascribed to the class *Stipo-Trachynietea distachyae*, very rich in species of high biogeographical interest. Due to local stress factors (summer drought, wind regime, etc.) and past disturbance (overgrazing after deforestation), even xeric grasslands are often substituted by an assemblage dominated by two poisonous stress-tolerant geophytes, *Charybdis maritima* and *Asphodelus ramosus*.

Soil treatment and afforestation practices

In order to restore succession processes and to stop soil erosion due to wind and extreme rainfall events, local afforestation activities were carried out on the above-mentioned degraded pre-forest communities. An overall surface of about 218 ha, i.e. nearly 10.8% of the whole island, has been afforested from 1967 to 1994 (Pasta and La Mantia, 2001). After some first unsuccessful experiences without soil treatments, from the late 1960s onwards subsoiling was carried out as a preliminary soil treatment before *Ph* planting, in order to crush and remove the outcropping rocks and to open furrows deep enough to allow the planting of the young trees with their root balls and to improve soil drainage. Unfortunately, these practices increased evapotranspiration, too. Moreover, young *Ph* trees were protected from wind through dry-stone walls. No thinning or pruning has been applied during the decades following plantation.

Today, most of the *Ph* plantations on Lampedusa differ largely in tree cover and density due to their uneven success rate.

Data sampling

In total, 16 sample plots differing in (1) preliminary soil-treatment and (2) *Ph* canopy cover were selected (see Table 1 for main characteristics). In six of these sites, *Ph* plantations have been carried out between 1967 and 1986, with preliminary subsoiling (hereinafter *Ph*-plots). In other 4 sites, subsoiling had been carried out as a preliminary treatment for afforestation, but no *Ph* plantation was ever realised (hereinafter *ST*-plots, as soil treatment). The remaining 6 sites are represented by natural garrigue communities (hereinafter *G*-plots, as garrigue), where neither *Ph* plantation nor subsoiling have ever been performed. Prior to subsoiling, *Ph*- as well as *ST*-sites hosted garrigue communities mixed with ephemeral and perennial grasslands degraded by sheep and goat grazing. *G*-plots shared the same plant communities up to 15 years ago, when grazing was abandoned in the sampled areas.

All sampling sites share the same aspect, soil bedrock, and a very similar altitude and slope. None of them has been influenced by recent (i.e. less than 10 years) management or disturbance events (e.g. grazing, slashing, fire).

In 2009, phytosociological relevés (Braun-Blanquet, 1932) on 100 m^2 surfaces were performed in each sample site. Relative abundance (cover) of plant species in each (tree, shrub and herbaceous) layer was recorded. Vascular plants were classified according to Tutin et al. (1964–1980, 1993) and Pignatti (1982), while their nomenclatural treatment mainly followed the checklist of Conti et al. (2005). The nomenclature of the considered phytosociological classes followed Rivas-Martínez et al. (1999).

In order to evaluate vegetation dynamics, in two *Ph*-plots and in one *G*-plot, phytosociological relevés were performed in 2002 and in 2010, respectively.

Data analysis

Species cover values of all phytosociological relevés were transformed following van der Maarel (1979). All data analyses refer to spontaneous vegetation; thus, *Ph* was deleted from the data set. All raw data used for data evaluation, including life forms (Raunkiær, 1934) and chorotypes, are reported in Appendix I.

Floristic composition and similarity

Multivariate analysis was used to identify environmental factors accounting for most of the variance within vegetation data. A data set including the 16 relevés carried out during 2009 was analysed with DCA, using CANOCO 4.0 (ter Braak and Smilauer, 2002). Downweighting of rare species was applied. The resulting axes were subsequently correlated to (1) percentage canopy cover of planted *Ph* trees, and (2) presence of soil-treatment.

Richness and evenness

Species richness and evenness (*E'*) were calculated for every sample plot. In order to calculate *E'* the formula proposed by Camargo (1993) was used. The use of *E'* provides two important advantages: 1) it does not rely on species richness and is relatively unaffected by the rare species present within the sample (Krebs, 1999), and 2) it has a value varying between 0.0 (species abundance significantly differs) to 1.0 (all species show the same abundance in a sample).

Moreover, in order to analyse the interaction between preliminary soil treatment and presence of *Ph* plantations, we used two-way ANOVA to compare the two levels of soil-treatment (applied vs not applied) and the two ones related to afforestation (done vs not done) with respect to the a) species richness and b) evenness.

Finally, the percentage cover of *Ph* trees was regressed against species richness. All statistical tests were computed with SigmaStat 3.0.

Endemic and threatened species

In order to evaluate the effect of plantations on the species of biogeographical/conservation interest, we checked the presence and frequence of both the endemic and the threatened species figuring within the red lists of Italian regions compiled by Conti et al. (1997) according to IUCN criteria.

Vegetation dynamics

In order to analyse vegetation dynamics in the afforested area and semi-natural garrigue communities, we calculated both the life form and the syntaxonomic spectra (i.e. the ratio of species belonging to different classes of vegetation) for the two *Ph*-sample plots and the one *G*-sample plot, where relevés had been taken in 2002 and 2010, respectively. Separate analyses took into account (1) the number of species, and (2) their cover values (= weighted spectra). We also checked for any important variation in total species number within each of the selected plots.

Results

Floristic composition and similarity

Eigenvalues of the first two axes of DCA are 0.672 and 0.362; total inertia is 3.8. Species axis 1 is well correlated with both the presence of soil-treatment practices (correlation coefficient r = -0.57) and the percentage cover of planted *Ph* trees (r = 0.52). Also species axis 2 is correlated with the presence of soil-treatment practices (r = 0.63).

In the sample/environmental data biplot (Fig. 2), *Ph*-samples mainly cluster in the lower left and *G*-samples in the upper right. The *Ph*-samples with the highest canopy cover values (about 80%) are found more on the left (*Ph* 1 and *Ph* 5), while the ones with lower cover are found more on the right (*Ph* 2, *Ph* 3, *Ph* 4 and *Ph* 6). So, the percentage of canopy cover of planted Pines seems to have an impact on spontaneous plant species composition. The few species common to all investigated *Ph* plots, which perform significant cover rates, are *Asparagus acutifolius*, *Charybdis maritima*, *Asphodelus ramosus* and *Oxalis pes-caprae*.

Also soil treatment has an impact on spontaneous vegetation composition, even if *ST*-plots do not form a unique cluster. Interestingly, the sites *ST* 2 and *ST* 3, which are dominated by *Phagnalon rupestre* and *Trachynia distachya*, cluster with *Ph* plots of low Pine canopy cover, while the sites *ST* 1 and *ST* 4, which are characterized by a high cover of *Charybdis maritima*, cluster with not-managed semi-natural plots (*G* 2, *G* 3 and *G* 6).

G-plots form two clusters: sites in the first cluster (*G* 1, *G* 4 and *G* 5) share similar high cover values of both *Thymbra capitata* and *Thymelaea hirsuta*, while in the sites of the second cluster (*G* 2, *G* 3 and *G* 6) *Phagnalon saxatile* and *Asphodelus ramosus* do prevail.

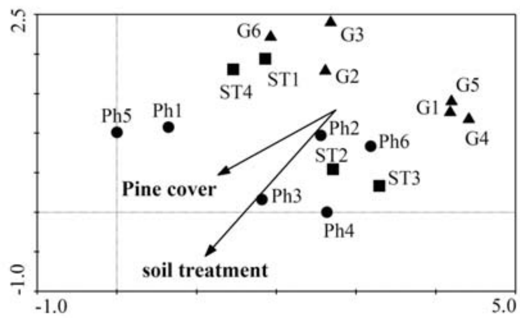

Fig. 2 DCA biplot of samples and environmental data (axes 1 and 2). Every relevé is represented by a symbol corresponding to its afforestation status: circles = *Ph*-plots; squares = *ST*-plots; triangles = *G*-plots. The eigenvalue of axis 1 is 0.672, while that of axis 2 is 0.362.

Richness and evenness

Species richness is quite variable among the sample plots, and ranges from a minimum of 17 species in a *Ph* site to a maximum of 53 in a *G* site (Table 1). Relative abundance of the species within the plots is quite uneven, as indicated by evenness values, ranging from 0.35 to 0.45.

Two-way ANOVA (Table 2) puts in evidence that neither species richness nor evenness differed significantly between treatment groups. However, within the *Ph* treatment group, there is a trend of decreasing species richness with increasing Pine canopy cover (R^2 = 0.75; Fig. 3). In fact, species-richness recorded within the densest afforestation plots are among the lowest of all the considered plots.

Endemic and threatened species

Table 3 lists the plants of biogeographical/conservation interest figuring within the field relevés. Interestingly, *Ph* afforestations with low Pine canopy cover (plots *Ph* 2, *Ph* 3 and *Ph* 4) host more plants of conservation interest than *G*-plots, while dense afforestation plots (*Ph* 1 and *Ph* 5) are the poorest ones with only one species, *Thapsia pelagica*.

Vegetation dynamics

Comparisons between two *Ph* afforestations and a garrigue community allowed to record clear differences in both life form and syntaxonomic spectra in the considered sites.

Table 1. Main characteristics, species richness (SR), evenness (*E'*) and number of taxa of conservation interest (TCI) according to Conti et al. (1997) of the plots sampled in 2009.

Plot	ST	aff	Pine %	Shrub %	Herb %	Rock %	Stone %	Pine cm	Shrub cm	SR	*E'*	TCI
Ph 1	yes	yes	95	4	10	5	10	360	80	17	0.381	1
Ph 2	yes	yes	70	4	20	5	30	250	50	42	0.499	9
Ph 3	yes	yes	20	4	30	5	40	150	60	40	0.444	6
Ph 4	yes	yes	1	10	50	5	30	130	60	42	0.329	10
Ph 5	yes	yes	80	4	70	10	20	300	50	26	0.204	1
Ph 6	yes	yes	75	25	50	15	40	230	50	22	0.354	3
ST 1	yes	no	-	15	65	10	40	-	35	46	0.363	5
ST 2	yes	no	-	20	30	0	50	-	30	37	0.349	8
ST 3	yes	no	-	1	75	10	40	-	50	18	0.177	3
ST 4	yes	no	-	10	70	20	30	-	40	46	0.350	7
G 1	no	no	-	40	50	10	10	-	25	25	0.419	6
G 2	no	no	-	60	40	10	40	-	40	39	0.211	9
G 3	no	no	-	50	40	5	30	-	40	49	0.312	7
G 4	no	no	-	45	25	15	25	-	50	22	0.380	8
G 5	no	no	-	55	25	0	15	-	15	26	0.264	3
G 6	no	no	-	30	45	5	35	-	60	53	0.417	5

ST = soil-treatment; aff = Pine afforestation; Pine % = percentage canopy cover of *Ph* trees; shrub % = percentage cover of spontaneous shrubs; herb % = percentage cover of spontaneous herbs; rock % = percentage cover of rock outcrop; stone % = percentage cover of stones; Pine cm = mean height of *Ph* tree layer; shrub cm = mean height of shrub layer.

Table 2. Results of two-way ANOVA.

Source of variation	DF	MS	F	P
Richness				
Soil treatment	1	2.817	0.018	0.895
Pine cover	1	66.150	0.424	0.526
Residual	13	156.122		
Evenness				
Soil treatment	1	0.00139	0.161	0.690
Pine cover	1	0.00828	0.961	0.350
Residual	13	0.00862		

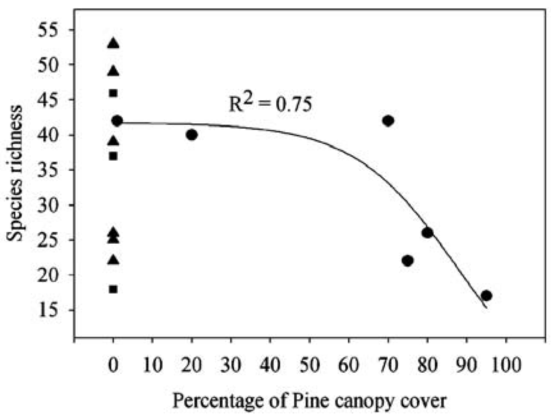

Fig. 3 Species richness along percentage canopy cover of *Ph*. Circles = *Ph*-plots; squares = *ST*-plots; triangles = *G*-plots.

Table 3. List of the plants of biogeographical/conservation interest figuring within the field relevés (see also Appendix I).

Taxon	Chorotype	IUCN
Anthemis lopadusana Lojac.	End Lampedusa	EN
Caralluma europaea (Guss.) N.E.Br. subsp. *europaea*	SW Medit	CR
Carlina involucrata Poir.	SW Medit	VU
Crucianella rupestris Guss.	SE Medit	VU
Cuscuta palaestina Boiss.	SE Medit	LR
Daucus lopadusanus Tineo	End Lampedusa	VU
Daucus siculus Tineo	End S Italy & Sicily	LR
Diplotaxis scaposa DC.	End Lampedusa	LR
Euphorbia pycnophylla (K.U.Kramer & Westra) C.Brullo & Brullo	End Lampedusa	VU
Filago gussonei Lojac.	End S Italy & Sicily	LR
Hypericum aegypticum L. subsp. *webbii* (Spach) N.K.B.Robson	S Medit	EN
Jasonia lopadusana (Brullo) Pardo de Santayana & Morales	End Lampedusa	VU
Lagurus ovatus L. subsp. *nanus*	CW Medit	VU
Limonium lopadusanum Brullo	End Pelagie	LR
Linaria reflexa (L.) Desf. subsp. *lubbockii* (Batt.) Brullo	S Medit	VU
Lycium intricatum Boiss.	S Medit	DD
Ophrys ciliata Biv.	Medit	LR
Periploca angustifolia Labill.	S Medit-Sahar	LR
Plantago afra L. subsp. *zwierleinii* (Nicotra) Brullo	End Sicily	LR
Reichardia tingitana (L.) Roth	Tetid	LR
Thapsia pelagica Brullo, Guglielmo, Pasta, Pavone & Salmeri[1]	End Lampedusa	-

[1]No risk level figures in Conti et al. (1997) because this species has been described afterwards.
End = endemic; CR = critically endangered, EN = endangered, VU = vulnerable, LR = subject to low risk, DD = data deficient.

As concerns life form, from 2002 to 2010 a strong decrease of frequency of therophytes (T), coupled to a slight reduction of hemicryptophytes (H) occurred within *Ph*-sites (Fig. 4). On the contrary, geophytes (G), chamaephytes (Ch) and phanerophytes (P) increased, while no nano-phanerophytes (NP) colonized the plots. In contrast, in the *G*-site a slight reduction of T and a small increase of H and NP have been recorded, while the other life forms did not experience any significant variation.

When cover pattern is considered, the life-form spectrum of *Ph*-sites (Fig. 5) shows the same trend as for "number", underlining the major role played by G (70-90%) and the dramatic reduction of T from 2002 to 2010. Only Ch show irregular changements, as they increase in *Ph* 1 and diminish in *Ph* 5. In the *G*-site, T and H experienced some reduction as well as G (50→30%), while woody plants (Ch, NP + P) increased.

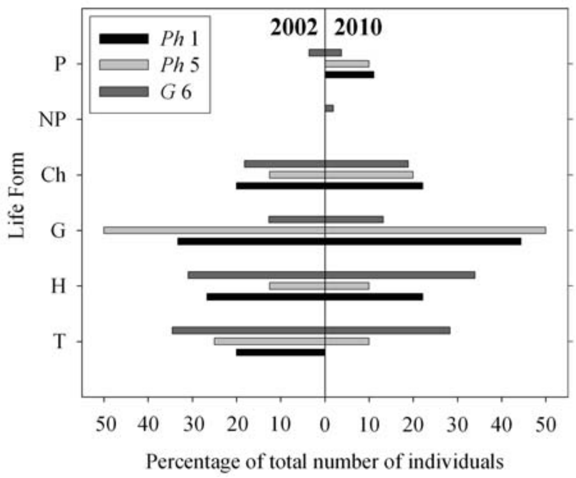

Fig. 4 Changes in number values of life-forms from 2002 to 2010. See Table 1 for plot codes. Life-form abbreviations (Raunkiær, 1934): T = Therophytes; H = Hemicryptophytes; G = Geophytes; Ch = Chamaephytes; NP = Nano-Phanerophytes; P = Phanerophytes.

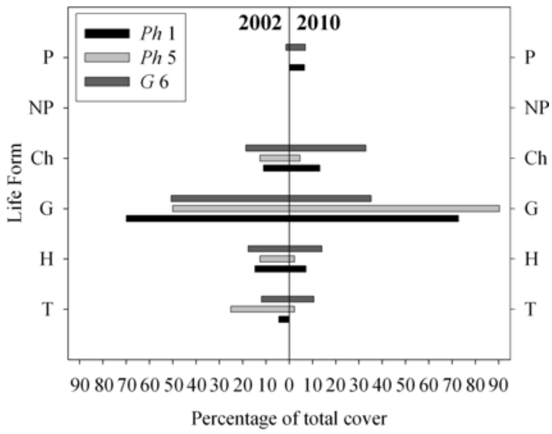

Fig. 5 Changes in cover values of life-forms from 2002 to 2010. Abbreviations as indicated in Fig. 4.

Regarding the number of individuals of each phytosociological class (Fig. 6), in *Ph*-sites *Quercetea ilicis* characteristic species increased from 2002 to 2010, while those linked to *Stellarietea mediae* and *Stipo-Trachynietea distachyae* decreased. Considering the perennial herbs linked to *Lygeo-Stipetea*, they increased in *Ph* 1 and decreased in *Ph* 5. Within the *G*-site *Lygeo-Stipetea*, *Stipo-Trachynietea distachyae* and *Crithmo-Limonietea* increase, the annual species linked to *Stellarietea mediae* decrease and the species characteristic of *Quercetea ilicis* do not change.

Changes in term of cover rate (Fig. 7), are quite different in comparison to individual numbers: within *Ph*-sites, *Lygeo-Stipetea* species nearly disappear and those of *Stipo-Trachynietea distachyae* decrease, while *Stellarietea mediae* ones increase. The evolution of *Quercetea ilicis* species is rather uncertain, as they increase in *Ph* 1 and decrease in *Ph* 5. The *G*-site is characterized by a significant decrease of *Cisto-Micromerietea* subshrubs, while those of *Stellarietea mediae* and *Lygeo-Stipetea* ones perform a slightly lower cover. Interestingly, *Quercetea ilicis* species experience a very strong increase, while the increase of those referred to *Stipo-Trachynietea distachyae* is less important.

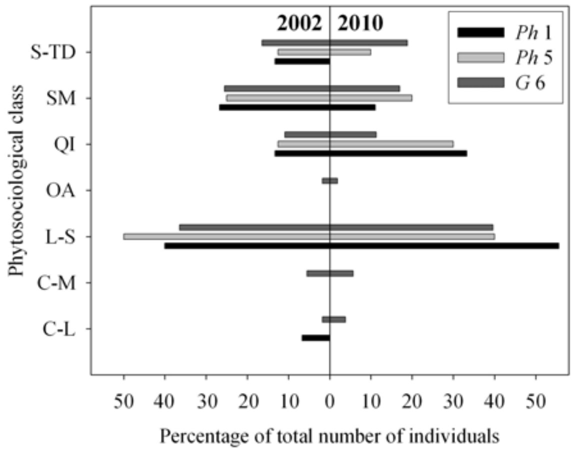

Fig. 6 Changes in number values of phytosociological classes from 2002 to 2010. See Table 1 for plot codes. Phytosociological class abbreviations: C-L = *Crithmo-Limonietea*; C-M = *Cisto-Micromerietea*; L-S: *Lygeo-Stipetea*; OA = *Onopordetea acanthii*; QI = *Quercetea ilicis*; SM = *Stellarietea mediae*; S-TD = *Stipo-Trachynietea distachyae*. Data concerning the classes *Papaveretea rhoeadis*, *Pegano-Salsoletea* and *Saginetea maritimae* were omitted because they reach very low values in all the considered plots.

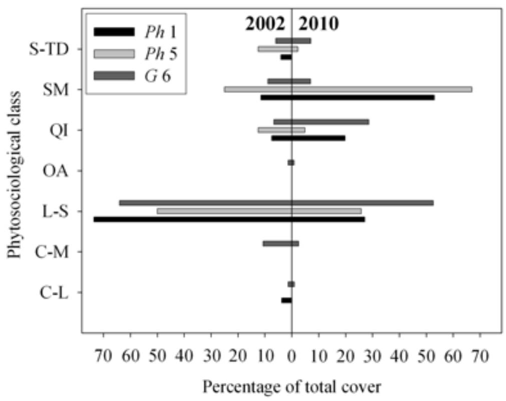

Fig. 7 Changes in cover values of phytosociological classes from 2002 to 2010. Abbreviations as indicated in Fig. 6.

In synthesis, afforestation sites with dense Pine canopy cover are not in a steady state, but are subject to vegetation dynamics. However, these dynamics are different from the ones in semi-natural garrigue, and, in terms of renaturation (i.e. increase of spontaneous woody species cover) they are much slower. Even if in *Ph* sites we registered a frequency increase of woody species, their cover on the contrary did not increase significantly, while geophytes gained much importance. In contrast, the garrigue community is steady in woody species' numbers, but gains much woody cover of species referred to *Quercetea ilicis,* which should be the final stage of progressive succession at Lampedusa.

Discussion

Floristic composition and similarity

Floristic species composition is influenced by the canopy cover of Pine trees as well as by soil-treatment practices. Too dense *Ph* plantations may inhibit understorey colonization by plants due to excessive shading and to litter accumulation. In fact, high *Ph* cover gives rise to a thick 'O' horizon made by undecomposed needles that hampers the establishment of native woody species (Navarro-Cano et al. 2009), has a strong allelopathic effect (Nektarios et al. 2005; Fernandez et al. 2006) and may reduce water infiltration through the soil by capturing the few water supply given by the rare rainfalls, as it has been observed also for other *Pinus* species by Shi and Gu (2007).

Preliminary soil-treatments may increase the average depth of available soil, but often promote soil erosion, alter water regime, induce microhabitat loss and nutrient depletion, thus biasing spontaneous seedling establishment (Maestre et al. 2007). Moreover, as already observed elsewhere in Mediterranean area (Puerto and Rico, 1997), the effects of these factors very likely overlap with fluctuations in soil depth, soil stoniness, microtopography and differences in the initial floristic composition at plot level.

In some sample plots (*ST* 1 and *ST* 4) in which subsoiling was carried out without subsequent afforestation, we found a high cover rate of *Charybdis maritima*. From a floristic point of view these sites are similar to some semi-natural *G*-sites where *Asphodelus ramosus* and *Phagnalon saxatile* are very common. *Charybdis* and *Asphodelus* often coexist as they share the same ecological requirements and probably dominated these areas already before subsoiling; thus soil treatment practices seem to not significantly affect the pre-existent vegetation pattern. Moreover, it must be highlighted that plant communities dominated by *Asphodelus ramosus* and *Charybdis maritima* are considered as the last degradation stages of the Mediterranean ecosystems. Both species take advantage from their strong tolerance to edapho-climatic stress factors (Rhizopoulou et al. 1997; Grammatikopoulos et al. 1999) and their high resistance and resilience to disturbance factors such as grazing (Pantis and Mardiris, 1993), competition and burning.

In subsoiled and afforested sample plots, the difference in species composition between dense and open *Ph* plantations is striking. The *Ph*-sites characterized by low Pine canopy cover show a similar floristic composition to those *ST*-sites which are dominated by *Phagnalon rupestre* and *Trachynia distachya*. To explain this pattern an edaphic explanation may be invoqued: in fact, both plants are helio-xerophilous pioneers, but *Phagnalon rupestre* prefers thin, sandy and/or stony soils, whereas *Trachynia* colonizes also rock crevices. Thus, we could argue that soil erosion due to subsoiling and/or to unsuccessful plantation biased any evolution of soil and vegetation within open and/or failed afforestations.

Richness and evenness

Species richness and evenness are not related to the execution of soil treatment nor to the presence/absence of Pine afforestation. However, in agreement with Alrababah et al. (2007), we noticed for the afforested sites that the denser *Ph* cover is, the lower is the number of species under its canopy. Richness decreases drastically when Pine cover exceeds 80%, a pattern observed also in other southern Italian *Ph* plantations (Pignatti, 1993).

In these cases, the nearly continuous canopy and the thick litter which covers the ground act as a complex barrier by strengthening the effect of local limiting factors such as light, water and nutrients. Concerning light, already Battles et al. (2001) noticed that plots with more bare ground and lower tree coverage showed higher species richness. As for water, competition by *Ph* must be considered a major constraint for the survival of herbaceous species and the seedlings of the understorey (Bellot et al. 2004): in fact, Aleppo pines have relatively shallow root systems, with maximum density of fine roots occurring at less than 50 cm from soil surface (Canadell et al. 1999).

Endemic and threatened species

Also the biogeographic value of the flora observed within the *Ph*-sites with high Pine cover is by far the lowest of all the considered plots, while the values of less dense Pine plantations are similar to the semi-natural garrigues. As most part of these noteworthy species are annual r-strategists (Grime, 2001), they are more common either in *G*-sites or in open *Ph* plantations, while they gradually succumb within too dense plantations because they are unable to compete with pines for nutrients, light and water.

Vegetation dynamics

Our initial hypothesis was partially contradicted: *Ph* afforestation sites are not in a steady state, as life form and phytosociological class spectra changed over the investigated time period. However, only a very slow renaturation process has been recorded within dense plantations, with a major increase in geophytes of *Stellarietea mediae* (i.e. *Oxalis pes-caprae*), and only slight increases in *Quercetea ilicis* woody species cover. The same factors invoqued to explain the patterns of floristic composition and similarity (i.e. allelopathy and competition for light, water and nutrients) may also explain the lowering of diversity of therophytes and the strong decline of the cover perfomed by both therophytes and hemicryptophytes underneath the canopy of dense *Ph* plantations. Thus, in sites where *Ph* cover exceeds about 80%, thinning is recommended not only in order to accelerate succession, but also to give a natural 'shape' to afforestations.

As regards geophytes, the case of *Oxalis pes-caprae* worths some more details. While its presence has been recorded in all the investigated *Ph*-sites and *ST*-sites (see Table 2), none of the *G*-sites hosts it. These data, together with the increase of its cover rate in both the *Ph*-sites compared for the analysis of vegetation dynamics, suggest that the disturbance induced by soil-treatment has favoured its vegetative spread. Our hypothesis agrees with the most recent literature on the dispersal strategies and the ecological niche of this invasive alien species (Verdaguer et al. 2010).

Within its natural range, *Ph* is considered to disappear once the communities in which it lives start to evolve towards more closed tree-dominated communities (Bartolo et al. 1986; Paola et al. 1991). In contrast, when *Ph* is used for afforestation, no or very slow spontaneous transformation into sclerophyllous maquis or forests is recorded. *Ph* plantations may have negative effects on existing late-successional shrubs, i.e. chamaephytes + nano-phanerophytes + phanerophytes (Benabdeli, 1998; Bellot et al. 2004; Chirino et al. 2006). Maestre and Cortina (2004) argued that its introduction - albeit ameliorating understorey microclimatic conditions – is not able to facilitate the establishment of shrubs under semi-arid conditions.

Concluding remarks

Our study represents the first trial to evaluate the combined effect of soil treatment and afforestation practices on plant species-richness and evenness and on the speed of dynamic processes in a central Mediterranean semi-arid area. It confirms that in order to maintain biodiversity, not only conservation forest management practices, but also their total absence must be correctly planned. Optimal management strategies strongly depend on *Ph* cover rate. Dense *Ph* plantations should also be avoided where they may cause direct and indirect damages to protected plants and habitats of community interest according to 92/43 EU Directive.

Finally, regarding the spontaneous evolution of *Ph* plantations towards natural woody communities, future investigations should be focused on their influence on soil dynamics. In the context of global climate change, the transformation of *Ph* plantations to natural communities gains an important aspect, since recent studies show that in Mediterranean semi-arid ecosystems the organic carbon content is far lower on *Ph* plantations than in autochthonous pre-forest communities.

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Appendix I. Raw data of sample site

Plot ID	Ph 1	Ph 2	Ph 3	Ph 4	Ph 5	Ph 6	ST 1	ST 2	ST 3	ST 4	G 1	G 2	G 3	G 4	G 5	G 6	Life form	Phyt. Cl.	Chorotype
Preliminary soil treatment	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	no	no	no			
Afforestation with *Pinus halepensis*	yes	yes	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no			
Outcropping rocks (%)	5	5	5	5	10	15	10	0	10	20	10	10	5	15	0	5			
Outcropping stones (%)	10	30	40	30	20	40	40	50	40	30	10	40	30	25	15	35			
Mean height of Pine layer (cm)	360	250	150	130	300	230	0	0	0	0	0	0	0	0	0	0			
Mean height of shrub layer (cm)	80	50	60	60	50	50	35	30	50	40	25	40	40	50	25	60			
Mean height of herbaceous layer (cm)	25	15	35	30	20	20	30	30	25	30	25	30	30	30	25	35			
***Pinus halepensis* Mill.**	5	4	2	+	4	3													
Maquis (class *Quercetea ilicis*)																			
Pistacia lentiscus L.	r	+	r		r	+											P caesp	QI	Medit
Periploca angustifolia Labill.										+		r	+			1	P caesp	QI	S.Medit-Sahar
Prasium majus L.	r	r			1		+			+		+				1	Ch frut	QI	Medit
Asparagus acutifolius L.	+	1	r	+			r					+	1			+	Ch frut	QI	Medit
Teucrium fruticans L.							+		+			1	r	+		1	Ch frut	QI	CW.Medit
Ruta chalepensis L.													+			1	Ch suffr	QI	S.Medit-Sahar
Rubia peregrina L. *s.l.*	r																P lian	QI	Medit-Atlant
Olea europaea L. var. *sylvestris* (Mill.) Lehr.																r	P scap	QI	Medit
Shrubland and garrigue (classes *Pegano-Salsoletea*, *Cisto-Micromerietea* and *Crithmo-Limonietea*)																			
Lycium intricatum Boiss.		r		+													NP	P-S	S.Medit
Thymbra capitata (L.) Cav.				+			+				2	1	1	2	2	+	Ch frut	C-M	Medit
Phagnalon rupestre (L.) DC.		+		r		+		2	+		r	+	+		1	+	Ch suffr	C-M	Medit-Macar
Jasonia lopadusana (Brullo) Pardo de Santayana & Morales			+	1			+	+		r		1	1			+	Ch frut	C-M	End Lampedusa
Caralluma europaea (Guss.) N.E. Br. subsp. *europaea*							r										Ch succ	C-M	SW.Medit
Thymelaea hirsuta (L.) Endl.				r		1					2			2	3	r	NP	C-L	Medit
Sonchus asper (L.) Hill. subsp. *glaucescens* (Jordan) Ball		+					r			r	r			+			H scap	C-L	C.Medit
Limonium lopadusanum Brullo						+								+			Ch frut	C-L	End Pelagie
Lotus cytisoides L.		r		+		1	+	+	+	+	1	+	+		+	+	Ch suffr	C-L	Medit
Hypericum aegypticum L. subsp. *webbii* (Spach) N.K.B. Robson											+			1			NP	C-L	S.Medit
Crucianella rupestris Guss.														+			Ch suffr	C-L	SE.Medit
HERBACEOUS LAYER																			
Xeric perennial grasslands (class *Lygeo-Stipetea*)																			
Phagnalon saxatile (L.) Cass. *s.l.*				r	r	r				+			2			1	Ch suffr	L-S	CW.Medit
Euphorbia pinea L.				1		r	r						+			+	Ch suffr	L-S	CW.Medit
Convolvulus lineatus L.		1		1		1		1	1		2			1	1	+	H scap	L-S	CE.Medit-Ir.Tur
Dactylis hispanica Roth		+		r		1	+	1			2		3	1	2	+	H caesp	L-S	Medit
Eryngium dichotomum Desf.		r	+	r			+	r	r	+	r	+	r		+	+	H bienn	L-S	SW.Medit
Carlina involucrata Poir.		r		+		1		+	+		1	1	+	1	+	+	H scap	L-S	SW.Medit
Hyoseris radiata L.	r	r		+		r	+	r			+			1	+	r	H ros	L-S	Medit
Sonchus bulbosus (L.) N. Kilian & Greuter	+	+		+	1	+	+			+		+	+				G bulb	L-S	Medit
Piptatherum miliaceum (L.) Cosson subsp. *miliaceum*																+	H caesp	L-S	Tetid
Piptatherum miliaceum (L.) Cosson subsp. *thomasii* (Duby) Freitag													+				H caesp	L-S	CE.Medit
Asphodelus ramosus L.	+	+	+	1	+		1	+	+	1		1	2			2	G rhiz	L-S	CW.Medit-Macar
Pallenis spinosa (L.) Cass.						+	+		+		r	+	r		+	+	H bienn	L-S	Tetid-Europ
Charybdis maritima (L.) Speta	+	+	1	+	1	+	2	1	+	2	r	1	2		1	1	G bulb	L-S	CW.Medit
Melica arrecta G. Kunze				2												+	H caesp	L-S	CW.Medit
Lobularia maritima (L.) Desv.				r	r		+			+		+	r			+	H scap	L-S	Medit
Leontodon tuberosus L.							r					+	r		+	+	G rhiz	L-S	Medit
Convolulus althaeoides L.			r				r					+	+		1	+	H scand	L-S	Medit

Continue Appendix I

Plot ID	Ph 1	Ph 2	Ph 3	Ph 4	Ph 5	Ph 6	ST 1	ST 2	ST 3	ST 4	G 1	G 2	G 3	G 4	G 5	G 6	Life form	Phyt. Cl.	Chorotype
Allium roseum L.					+					1			+		+	+	G bulb	L-S	Medit
Thapsia pelagica Brullo, Guglielmo, Pasta, Pavone & Salmeri	+	+	+	+	+	r	1	1	+	1	r	1	1	+		+	H scap	L-S	End Lampedusa
Allium pallens L.			+	r								+				+	G bulb	L-S	Medit
Reichardia picroides (L.) Roth		+					+	+		+	r	+	+	+	+	+	H scap	L-S	Medit
Ophrys ciliata Biv.								r				r					G bulb	L-S	Medit
Lathyrus clymenum L.					+												T scap	L-S	Medit
Foeniculum vulgare Mill. subsp. *vulgare*										+							H scap	L-S	Medit-Ir.Tur
Hyparrhenia hirta (L.) Stapf *s.l.*																+	H caesp	L-S	Tetid-Paleotrop
Poa bulbosa L.																+	H caesp	L-S	Tetid-Eurosib
Ephemeral prairies (classes *Stipo-Trachynietea distachyae* and *Saginetea maritimae*)																			
Trachynia distachya (L.) Link		+	1	1	+	2			3	+	1			+	+	+	T scap	S-TD	Tetid
Reichardia tingitana (L.) Roth		+		1		+			+								T scap	S-TD	Tetid
Scorpiurus muricatus L. *s.l.*		+	1	r		+	+	+		r			+	r	+	+	T scap	S-TD	Medit
Linum trigynum L.				+			+		+				r			+	T scap	S-TD	Tetid-Europ
Linum strictum L. *s.l.*			+			+		+		r	+		+	+	+	+	T scap	S-TD	Medit
Salvia verbenaca L. *s.l.*		r				r	r					+				+	H bienn	S-TD	Medit-Atlant
Plantago afra L. subsp. *zwierleinii* (Nicotra) Brullo		+	1	1				1		+		r					H scap	S-TD	End Sicily
Diplotaxis scaposa DC.		+		+			+					+	r				T scap	S-TD	End Lampedusa
Daucus siculus Tineo				+								+	r		+	r	H bienn	S-TD	End S.Italy & Sicily
Linaria reflexa (L.) Desf. subsp. *lubbockii* (Batt.) Brullo				+			r	+									T rept	S-TD	S.Medit
Hypochoeris achyrophorus L.	r	+	1	+			+	1		+		+	1	+	+	+	T ros	S-TD	Medit
Euphorbia pycnophylla (K.U. Kramer & Westra) C. Brullo & Brullo		+	+	r				+		+	+		r	+	+		T scap	S-TD	End Lampedusa
Sideritis romana L.				r				+	r	r			+				T scap	S-TD	Medit
Tordylium apulum L.		+	+		r		+	1		+			+			+	T scap	S-TD	Medit-Europ
Filago pygmaea L.			r					+									T rept	S-TD	Medit-Macar
Senecio leucanthemifolius Poir. *s.l.*				+			+			+							T scap	S-TD	CW.Medit
Tripodion tetraphyllum (L.) Fourr.			+							r			r			r	T scap	S-TD	Medit
Hedypnois rhagadioloides (L.) F.W. Schmidt			+		+		r			+	+					+	T ros	S-TD	Medit-Ir.Tur
Lagurus ovatus L. subsp. *nanus*			+					+		r				+			T scap	S-TD	CW.Medit
Stipa capensis Thunb.			+					+									T scap	S-TD	Subcosmop
Ononis reclinata L.											r	r	r				T scap	S-TD	Tetid-Atlant
Centaurium pulchellum (Swartz) Druce													+				T scap	S-TD	Olart
Lotus edulis L.	+		r					+					+		+		T scap	S-TD	Medit
Daucus lopadusanus Tineo		r									1	+		1			T scap	S-TD	End Lampedusa
Filago gussonei Lojac.		r								+							T scap	S-TD	End S.Italy & Sicily
Ononis sieberi DC.		+					+										T scap	S-TD	CE.Medit
Hyoseris scabra L.		+					+										T ros	S-TD	Medit
Frankenia hirsuta L.																	Ch suffr	SaM	Medit-Pont
Evax pygmaea (L.) Brot.											1				+		T ros	S-TD	Medit-Macar
Anthemis lopadusana Lojac.											+						T scap	SaM	End Lampedusa
Asteriscus aquaticus (L.) Less.																	T scap	SaM	Medit-Macar
Nitrophilous-ruderal communities (classes *Stellarietea mediae*, *Papaveretea rhoeadis* and *Onopordetea acanthii*)																			
Avena barbata Link *s.l.*			1	+	+			+	+	+		r	+	+	+	+	T scap	SM	Tetid-Pont
Anagallis arvensis L. *s.l.*		+	+	+			+	+	+	+		+	+		+	+	T rept	SM	Tetid-Europ
Erodium malacoides (L.) L'Hérit.		+	+	+	r		+	+		+							T scap	SM	Tetid
Sonchus oleraceus L.	+	r	1	+	+	+	+					r		+	+	r	T scap	SM	Bor-Tetid
Oxalis pes-caprae L.	1	+	1	+	3	1	+			1							G bulb	SM	Introd
Urospermum picroides (L.) F.W. Schmidt	r		+	+	r												T scap	SM	Tetid
Carduus argyroa Biv.	r		+	r				+	r								T scap	SM	CW.Medit
Galium verrucosum Schreber				r			+			r							T scap	SM	Medit
Echium plantagineum L.			+	+				r	r							+	H bienn	SM	Tetid-Europ
Hippocrepis ciliata Willd.								r									T scap	SM	Medit-Pont

Continue Appendix I

Plot ID	*Ph 1*	Ph 2	Ph 3	Ph 4	Ph 5	Ph 6	ST 1	ST 2	ST 3	ST 4	G 1	G 2	G 3	G 4	G 5	G 6	Life form	Phyt. Cl.	Chorotype
Allium ampeloprasum L.										r		+				+	G bulb	SM	Tetid-Europ
Euphorbia peplus L. *s.l.*	+	+			+		r			+							T rept	SM	Medit-Europ
Medicago polymorpha L.	r		r							r							T scap	SM	Bor-Tetid
Scandix pecten-veneris L. *s.l.*			+		r			+		+							T scap	SM	Tetid-Europ
Carlina lanata L.			+					+									T ros	SM	Medit
Bromus hordeaceus L. *s.l.*			+		+												T scap	SM	Subcosmop
Malva nicaeensis All.			1														T scap	SM	Medit
Hordeum leporinum Link			+														T scap	SM	Medit-Europ
Lotus ornithopodioides L.			+		1					+			+				T scap	SM	Medit
Lolium perenne L.			+														H caesp	SM	Tetid-Europ
Rostraria cristata (L.) Tzvelev			+										1				T scap	SM	Tetid-Europ
Cuscuta palaestina Boiss.			r														T par	SM	SE.Medit
Sonchus tenerrimus L.								r				r					H scap	SM	Tetid-Paleotrop
Melilotus sulcatus Desf.								r									T scap	SM	Medit-Europ
Galium murale L.		+					+	r				r					T scap	SM	Medit
Valantia muralis L.								+									T scap	SM	Medit
Gladiolus italicus Mill.					r					+		+	+			+	G bulb	SM	Tetid-Europ
Allium commutatum Guss.										+			+				G bulb	SM	Medit
Theligonum cynocrambe L.													+				T scap	SM	Medit
Geranium rotundifolium L.										+			+				T scap	SM	Tetid-Europ
Catapodium rigidum (L.) C.E. Hubbard subsp. *rigidum*													r				T scap	SM	Tetid-Europ
Echium parviflorum Moench							r						r				T scap	SM	Medit
Silene gallica L.													r				T scap	SM	Tetid-Europ
Mercurialis annua L.					1		r			+						+	T scap	SM	Tetid-Europ
Fumaria sp.					+												T scap	SM	
Helminthotheca echioides (L.) J. Holub		+															H bienn	SM	Medit-Europ
Carrichtera annua (L.) DC.		r					+			+		+					T scap	SM	Tetid
Arisarum vulgare Targ.-Tozz.							1										G rhiz	SM	Medit
Romulea columnae Seb. & Mauri											+	+					G bulb		Medit-Atlant
Astragalus hamosus L.		+					+					r					T scap	SM	Tetid-Europ
Bromus fasciculatus C. Presl										r							T scap	SM	Tetid
Sherardia arvensis L.		r					+										T scap	SM	Tetid-Europ
Convolvulus siculus L.							+			+							T scap	SM	Tetid
Sonchus asper (L.) Hill subsp. *asper*		r															T scap	SM	Bor-Tetid
Melomphis arabica (L.) Raf.												+					G bulb	SM	S.Medit
Carthamus lanatus L. subsp. *lanatus*		r															H bienn	SM	Tetid-Europ
Medicago truncatula Gaertner																	T scap	SM	Medit-Europ
Carduus pycnocephalus L.																	T scap	SM	Tetid-Europ
Cynara cardunculus L.										r						+	H scap	OA	Medit
Nigella damascena L.					1								+			r	T scap	PR	Tetid-Pont
Lolium rigidum Gaudin											+						T scap	SM	Tetid-Europ
Bromus rubens L.																+	T scap	SM	Tetid-Europ
Plantago afra L. subsp. *afra*																+	T scap	SM	Tetid-Europ

Life form: P = Phanerophyta, with three subcategories: scap = scaposa, caesp = caespitosa and lian = lianosa; NP = Nano-Phanerophyta; Ch = Chamaephyta, with three subcategories: frut = fruticosa (shrubs), suffr = suffruticosa (subshrubs) ans succ = succulenta (succulents); H = Hemicryptophyta, with five subcategories: scap = scaposa, caesp = caespitosa, bienn = biennia, scand = scandentia and ros = rosulata; G = Geophyta, with two subcategories: rhiz = rhizomatosa and bulb = bulbosa; T = Therophyta, with four subcategories: scap = scaposa, rept = reptantia, ros = rosulata and par = parasytica. Phytosociological class: C-L = *Crithmo-Limonietea*; C-M = *Cisto-Micromerietea*; L-S: *Lygeo-Stipetea*; OA = *Onopordetea acanthii*; PR = *Papaveretea rhoeadis*; P-S = *Pegano-Salsoletea*; QI = *Quercetea ilicis*; SaM = *Saginetea maritimae*; SM = *Stellarietea mediae*; S-TD = *Stipo-Trachynietea distachyae*. Chorotype: (CW) Medit-Macar = (CW) Mediterranean-Macaronesian; (S, SW, SE, C, CW, CE) Medit = (S, SW, SE, C, CW, CE) Mediterranean; Bor-Tetid = Borea-Tethisian; (CE) Medit-Ir.Tur = (CE) Mediterranean-Irano-Turanian; End = endemic; Introd = introduced; Medit-Atlant = Mediterranean-Atlantic; Medit-Europ = Mediterranean-European; Medit-Pont = Mediterranean-Pontian; Olart = Holarctic; S.Medit-Sahar = S Mediterranean-Saharian; Subcosmop = Subcosmopolitan; Tetid = Tethisian; Tetid-Atlant = Tethisian-Atlantic; Tetid-Europ = Tethisian-European; Tetid-Eurosib = Tethisian-Eurosiberian; Tetid-Paleotrop = Tethisian-Palaeotropical