Forest management and plant species diversity in chestnut stands of three Mediterranean areas

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Abstract. Over many centuries, chestnut fruits had an important role as food, while chestnut wood was used for local purposes. Today sweet chestnut stands are very common around the western Mediterranean Basin, and it is necessary to analyze the dynamic of plant species diversity in different chestnut stand types (groves and coppices) to guide management strategies that will allow the conservation of biodiversity. Our objective was to analyze consequences on plant species diversity of various management strategies in chestnut stands of three Mediterranean areas, Salamanca (Spain), the Cévennes (France), and Etna volcano (Italy). We found that plant species diversity is different according to management types; it is higher in groves than in coppice stands. We also demonstrated that Castanea sativa cultivated groves were characterized by small heliophillous therophytes. C. sativa abandoned groves, mixed C. sativa–Quercus pyrenaica coppice stands, Q. pyrenaica coppice stands, and young C. sativa coppice stands were characterized by hemicryptophytes with anemochorous dispersal mode and chamaephytes. Medium and old C. sativa coppice stands (that differ by the shoot age) were characterized by phanerophytes with zoochorous dispersal mode. Human perturbations maintain a quite high level of species diversity. In contrast, the abandonment of chestnut stands leads to homogeneous vegetation with decreasing diversity. One solution could be to maintain a landscape mosaic constituted of diverse chestnut stands modified by human activities (groves, cultivated or abandoned, and coppice stands). This could enhance regional plant diversity.

Nomenclature – Flora Europaea (Tutin et al. 1964–1980)

Introduction

Sweet chestnut (Castanea sativa Mill) stands are very common around the western Mediterranean Basin. Over many centuries, chestnut fruits had an important role as food for humans and as feed for domestic animals, while chestnut wood was used for local purposes such as wine barrels, vineyard pegs, tool handles and carpentry (Arnaud and Bouchet 1995). Today, chestnut

stands cover large areas particularly in Portugal, Spain, France, Italy and Greece. Thus, it is necessary to analyze the dynamic of plant species diversity in different chestnut stand types (groves and coppices) to guide management strategies that will allow the conservation of biodiversity and at the same time to optimize productivity and profitability.

The characterization of community response to different management types in terms of functional traits appears as a promising tool to achieve this goal (McIntyre et al. 1995; Hadar et al. 1999; Lavorel et al. 1999; Gondard et al. 2003). Indeed, from an ecosystem perspective, species richness (number of species), which is the conventional metric of biodiversity, is not as important as functional trait richness. This approach analyzes the functioning of the ecosystem, and its response to abandonment, by focusing on vegetation description defined by functional traits not necessarily linked with taxonomic attribution (Pillar 1999). Functional traits fall into three biological categories: morphological traits describing aspect, life history traits indicating plant behavior in the environment, and regeneration traits (Lavorel et al. 1997). The use of functional traits for the comprehension and analysis of plant species dynamics in relation with perturbation is clearly demonstrated by many authors (Díaz and Cabido 1997; Lavorel and Cramer 1999; McIntyre et al. 1999; McIntyre and Lavorel 2001; Díaz et al. 2002; Gondard and Deconchat 2003).

Consequently, our objective was to analyze consequences on plant species diversity of various management strategies in chestnut stands of three Mediterranean areas, Salamanca (Spain), the Cévennes (France), and Etna volcano (Italy). We hypothesized that, whatever area, species diversity between groves and coppice stands is different essentially according to dendrometric characteristics and management types. Indeed, groves have, in general, large trees with regular pruning, understorey cleaning, etc., and coppices have many shoots without clearing but logging. We assumed that species diversity is highest in groves. We focused on understorey stratum which is sensitive to changes of ecosystem conditions (Pregitzer and Barnes 1982; Strong et al. 1991; Mitchell et al. 1997, 1998) and recognized like a very important component in ecosystem functioning (Host and Pregitzer 1991; Arsenault and Bradfield 1995; Brakenhielm and Lui 1998).

Materials and methods

The experiment was carried out in three Mediterranean areas, in the Honfría forest, located in the southern of Salamanca province in Spain, in the Cévennes in southern France, and on Etna volcano in Italy (Table 1). The Honfría forest is representative of traditional chestnut (*Castanea sativa*) management over many centuries in Spain, but also a model of possible sustainable management in the future. In this forest, chestnut is considered as a paraclimax species and the deciduous oak (*Quercus pyrenaica*) as a climax species. Thus, we selected five stands that are representative of this forest: a chestnut cultivated grove, a

chestnut abandoned grove, a chestnut coppice stand, a mixed chestnut-oak stand, and an oak pure stand. In the Cévennes, we identified a succession following agricultural abandonment from chestnut cultivated grove to chestnut old coppice stand. Thus, we selected five stages that form the successional gradient: a cultivated grove, an abandoned grove, a young coppice (< 25 years old), a medium coppice stand (between 26 and 50 years old), and an old coppice stand (> 51 years old). On Etna volcano, the tradition is coppice management and not grove. Thus, we selected five coppice stands (Fornazzo, Trisciala, Balilla, Monte Crisimo, Piano Lepre) that are representative of the study area and differ by their stand characteristics (Table 2).

In each stand, we established five 10×10 m plots. The plots were contiguous because there was only little area available at the site with relatively homogeneous topographic conditions, and in order to respect 100 m^2 plot size minimum. In each plot, we recorded all plant species occurring in the understorey stratum. The plant cover of each species was estimated by the point quadrat method (Gounot 1969), using 100 points, i.e. one point each 10 cm, along a 10 m line traversing each plot. According to previous observations, realized by one of us, 100 m^2 plots appeared to be suitable for monitoring this kind of vegetation. Data were collected during June month in 2001 in the Cévennes, 2002 in the Honfría forest, and 2003 in Italy. Moreover, plant species recorded were characterized by functional traits such as plant height and life form that refer to morphology, light tolerance that refers to life history traits, and dispersal mode to regeneration traits (Appendix 1).

Data analyses

The criteria to compare stands were species richness (number of taxa per 100 m^2) and species diversity (Pielou 1975; Magurran 1988). Among the many diversity indices available, we chose the Shannon index (H'), which was recommended by Pielou (1975): $H' = -\sum_{i=1,n}(p_i\log_2(p_i))$ where p_i is the abundance ratio of species (i) in the square, and n is the species number in the square.

Forest stands in the three geographical areas are submitted to different silvicultural management and also to contrasting environment and climate con-

Table 1. Characteristics of the three Mediterranean areas studied.

	Honfría Forest	Cévennes	Etna volcano
	Spain	France	Italy
Altitude (m)	900	650	1000
Mean annual rainfall (mm yr^{-1})	1500	1400	1100
Mean annual temperature (°C)	11	11	12
Parent material	Schist	Schist	volcanic ash, lava
Soil	Cambisol	Cambisol	regosol volcanic

Table 2. Main characteristics of chestnut stands selected in the Cévennes in France, on Etna volcano in Italy and in Honfría Forest in Spain. Confidence intervals $p = 0.05$. For each site, mean values in the same column followed by different letters are significantly different. $p < 0.05$, Mann–Whitney test.

Site	Stand	Tree age (years)	Tree height (m)	Diameter at breast height (cm)	Shoot density (shoot ha^{-1})	Basal area (m^{2}ha^{-1})
Honfría Forest Spain	*C. sativa* cultivated grove	90	11.30 ± 1.3^b	18.30 ± 2.1^c	295 ± 20^a	23 ± 5^b
	C. sativa abandoned grove	85	8.90 ± 0.8^a	20.40 ± 3.0^c	382 ± 30^a	19 ± 4^a
	C. sativa coppice stand	70	15.3 ± 1.3^c	12.90 ± 1.7^b	1892 ± 100^b	28 ± 8^c
	Mixed *C. sativa–Q. pyrenaica* stand	60	10.7 ± 0.8^b	8.90 ± 1.2^a	3208 ± 150^c	21 ± 5^a
	Q. pyrenaica pure stand	75	12.2 ± 1.0^b	11.60 ± 1.5^b	2960 ± 125^c	27 ± 7^c
Cévennes France	Cultivated grove	70	18.00 ± 1.0^a	45.00 ± 7.1^a	120 ± 45^a	26 ± 18^a
	Abandoned grove	75	17.40 ± 0.5^a	44.60 ± 11.5^a	440 ± 195^a	45 ± 21^a
	Young coppice	16	$11.20 \pm 0.8^{b,c}$	9.40 ± 1.5^b	1040 ± 611^b	8 ± 4^b
	Medium coppice	39	12.40 ± 0.9^c	$17.80 \pm 7.8^{c,d}$	1080 ± 396^b	$17 \pm 14^{c,d}$
	Old coppice	56	16.40 ± 0.5^d	24.00 ± 4.8^d	840 ± 488^b	35 ± 13^d
Etna volca Italy	Fornazzo coppice	31	17.67 ± 0.7^a	9.20 ± 0.5^a	$4680 \pm 1242^{a,c}$	$38 \pm 8^{a,b}$
	Trisciala coppice	28	12.17 ± 0.3^a	7.20 ± 0.3^b	6020 ± 895^a	29 ± 3^a
	Balilla coppice	37	16.67 ± 2.3^a	20.9 ± 1.7^c	1140 ± 331^b	43 ± 8^b
	Monte Crisimo coppice	26	16.00 ± 0.0^a	7.10 ± 1.2^d	2900 ± 919^c	24 ± 6^c
	Piano Lepre coppice	27	15.67 ± 3.2^a	9.90 ± 0.5^a	$4180 \pm 394^{d,c}$	$38 \pm 1^{a,b}$

ditions, so differences are expected between them. However, due to the low number of stands analyzed, we used non-parametric test that allows to work with low size samples. We chose the Mann–Whitney non-parametric test that allows to compare means pairwise (Falissard 1998).

In each Mediterranean area, we used Correspondence Analysis (CA) and Canonical Correspondence Analysis (CCA, ter Braak 1987) to quantify the effects of management types with species functional traits. We performed a Correspondence Analysis (CA,Greenacre 1984) of plant species observed on the entire point quadrat set (67 in Honfría forest in Spain, 41 in the Cévennes in France, and 40 on Etna volcano in Italy) and management types (coppice stands and groves in Honfría forest and in the Cévennes, and different coppice stand types on the Etna volcano). We used CCA to determine the fraction of variance of the species among management types explained by the species and functional traits. For each Mediterranean area, we carried out the CCA by confronting the CA table with another table composed by the same species
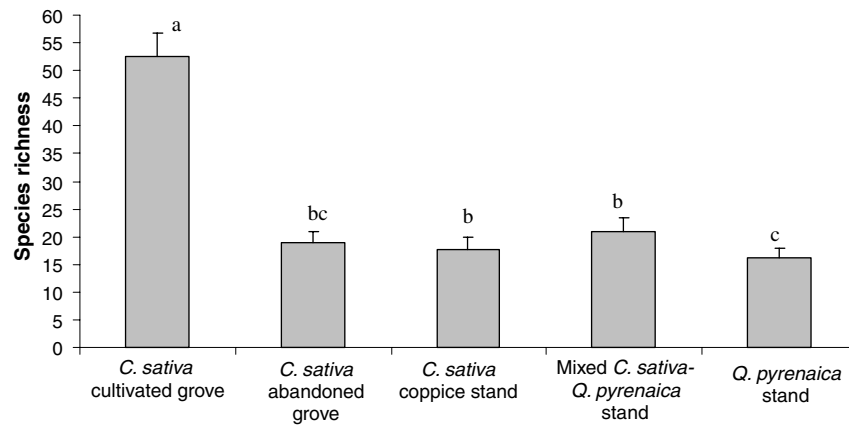
Figure 1. Mean species richness in the understorey of the *C. sativa* and *Q. pyranaica* stands of the Honfría forest in the southern of Salamanca province in Spain. Error bars at ±95% confidence limits. Two different letters between the coppice stands indicated significant statistical difference (Mann–Whitney non-parametric test, $p < 0.05$).

number and functional traits separated in subclasses. Moreover, hierarchical ascending classification was used to make easier the identification of groups in factorial plans (Roux 1985).

Results

Species richness and species diversity (Shannon index)

In the Honfría forest and the Cévennes, species richness was highest in cultivated groves, (Figures 1, 2). On Etna volcano, species richness was highest in
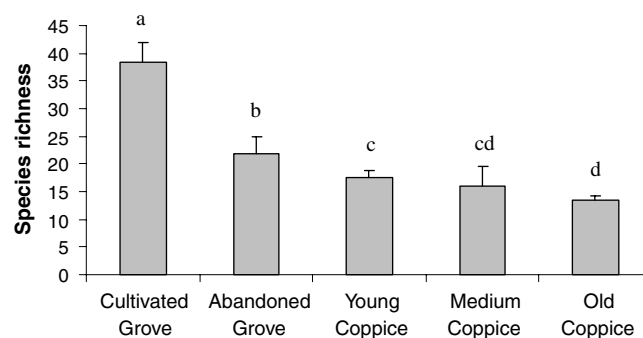

Figure 2. Mean species richness along a successional gradient from cultivated chestnut grove to old *C. sativa* coppice stand (Le Cros site in the Cévennes). Error bars at ±95% confidence limits. Two different letters between the coppice stands indicated significant statistical difference (Mann–Whitney non-parametric test, $p < 0.05$).

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Figure 3. Mean species richness in the understorey in the five coppice *C. sativa* stands on the Etna volcano in Italy. Error bars at ±95% confidence limits. Two different letters between the coppice stands indicated significant statistical difference (Mann–Whitney non-parametric test, $p < 0.05$).
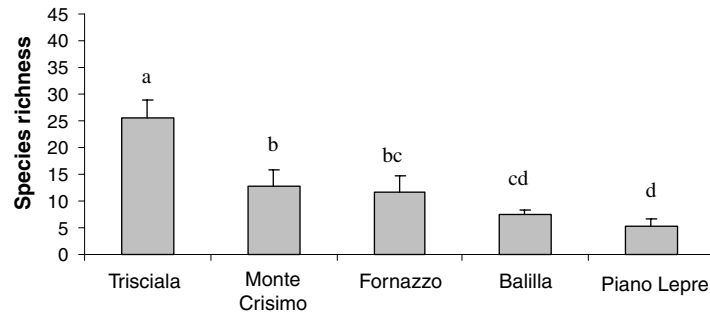
the Trisciala coppice stand (Figure 3), and not significantly different from the abandoned grove in the Cévennes ($p > 0.05$). Species diversity was also highest in cultivated groves and Trisciala coppice stand.

Plant functional traits and management types

Consequences of various management types on plant species in term of functional traits were analyzed with CCA, and hierarchical ascending classification allowed the identification of several groups in each Mediterranean area

Figure 4. Ordination in the plane of the two axes of functional traits after a canonical correspondence analysis from a matrix composed by the 67 plant species observed on the line point quadrat of the 25 plots in the Honfría forest in Spain and a matrix composed by the same plant species and their functional traits. Groups were identified by an hierarchical ascending classification. Plots, and some plant species associated to each group were indicated on the figure. Codes of plant species are indicated in Appendix 1. The total variation explained by CCA is 39%.
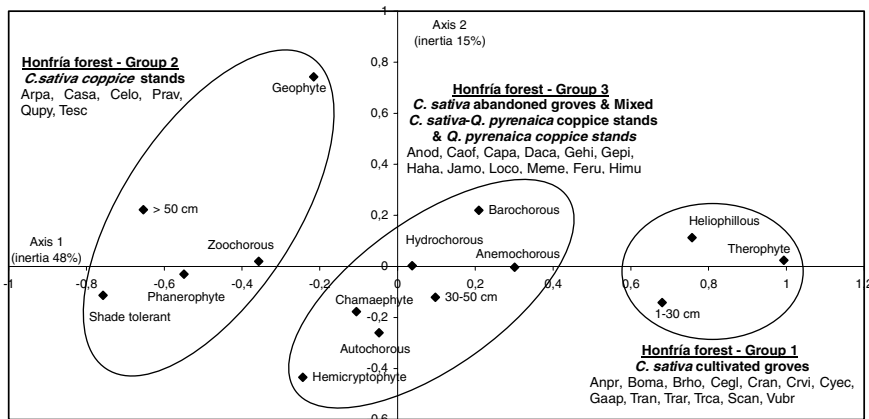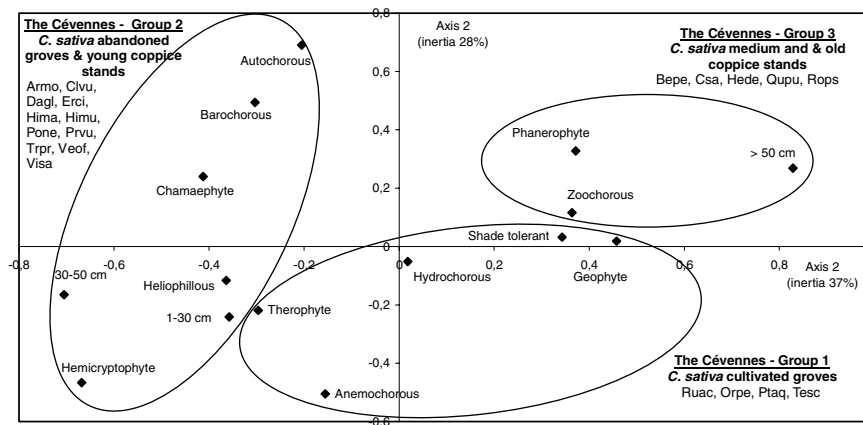
Figure 5. Ordination in the plane of the two axes of functional traits after a canonical correspondence analysis from a matrix composed by the 41 plant species observed on the line point quadrat of the 25 plots in the Cévennes in France and a matrix composed by the same plant species and their life traits. Groups were identified by an hierarchical ascending classification. Plots, and some plant species associated to each group were indicated on the figure. Codes of plant species are indicated in Appendix 1. The total variation explained by CCA is 46%.

studied. In the Honfría forest, the *C. sativa* cultivated groves (group 1) were characterized by small heliophillous therophytes (Figure 4). The *C. sativa* coppice stands (group 2) were characterized by shade tolerant phanerophytes with zoochorous dispersal mode and geophytes. The *C. sativa* abandoned groves, mixed *C. sativa–Q. pyrenaica* coppice stands and *Q. pyrenaica* coppice stands (group 3) were composed essentially by hemicryptophytes and chamaephytes with anemochorous or barochorous dispersal mode.

In the Cévennes, the *C. sativa* cultivated groves (group 1) were characterized by therophytes with anemochorous dispersal mode and geophytes (Figure 5). The *C. sativa* abandoned groves and the young coppice stands (group 2) were characterized by heliophillous hemicryptophytes and chamaephytes. The *C. sativa* medium and old coppice stands (group 3) were composed more particularly by phanerophytes with zoochorous dispersal mode.

In the case of *C. sativa* coppice stands on Etna volcano in Italy, Monte Crisimo (group 1) were more particularly characterized by therophytes and chamaephytes (Figure 6), Triciala (group 2) by hemicryptophytes with anemochorous dispersal mode, Piano Lepre (group 3) by geophytes with barochorous dispersal mode, and Balilla and Fornazzo (group 4) by shade tolerant phanerophytes with zoochorous dispersal mode.

Discussion and concluding remarks

A main trend emerging from our species richness data was higher species richness in the chestnut cultivated groves than in coppice stands; both in the
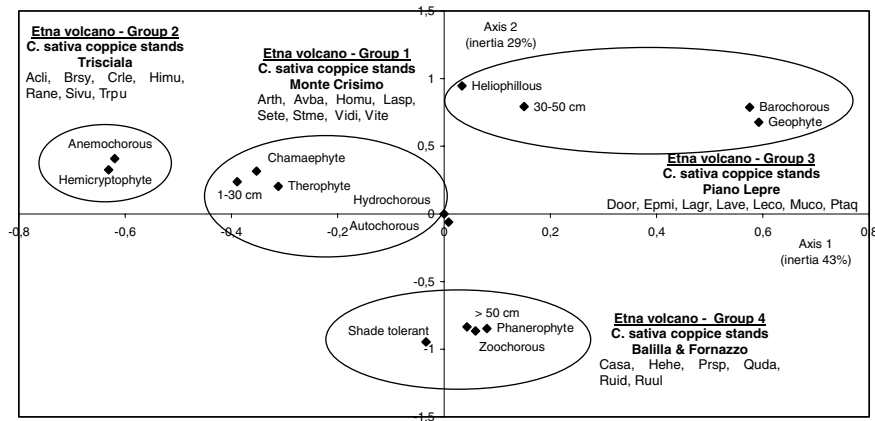
Figure 6. Ordination in the plane of the two axes of life traits after a canonical correspondence analysis from a matrix composed by the 40 plant species observed on the line point quadrat of the 25 plots on Etna volcano in Italy and a matrix composed by the same plant species and their life traits. Groups were identified by an hierarchical ascending classification. Plots, and some plant species associated to each group were indicated on the figure. Codes of plant species are indicated in Appendix 1. The total variation explained by CCA is 49%.

Honfría forest in Spain and in the Cévennes in France. However, species richness in the cultivated groves of the Honfría forest (53 ± 4 species) was significantly higher than in the cultivated groves of the Cévennes (38 ± 4 species) ($p < 0.01$). The strawberry culture in some years under chestnut groves in the Honfría forest can explain this difference. Indeed, the high bio-diversity among plants was always related to perturbations (pruning, grazing, fire, etc.), and often observed in Mediterranean areas (Romane et al. 1992). The species diversity decrease observed along the successional gradient in the Cévennes appears to be a general trend in Mediterranean Basin (Tatoni and Roche 1994; Debussche et al. 1996). On Etna volcano, tradition is coppice management and not grove, and species diversity in coppice stands was lowest than in the chestnut cultivated groves of the Honfría forest and the Cévennes. Nevertheless, species diversity in Trisciala coppice stand was not significantly different from chestnut abandoned groves in the Cévennes ($p > 0.05$). In Tri-sciala, stumps have regular and large spacing and thus light, which is recognized as a factor linked positively with species richness (Grime and Jarvis 1975; Gilliam et al. 1995; Yorks and Dabydeen 1999), is available in the understorey and favour growth. Like in the study of Rubio et al. (1999) in Extremadure (Central Spain), or Kitazawa and Ohsawa (2002) in Chiba (Central Japan), the difference according to management type was well observed.

The species composition differences among management type showed us that generally small heliophillous therophytes characterized *C. sativa* cultivated groves. Low intensity disturbance can explain the persistence of annual species in cultivated groves (Lavorel 1999). Hemicryptophytes with anemochorous

dispersal mode and chamaephytes characterized *C. sativa* abandoned groves, mixed *C. sativa–Q. pyrenaica* coppice stands, *Q. pyrenaica* coppice stands, and young *C.sativa* coppice stands. Phanerophytes with zoochorous dispersal mode characterized more particularly medium and old coppice stands (coppice stands that differ by the shoot age). This pattern coincides with the general trend described in Southern France; annual plants are substituted by perennial grasses and shrubs with canopy closure (Houssard et al. 1980; Escarré et al. 1983; Tatoni and Roche 1994).

Perturbations were necessary to maintain a quite high level of species diversity. In contrast, the abandonment of chestnut stands, for decades or even centuries, will turn into closed and homogeneous vegetation with decreasing plant diversity. One solution could be to maintain a landscape mosaic consisting of diverse chestnut stands modified by human activities (chestnut groves, abandoned chestnut groves and chestnut coppice stands) (Gondard et al. 2001; Rubio and Escudero 2003). This could enhance regional plant diversity. However, in our study we recorded only common species, thus if rare species have been observed, the estimation of biodiversity would be review, and quality aspect take into account. Moreover, due to some of the unsatisfactory aspects of the experimental design (replication number), our study only indicates, but does not validate, several possible management techniques, of which remain to be tested further.

Acknowledgements

Appendix 1. Functional traits (life form, dispersal mode, plant height and light tolerance) of plant species observed along the point quadrat line and used in the Canonical Correspondence Analysis according to available data: Molinier and Müller 1938; Pignatti 1982; van der Pijl 1982; Bonnier 1990; De Bolos et al. 1993. Th – therophyte, G – geophyte, H – hemicryptophyte, Ch – chamaephyte, Ph – phanerophyte.

Code	Species	Life form	Dispersal mode	Height	Light tolerance
Acli	*Achillea ligustica*	H	Anemochorous	30–50 cm	shade tolerant
Acmi	*Achillea millefolium*	H	Anemochorous	30–50 cm	shade tolerant
Alpe	*Alliaria petiolata*	H	Anemochorous	30–50 cm	shade tolerant
Anod	*Anthoxantum odoratum*	H	Anemochorous	30–50 cm	heliophillous
Anpr	*Anthemis pratensis*	Th	Anemochorous	1–30 cm	heliophillous
Armo	*Arenaria montana*	H	Anemochorous	1–30 cm	heliophillous

Appendix 1. Continued.

Code	Species	Life form	Dispersal mode	Height	Light tolerance
Arpa	*Aristolochia pallida*	G	Barochorous	30–50 cm	shade tolerant
Arth	*Asplenium trichomanes*	Th	Anemochorous	1–30 cm	shade tolerant
Asal	*Asphodelus albus*	G	Barochorous	30–50 cm	heliophillous
Astr	*Asplenium trichomanes*	H	Zoochorous	1–30 cm	shade tolerant
Avba	*Avena barbata*	Th	Anemochorous	> 50 cm	heliophillous
Avsu	*Avena sativa*	Th	Zoochorous	> 50 cm	heliophillous
Bepe	*Betula pendula*	Ph	Anemochorous	> 50 cm	shade tolerant
Brsy	*Brachypodium sylvaticum*	H	Anemochorous	30–50 cm	shade tolerant
Brma	*Bromus maximus*	Th	Anemochorous	30–50 cm	heliophillous
Brho	*Bromus hordeaceus*	Th	Zoochorous	1–30 cm	heliophillous
Cadi	*Carex distachia*	H	Barochorous	1–30 cm	shade tolerant
Caof	*Calamintha officinalis*	H	Zoochorous	30–50 cm	heliophillous
Capa	*Campanula patula*	H	Anemochorous	30–50 cm	heliophillous
Casa	*Castanea sativa*	Ph	Zoochorous	> 50 cm	shade tolerant
Cavu	*Calluna vulgaris*	Ch	Anemochorous	30–50 cm	shade tolerant
Cegl	*Cerastium glomeratum*	Th	Anemochorous	1–10 cm	heliophillous
Celo	*Cephalanthera longifolia*	G	Anemochorous	1–30 cm	shade tolerant
Chju	*Chondrilla juncea*	H	Anemochorous	> 50 cm	shade tolerant
Coma	*Conopodium majus*	G	Barochorous	> 50 cm	shade tolerant
Clvu	*Clinopodium vulgare*	H	Hydrochorous	30–50 cm	heliophillous
Coar	*Convolvulus arvensis*	H	Barochorous	30–50 cm	heliophillous
Coav	*Corylus avellana*	Ph	Zoochorous	> 50 cm	shade tolerant
Coli	*Corrigiola littoralis*	H	Autochorous	1–30 cm	shade tolerant
Cran	*Crucianella angustifolia*	Th	Anemochorous	1–30 cm	heliophillous
Crle	*Crepis leontodontoides*	H	Anemochorous	30–50 cm	heliophillous
Crvi	*Crepis virens*	Th	Anemochorous	30–50 cm	heliophillous
Cyec	*Cynosurus echinatus*	Th	Anemochorous	1–30 cm	heliophillous
Cysc	*Cytisus scoparius*	Ph	Autochorous	> 50 cm	shade tolerant
Daca	*Daucus carota*	H	Anemochorous	30–50 cm	heliophillous
Dagl	*Dactylis glomerata*	H	Anemochorous	> 50 cm	heliophillous
Deme	*Deschampsia media*	H	Zoochorous	30–50 cm	shade tolerant
Door	*Doronicum orientale*	G	Anemochorous	30–50 cm	shade tolerant
Epla	*Epilobium lanceolatum*	H	Anemochorous	30–50 cm	shade tolerant
Epmi	*Epipactis microphylla*	G	Anemochorous	1–30 cm	shade tolerant
Erar	*Erica arborea*	Ch	Barochorous	> 50 cm	shade tolerant
Erci	*Erica cinerea*	Ch	Barochorous	30–50 cm	shade tolerant
Feov	*Festuca ovina*	H	Anemochorous	30–50 cm	heliophillous
Feru	*Festuca rubra*	H	Anemochorous	30–50 cm	shade tolerant
Gaap	*Galium aparine*	Th	Zoochorous	1–30 cm	heliophillous
Gamo	*Galium mollugo*	H	Barochorous	30–50 cm	shade tolerant
Gasa	*Galium saccharatum*	Th	Zoochorous	1–30 cm	shade tolerant
Gefl	*Genista florida*	Ch	Autochorous	1–30 cm	shade tolerant
Gehi	*Genista hispanica*	Ch	Autochorous	1–30 cm	shade tolerant
Gepi	*Genista pilosa*	Ch	Autochorous	1–10 cm	shade tolerant
Gero	*Geranium robertianum*	Th	Autochorous	1–30 cm	shade tolerant
Gnlu	*Gnaphalium lutescens*	H	Autochorous	1–30 cm	heliophillous
Haha	*Halimium lasianthum*subsp *.alyssoides*	Ch	Zoochorous	30–50 cm	shade tolerant
Hehe	*Hedera helix*	Ph	Zoochorous	> 50 cm	shade tolerant
Hico	*Hippocrepis comosa*	H	Autochorous	1–30 cm	shade tolerant

Appendix 1. Continued.

Code	Species	Life form	Dispersal mode	Height	Light tolerance
Hihi	*Hispidella hispanica*	H	Anemochorous	1–30 cm	heliophillous
Hima	*Hieracium maculatum*	H	Anemochorous	30–50 cm	shade tolerant
Himu	*Hieracium murorum*	H	Anemochorous	30–50 cm	shade tolerant
Hipi	*Hieracium pilosella*	H	Anemochorous	1–30 cm	shade tolerant
Hium	*Hieracium umbellatum*	H	Anemochorous	30–50 cm	heliophillous
Hola	*Holcus lanatus*	H	Anemochorous	> 50 cm	heliophillous
Homo	*Holcus mollis*	H	Zoochorous	30–50 cm	heliophillous
Homu	*Hordeum murinum*	Th	Anemochorous	1–30 cm	heliophillous
Hyra	*Hypochaeris radicata*	H	Anemochorous	30–50 cm	heliophillous
Ilaq	*Ilex aquifolium*	Ph	Anemochorous	> 50 cm	shade tolerant
Jamo	*Jasione montana*	H	Anemochorous	1–30 cm	shade tolerant
Laan	*Lathyrus angulatus*	Th	Barochorous	30–50 cm	heliophillous
Lagr	*Lathyrus grandiflorus*	G	Autochorous	> 50 cm	heliophillous
Lasp	*Lathyrus sphaericus*	Th	Autochorous	1–30 cm	heliophillous
Lave	*Lathyrus venetus*	G	Barochorous	30–50 cm	heliophillous
Leco	*Leopoldia comosa*	G	Anemochorous	1–30 cm	heliophillous
Lihe	*Linaria heterophylla*	H	Anemochorous	1–30 cm	heliophillous
Litr	*Linaria triornitophora*	H	Autochorous	30–50 cm	shade tolerant
Loco	*Lotus corniculatus*	H	Autochorous	1–30 cm	heliophillous
Loet	*Lonicera etrusca*	Ph	Zoochorous	30–50 cm	shade tolerant
Luca	*Luzula campestris*	H	Zoochorous	1–30 cm	heliophillous
Lufo	*Luzula forsteri*	H	Anemochorous	1–30 cm	shade tolerant
Lusi	*Luzula sieberi*	H	Zoochorous	1–30 cm	shade tolerant
Meme	*Melittis melissophyllum*	H	Zoochorous	30–50 cm	shade tolerant
Meun	*Melica uniflora*	H	Anemochorous	30–50 cm	shade tolerant
Muco	*Muscari commutatum*	G	Anemochorous	1–30 cm	heliophillous
Orco	*Ornithopus compressus*	Th	Zoochorous	30–50 cm	heliphillous
Orpe	*Ornithopus perpusillus*	Th	Zoochorous	1–30 cm	shade tolerant
Pehi	*Petrorhagia hispanica*	H	Autochorous	1–30 cm	heliophillous
Pimu	*Piptaterum multiflorum*	H	Anemochorous	> 50 cm	heliophillous
Plla	*Plantago lanceolata*	H	Anemochorous	1–30 cm	heliophillous
Pobu	*Poa bulbosa*	H	Barochorous	1–30 cm	heliophillous
Pone	*Poa nemoralis*	H	Anemochorous	30–50 cm	shade tolerant
Posy	*Poa trivialis* subsp. *sylvicola*	H	Anemochorous	30–50 cm	heliophillous
Prav	*Prunus avium*	Ph	Zoochorous	> 50 cm	shade tolerant
Prgr	*Prunella grandiflora*	H	Barochorous	1–30 cm	shade tolerant
Prsp	*Prunus spinosa*	Ph	Zoochorous	> 50 cm	shade tolerant
Prvu	*Prunella vulgaris*	H	Hydrochorous	1–30 cm	shade tolerant
Ptaq	*Pteridium aquilinum*	G	Anemochorous	> 50 cm	shade tolerant
Quda	*Quercus dalechampii*	Ph	Zoochorous	> 50 cm	shade tolerant
Qupu	*Quercus pubescens*	Ph	Zoochorous	> 50 cm	shade tolerant
Qupy	*Quercus pyrenaica*	Ph	Zoochorous	> 50 cm	shade tolerant
Rabu	*Ranunculus bulbosus*	H	Barochorous	30–50 cm	heliophillous
Rane	*Ranunculus neapolitanus*	H	Anemochorous	1–30 cm	shade tolerant
Rops	*Robinia pseudo-acacia*	Ph	Autochorous	> 50 cm	heliophillous
Ruac	*Rumex acetosella*	G	Anemochorous	> 50 cm	heliophillous
Ruid	*Rubus idaeus*	Ph	Zoochorous	> 50 cm	shade tolerant
Rupe	*Rubia peregrina* var . *longifolia*	H	zoochorous	> 50 cm	shade tolerant

Appendix 1. Continued.

Code	Species	Life form	Dispersal mode	Height	Light tolerance
Ruul	*Rubus ulmifolius*	Ph	zoochorous	> 50 cm	shade tolerant
Scan	*Scleranthus annuus*	Th	zoochorous	1–30 cm	heliophillous
Sete	*Sedum tenuifolium*	Ch	anemochorous	1–30 cm	heliophillous
Siin	*Silene inflata*	H	anemochorous	30–50 cm	shade tolerant
Sivu	*Silene vulgaris* subsp. *angustifolia*	H	anemochorous	30–50 cm	shade tolerant
Sovi	*Solidago virgaurea*	H	anemochorous	30–50 cm	shade tolerant
Stme	*Stellaria media*	Th	anemochorous	1–30 cm	shade tolerant
Tesc	*Teucrium scorodonia*	G	barochorous	30–50 cm	shade tolerant
Thga	*Thapsia garganica*	H	anemochorous	> 50 cm	heliophillous
Toar	*Torilis arvensis*	Th	zoochorous	30–50 cm	shade tolerant
Tran	*Trifolium angustifolium*	Th	anemochorous	1–30 cm	heliophillous
Trar	*Trifolium arvense*	Th	anemochorous	1–30 cm	heliophillous
Trca	*Trifolium campestre*	Th	anemochorous	1–30 cm	heliophillous
Trpr	*Trifolium pratense*	H	anemochorous	1–30 cm	heliophillous
Trpu	*Trifolium pratense* subsp. *semi-purpureum*	H	anemochorous	1–30 cm	heliophillous
Trre	*Trifolium repens*	H	anemochorous	1–30 cm	shade tolerant
Veof	*Veronica officinalis*	H	hydrochorous	1–30 cm	shade tolerant
Vidi	*Vicia disperma*	Th	anemochorous	30–50 cm	heliophillous
Vilu	*Vicia lutea*	Th	autochorous	30–50 cm	heliophillous
Vips	*Vicia pseudocracca*	Th	barochorous	30–50 cm	heliophillous
Visa	*Vicia sativa*	H	autochorous	30–50 cm	heliophillous
Vite	*Vicia tenuifolia*	Th	anemochorous	30–50 cm	heliophillous
Vubr	*Vulpia bromoides*	Th	zoochorous	1–30 cm	heliophillous

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