ORIGINAL PAPER

From the backyard to the backcountry: how ecological and biological traits explain the escape of garden plants into Mediterranean old fields

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Abstract To explain current ornamental plant invasions, or predict future ones, it is necessary to determine which factors increase the probability of an alien species becoming invasive. Here, we focused on the early phases of ornamental plant invasion in order to identify which plant features and cultivation practices may favor the escape of ornamental plants from domestic gardens to abandoned agricultural land sites in the Mediterranean Region. We used an original approach which consisted in visiting 120 private gardens in an urbanizing rural area of the French Mediterranean backcountry, and then visited surrounding old fields to determine which planted species had escaped out of the gardens. We built a database of 407 perennial ornamental alien species (most of which were animal-dispersed), and determined nineteen features that depicted the strength of species' propagule pressure within gardens, the match between species requirements and local physical environment, and each species' reproductive characteristics. Using standard and phylogenetic logistic regression, we found that ornamental alien plants were more likely to have escaped if they were planted in gardens' margins, if they had a preference for dry soil, were tolerant to high-pH or pH-indifferent, and if they showed a capacity for clonal growth. Focusing only on animal-dispersed plants, we found that alien plants were more likely to have escaped if they were abundant in gardens and showed preference for dry soil. This suggests that gardening practices have a primary impact on the probability of a species to escape from cultivation, along with species pre-adaptation to local soil conditions, and capacity of asexual reproduction. Our results may have important implications for the implementation of management practices and awareness campaigns in order to limit ornamental plants to becoming invasive species in Mediterranean landscapes.

Keywords Biological invasions ·
Ornamental plants · Propagule pressure ·
Pre-adaptation · Phylogenetic regression

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Introduction

Many invasive plant species have been accidentally transported by humans or deliberately introduced for ornamental, forestry or agricultural purposes (Mack

and Lonsdale 2001). Horticulture is now recognized as a major pathway for the introduction of alien terrestrial plants (Hodkinson and Thompson 1997; Reichard and White 2001; Dehnen-Schmutz et al. 2007a, b; Foxcroft et al. 2008; Křivánek and Pyšek 2008; Lambdon et al. 2008a). Although the majority of plants imported for horticulture will never become invasive (Williamson and Fitter 1996; Burt et al. 2007), many successful horticultural escapees have caused severe economic (McNeely 2001; Pimentel et al. 2005) and ecological damages (Vitousek et al. 1997; Whelan et al. 2006). Thus, disentangling the sociological, ecological and biological factors that allow introduced ornamental plants to become harmful invaders is of major importance.

From a theorical perspective, an introduced species will succeed in a new region if it overcomes the following stages: introduction of alien propagules, existence as casual alien, naturalization, and spread (Richardson et al. 2000a). However, a number of geographical, abotic and biotic barriers may prevent the introduced plant from becoming invasive (Richardson et al. 2000a), and it is crucial to understand which factors may allow alien plants to overcome these barriers and favor the transition from one stage of invasion to another (Milbau and Stout 2008). To do so, comparing species of varying invasive potential (i.e., cultivated, casual, naturalized, and invasive) may be the most promising way to identify factors that promote invasiveness in introduced plants (Nijs et al. 2004; Milbau and Stout 2008). Although some studies have focused on the early stages by a "source-area" approach (Goodwin et al. 1999; Prinzing et al. 2002), there is still a lack of information about the transition between plant cultivation and plant naturalization outside of cultivation. Given the constant rise of gardening practices and the increasing urbanization which favors managed parks and residential areas with gardens, the risks of escape of ornamental plant species to natural communities is constantly increasing. Thus, identifying the factors which allow horticultural plants to become invasive would be an important step in assessing the risks associated with different ornamental plant species and preserving biodiversity in natural habitats.

First of all, propagule pressure may strongly influence a species' colonization success (Lockwood et al. 2005), in particular for ornamental plants (Dehnen-Schmutz et al. 2007a). Species introduced for horticultural purposes may have an advantage over accidentally introduced species because they may suffer less from demographic stochasticity due to small founding populations (Mack 1995, 2000). If ornamental plants are planted in high local abundance, introduced populations of ornamental plants may become demographic sources that will send a number of immigrants to surrounding landscapes (Maron 2006). High propagule pressure may also have evolutionary consequences: recent experimental results proved that multiple introductions of ornamental or agronomic species may increase their evolutionary potential in their introduced populations by favoring genetic admixture and emergence of novel genotypes with higher invasive potential (Lavergne and Molofsky 2007).

Second, ornamental species that have gone through the dispersal phase do not necessarily colonize habitats outside cultivation since their environmental requirements (e.g., soil type and climatic conditions) will also determine their probability of naturalization (Theoharides and Dukes 2007). Many alien species introduced to a new region do not survive because they are generally not adapted to the abiotic conditions of their new environment. This may be particularly true in harsh environments (Prinzing et al. 2002). After passing through a climate-matching filter, ornamental species can form stable source populations that may eventually spread into natural areas (Mack and Lonsdale 2001; Theoharides and Dukes 2007). It has been shown that species intentionally or accidentally transferred into a new region are more likely to become invasive if the climate of their donor region is at least partly overlapping with the one of its alien range (Thuiller et al. 2005). This has often been termed pre-adaptation of introduced species to their region of introduction, and may strongly contribute to the naturalization and further spread of introduced species. This pre-adaptation may concern a number of edaphic (soil type, fertility, humidity, pH) (Prinzing et al. 2002) and climatic conditions (cold tolerance and drought resistance) (Prinzing et al. 2002; Maron 2006).

Third, the spread of ornamental plants out of gardens is also determined by their capacity of dispersing reproductive or vegetative propagules across the landscape (Myers and Bazely 2003). Mode of seeds or fruits dispersal may play a primary role, since wind, water and animal-mediated dispersal are

known to be efficient dispersal mechanisms (Lloret et al. 2005). Also, asexual reproduction is another potentially efficient mechanism of local spread for invasive plants (Pauchard and Shea 2006). Many ornamental plants will have 'showy' fruit displays, attracting generalist seed dispersers; such species, grown by gardeners at numerous foci near the urban/wildland interface, are well placed to spread into natural areas (Alston and Richardson 2006). Thus, dispersal of these species depends on the presence of birds (Richardson et al. 2000b), which may also be affected by the landscape structure (Gosper et al. 2005; Buckley et al. 2006). Fruit traits may also be important for the spread of ornamental plants, such as fruit morphology, colour and display, nutritional quality, accessibility and phenology, because these traits may affect frugivory and thus seed dispersal (Gosper et al. 2005).

The Mediterranean Region is particularly appropriate for the study of ornamental plant invasions. The Region has experienced a long history of species introduction (Hulme 2004) which continue to increase (Lambdon et al. 2008b) with the development of residential areas in semi-natural and natural areas (Julien 1999; European Environment Agency Report 2006), thus contributing to a high diversity of introduced alien taxa. The increase of garden/fallow land interfaces particularly in urbanizing rural areas constitutes suitable ecotones that may favor the escape of alien plants. These interfaces are vulnerable to invasion since they are subject to edge effects due to fragmentation and high propagule transport resulting from their proximity to urban environments (Alston and Richardson 2006). Also, the mediterranean context where alien zoochorous species can be dispersed by generalist animals (Debussche and Isenmann 1990; Debussche and Lepart 1992; Debussche and Isenmann 1994; Ne'eman and Izhaki 1996) may cause introduced zoochorous species to become more likely invasive because natural vectors are already present for their dispersion. Finally, many Mediterranean-climate regions of the world, such as South Africa, California, Central Chile and Western Autralia are important donor regions of alien ornamental plants (e.g., Thuiller et al. 2005), so that many introduced ornamentals are potentially pre-adapted to the environmental conditions of the Mediterranean Basin (arid climate, strong summer drought, calcareous soil, nutrient poor soils).

In this study, we aim at identifying which ornamental plant features and cultivation habits favor the escape of ornamental plants into mediterranean old fields according to the three hypotheses detailed above, namely 'propagule pressure', 'climate matching' and 'reproductive characteristics' hypotheses (see Table 1). In an urbanizing rural area of the French Mediterranean backcountry, we visited 120 private gardens to estimate the pool of perennial ornamental cultivated species (Marco et al. 2008a) and then visited surrounding old fields to determine which species had successfully escaped outside of cultivation. We previously analyzed local and landscape factors that enhanced richness of escaped garden plants in old fields in the same study area (Marco et al. 2008b). The situation of study gardens near semi-natural and natural areas gives us the opportunity to focus on the early transition phases of the process of ornamental plant invasions. We used standard and phylogenetic logistic regression to test whether perennial garden species were more likely to escape to surrounding old fields, (1) when they were abundant and planted near the margins of gardens ('propagule pressure'), (2) when their edaphic and climatic tolerance match local ones in natural habitats ('climate matching'), (3) their flowering period was longer and extended through the summer, and when they were dispersed by birds ('reproductive characteristics'). We also specifically focused on zoochorous species to test whether zoochorous species were more likely to escape when (1) their fruit size ranged between 6 and 10 mm, the most common sizes for bird-dispersed fruits (Gosper et al. 2005), (2) their fruits were of a 'showy' colour and (3) their fruiting period was longer and matched with major bird migration periods.

Methods

Species list, data, and phylogeny

Our study was performed in the Lauris neighborhood, an urbanizing rural area of the French Mediterranean backcountry (2,181 ha), located 70 km north-west of Marseille. To estimate the pool of ornamental cultivated species we visited 120 private gardens owing three housing density type (Marco et al. 2008a). In order to provide a homogeneous distribution of gardens, houses from five main streets within

Table 1 Description of the variables used to predict species' probability of escaping out of cultivation

Hypotheses	Variables	Abbreviation	Type	Data sources	Levels
Propagule pressure	Garden position	GARL	Continuous	a	1,2,3,4 from house to garden margins
	Abundance in gardens	ABUN	Continuous	a	Very low (<50), low (50–100), medium (10–500), strong (>500)
Climate-matching	Hardiness	HARD	Continuous	c, d, f, i, j	Frost intolerant (T° > 5°C), semi-hardy (T° > 0°C), hardy and very hardy (T° > −5°C).
	Drought resistance	RESI	Continuous	c, d, f, i, j	Very low, low, medium, strong, very strong
	pH	pH	Categorical	c, d, f, i, j	pH ≤ 7, pH = 7, pH ≥ 7, indifferent
	Soil moisture	HUMI	Continuous	c, d, f, i, j	Dry, normal, fresh soil
	Soil type	TYPE	Categorical	c, d, f, i, j	Clayey-humid, normal, sandy-calcareous-indifferent
	Soil fertility	FERT	Continuous	c, d, f, i, j	Poor, normal, rich
Reproductive characteristics	Flowering phenology	FLOP	Categorical	b, g, k, l, m, n, o, p	None, autumn–winter, spring, summer
	Length of flowering period	FLOS	Continuous	b, g, k, l, m, n, o, p	None, short (1–3 months), medium (4–6 months), long (>6 months)
	Pollination vector	POLL	Categorical	b, g, k, l, m, n, o, p	None, abiotic, biotic, autogamous, mixed
	Sex repartition	SREP	Categorical	g, k, l, m, n, o, p	Dioecious, monoecious
	Mating system	REPT	Categorical	g, h, k, l, m, n, o, p	None, allogamous, autogamous, mixed
	Fruiting phenology	FRUP	Categorical	e, j	None, not indicated, spring–summer, autumn–winter
	Length of fruiting period	FRUS	Continuous	e, j	None, not indicated, short (<1 month), medium (1–3 months), long (>3 months)
	Dispersal mode	DISM	Categorical	b, g, h, k	None, zoochory, anemochory, myrmecochory-barochory-autochory
	Vegetative reproduction	VEGR	Categorical	g, h, k	Yes, no
	Seed size	SEES	Categorical	g, k	Unknown, indicated, medium (<5 mmΦ), large (5–10 mmΦ), very large (>10 mmΦ)
	Seed colour	SEEC	Categorical	a, b, e	Dark, red–orange, yellow, others, not indicated

Variables are organized relative to our different working hypotheses, being 'climate matching', 'propagule pressure' and 'reproductive characteristics'. For each variable, we give the abbreviation used in the results description (Abbreviation), its variable type (Type), i.e., being continuous or categorical, and its respective categories (Levels). Data were drawn from field observations, from horticultural literature and from species traits databases (Data sources)

The main sources of information used to complete the database of species traits were a: field observations; b: Fournier (1947); c: Collectif (1990); d: Huxley (1992); e: De Belder and Misonne (1997); f: Bärtels (1998); g: Julve (1998); h: Gachet et al. (2004); i: Brickell and Mioulane (2004); j: Burnie et al. (2006); k: The Flora of China (http://hua.huh.harbard.edu/china/); l: The Ecological Flora of the British Isles (http://www.york.ac.uk/res/ecoflora/cfm/ecofl/index.cfm); m: Interactive Flora of NW Europe (http://ip30.eti.uva.nl/bis/flora.php); n: FloraBase the Western Australian Flora (http://florabase.calm.wa.gov.au/); o: Plants for a Future database (http://www.pfaf.org); p: Swaziland's Flora Database (http://www.sntc.org.sz/flora/)

each housing density type were chosen for survey. Each street was then exhaustively visited so that the entire length and both sides of each street were examined and each house visited. After requesting permission to undertake the survey on the resident's property, native and alien cultivated plants were recorded during an exhaustive survey of the garden. The garden size of these dwellings ranged from 2 to

10,000 m^2 and the combined area of all the gardens sampled was 21.5 ha. Given that 92% of ornamental species cultivated in the study neighborrhood were perennials, we focused our study only on perennial species. Perennial species are also the major group of invasive plant species in the world (Weber 2003).

Then we recorded all perennial alien cultivated plants that had escaped in 180 abandoned agricultural land sites of the same study area. This habitat represents 10% of the entire of study area, and was chosen because ruderal, early successionnal habitats are the ones that receive the most invasive species in Mediterranean regions (Le Floc'h 1991; Meiners et al. 2002). Abandoned agricultural land site areas ranged from 0.056 to 44.8 ha and the total area of all the sampled abandoned agricultural land sites was 101 ha. In each abandoned agricultural land site, all the alien perennial escaped plants from gardens were recorded by walking all over the site using a reasonably consistent search effort (e.g., 60 min ha^{-1}).

Each species was assigned to its proper systematic family, order and class according to the Angiosperm Phylogeny Group (2003). For each species, we also gathered nineteen traits in order to test working hypotheses (Table 1). Data were drawn from our own field observations, from horticultural literature and from species traits databases. Refer to Table 1 for a full description of the study species characteristics and the data sources used to complete the database. Finally, each species was coded as 1 if it was escaped (either casual, established, or invasive species) or as 0 if it was not escaped.

Phylogenetically related species may have similar traits and tend to occupy similar niches because of their shared evolutionary history (Harvey and Pagel 1991). Hence, relationships between species traits and likelihood of escape from gardens could reflect phylogenetic effects unrelated to the traits used in this study. By including phylogenetic information in the analyses, it is possible to determine to what extent escaped status of introduced species may be correlated with certain traits throughout a particular phylogeny. To obtain a conservative phylogenetic hypothesis, we used the web-tool Phylomatic (Webb and Donoghue 2005). Phylomatic takes as input a list of taxa, matches the taxa to the most resolved position possible in any of a set of master trees, and returns the phylogeny in a newick format. We arbitrarily set all branch lengths equals to unity, as advised in the absence of molecular

Fig. 1 Phylogenetic supertree of the 116 families that ▶ included the 407 species. Branch lengths are arbitrary. The two numbers following family names depicts the number of escaped species and the total species number of this family recorded in the study area, respectively

data (Martins and Garland 1991; Fig. 1). This approach is sometimes considered to assume a speciational mode of trait evolution (where phenotypic change occurs only at speciation, independently of branch lengths).

A potential bias could arise from the occurrence of hybrid taxa in our data set. We believe this has caused only a very small bias in our study, if any; since species numbers per study genus were always very small and some hybrid taxa were generally the only representatives of their genus in our data set.

Statistical analyses

We analysed the relationship between the probability of species escape of and their phylogenetic groups (Family, Class, Order) by performing Chi-square contingency tests. This was done for all species and also for focusing only on zoochorous species.

Before analysing the effect of species characteristics (Table 1) on probability of escaping, we looked for statistical associations between characteristics in order to prevent collinearity in our analysis. One way ANOVA was used to determine relationships between categorical and continuous variables (homogeneity of variance checked with Levene's Test), chi-square contingency tests were performed to detect association between categorical variables, and Pearson correlations tests were computed to test for relationships between continuous variables.

Probability of species' escape was modeled as a binomial process (0 = not escaped; 1 = escaped), using logistic regressions with species characteristics listed in Table 1 as explanatory variables. To do so, we used standard generalized linear models (GLM) with a uniform correlation structure (non-phylogenetic model) and generalized estimating equations (GEE) with a phylogenetic correlation structure. Test for the significance of each explanatory variable was performed using a Fischer test. Since the set of explanatory variables was quite large, we used a stepwise selection procedure based on Akaike's information criterion (AIC) to determine the minimum adequate GLM model. Then the same minimum
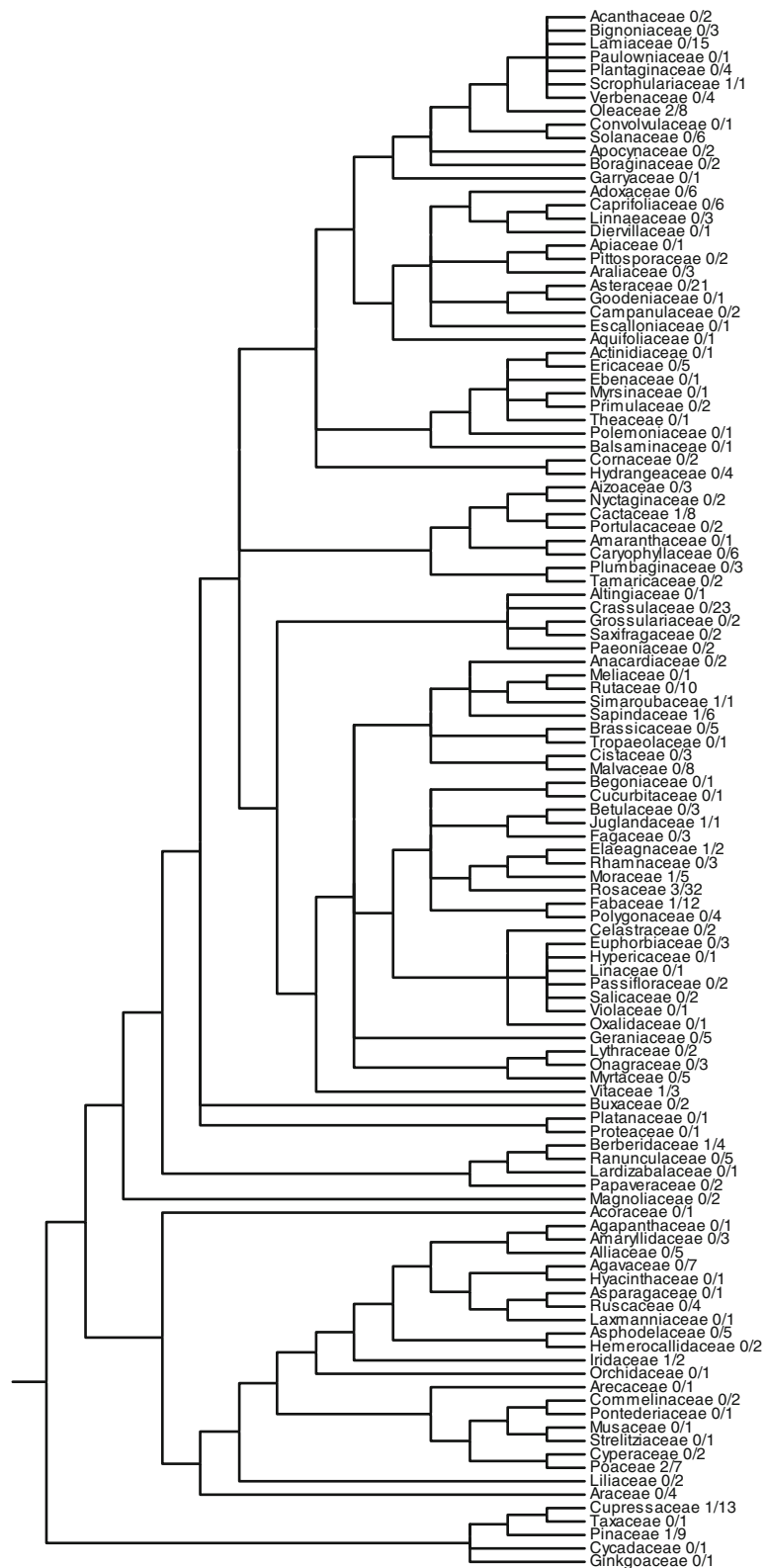
adequate model was fitted using GEE to test whether the integration of phylogenetic correlation structure into the model affected the significance of independent variables selected in the minimum adequate model. Note that there exists no information criterion allowing the comparison of GLM and GEE models with same fixed effects. The same procedure was employed for all species, but also focusing only on zoochorous species. All statistical analyses were performed using R (Ihaca and Gentleman 1996) using MASS package (Venables and Ripley 2002) and APE library (Paradis and Claude 2002).

Results

Around 88% of ornamental species planted in the study gardens were alien species. The inventories of perennial alien plant species, respectively in gardens and abandoned agricultural land sites, yielded a final list of 407 perennial alien plant species among which 20 were observed to have escaped into adjacent abandoned agricultural land sites (Appendix). Study species represented 116 different angiosperm families (Fig. 1). Only 119 species were zoochorous, among which 11 species had escaped. Out of the 407 cultivated perennial alien plants species collected in the combined area of all gardens the most frequent species was *Rosa* sp. (86%). The most abundant planted species were *x Cupressocyparis leylandii*, *Cupressus arizonica*, *Pyracantha* sp., *Prunus lauro-cerasus*, which were all planted in garden hedges (Marco et al. 2008a). Out of the 407 species, 20 were observed to have escaped into abandoned agricultural land sites. These had highly variable abundances ranging from one to >1,000 individuals. The most abundant escaped garden plant was *Pyracantha* sp.

with 1,653 individuals in the combined area of all abandoned agricultural land sites (101 ha). Among the most abundant escaped aliens, six species, namely *Acer negundo*, *Buddleia davidii*, *Ailanthus altissima*, *Robinia pseudoacacia*, *Cortaderia selloana* and *Opuntia ficus-indica,* are recognized 'harmful invasives' in the French Mediterranean and beyond, and twelve other escaped aliens are listed as 'potentially harmful invasives' on the French territory (Müller 2004).

We found no significant association between phylogenetic groups (Family, Order and Class) and species' escape probability for both all species and zoochorous species (Table 2), suggesting that phylogenetic effects on the probability species' escape was quite low.

Analyses of associations between traits showed that the variable "soil Type" was strongly correlated with many other ecological traits; hence we excluded this variable from further analyses based on the whole set of species. We also excluded the variable "soil Type" and "soil pH" for analyses concerning the zoochorous species database due to a strong statistical association.

Single logistic models (listed in Table 3) showed that many ecological and biological traits had significant effects on the probability of species escape. All variables but "Flowering phenology" and "Reproduction type" had a significant effect on the probability of species escape. All traits concerning climate-matching process and propagule pressure were significant. However, after incorporating phylogenetic information, "Hardiness" and "Resistance to drought", "Flowering span", "Fruiting phenology", "Fruiting span", "Dispersal type" and "Seed colour" were no longer significant. Only four out of the 18 study characteristics were included in the minimum adequate

Table 2 Results of contingency tests of association between species phylogenetic groups (Family, Order and Class) and species probability of escaping out of cultivation

| Escape probability | Phylogenetic groups | | | | | | | | |
| | Family | | | Order | | | Class | | |
	Chi^2	df	P	Chi^2	df	P	Chi^2	df	P
All species	123.78	113	0.229	27.68	41	0.944	0.718	2	0.698
Zoochorous species	43.44	51	0.764	12.63	27	0.991	1.169	2	0.557

For each test, we give the computed chi-square statistics (Chi^2), its degrees of freedom (df) and significance P-value (P). The same test was performed for the complete list (407 species) and also for the subset of 119 zoochorous species

Table 3 Results of standard and phylogenetic logistic regressions (GLM and GEE, respectively) of species probability of escaping outside cultivation as a function of predictive variables (abbreviations given in Table 1)

	GLM			GEE		
	df	F	P	df	F	P
Single models						
HARD	1	13.461	***	1	0.1286	NS
RESI	1	24.715	***	1	0.237	NS
PH	3	23.864	***	3	16.794	***
HUMI	1	31.106	***	1	13.397	***
FERT	1	6.5448	*	1	3.8943	*
VEGR	1	10.136	**	1	9.9513	**
FLOP	2	2.2968	NS	2	0.5155	NS
FLOS	1	6.9128	**	1	0.1304	NS
POLL	3	5.9884	***	1	6.2338	*
ABUN	1	10.327	**	1	12.238	***
SREP	1	12.851	***	1	8.3882	**
REPT	2	0.2899	NS	2	0.2244	NS
FRUP	3	7.1151	***	1	0.9644	NS
FRUS	1	11.264	***	1	2.8524	NS
DISM	3	6.8174	***	1	3.3348	NS
GARL	1	58.491	***	1	14.768	***
SEES	3	6.958	***	3	8.3381	***
SEEC	4	8.2664	***	1	1.8624	NS
Stepwise selection						
HUMI	1	47.420	***	1	14.7018	***
pH	3	21.710	***	3	13.8428	***
VEGR	1	12.003	***	1	4.9041	*
GARL	1	42.803	***	1	11.4633	***

Analyses done with the entire sample of study species. Results concern single-variable models and results of stepwise selection in order to reduce the entire set of predictive variables to the minimum adequate model. Significance of variables was assessed with a Fisher test

Degrees of freedom (*df*), Fisher test statistics (*F*) and associated *P*-value are given. *P*-values indicated as follows: *NS* no significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

model following the stepwise selection procedure (Table 3): alien introduced plants were more likely to be escaped if they had a preference for dry soil, if they were planted in gardens' margins, were high-pH or pH-indifferent species for soil conditions; and showed capacity for clonal growth (Fig. 2). The effects of independent variables were equally significant in the GLM and GEE minimum adequate models, suggesting that incorporating phylogenetic information into the model did not change model's fit (Table 3).

Concerning the subset of zoochorous species; single binomial models showed that all traits related to propagule pressure had a significant effect on the probability of species escaping out of gardens (Table 4). "Resistance to drought", "Humidity" and "Fertility" also had a significant effect. About reproductive traits, only "Vegetative reproduction" and "Seed colour" were correlated to the escape probability but had no significant effects after incorporating phylogenetic information. Only two out of the 16 traits tested were included in the minimum adequate model (Table 4). We found that zoochorous alien plants were more likely to have escaped if they were abundant in gardens and showed a preference for dry soils (Fig. 3). All species characteristics retained in the minimum adequate model remained significant after incorporating phylogenetic information (Table 4).

Discussion

Our work provides an original and interesting account of the factors that favour the escape of ornamental plants into abandoned agricultural lands in the Mediterranean backcountry. A primary result of our study was that almost 90% of ornamental species planted in private gardens have an alien origin, and that these planted alien species come from extraordinarily diverse phylogenetic origins. These two factors dramatically increase the probability that among the alien species planted in private gardens, a few will be 'pre-adapted' to regional environmental conditions and able to escape and colonize surrounding natural or semi-natural habitats. Indeed, most species escaped out of gardens in our study area are listed as harmful or potentially harmful invasives on the French territory. Our results are consistent with previous studies on ornamental plant invasiveness where species pre-adaptation to local abiotic conditions and ability for vegetative reproduction were found to have primary effects. The explanatory power of our models (34% for all ornamental species and 42% for zoochorous species) was inferior to the ones of previous studies (Dehnen-Schmutz et al. 2007a, b). This may be due to the lower number of escaped species in our study system and to the lack of available data on the history of species introductions. Data about species use in horticultural trade (Dehnen-Schmutz et al. 2007a, b) and species residence time
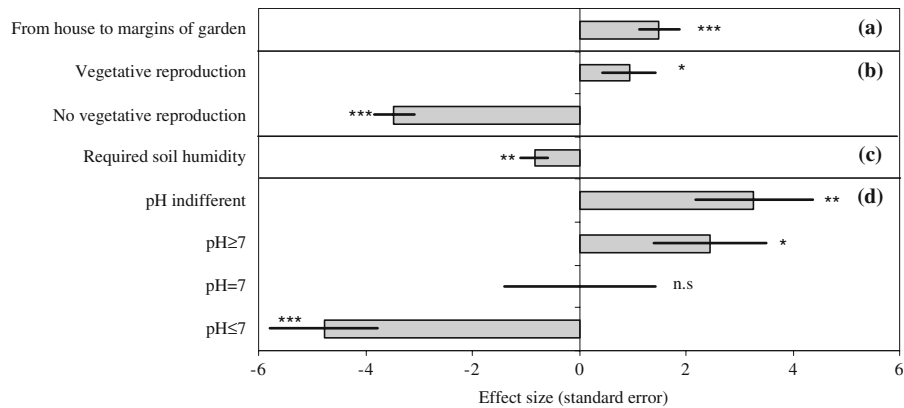
Fig. 2 Histogram depicting the estimated effects and their standard errors (*error bars*) of each class of ecological and biological traits on the probability of alien cultivated species escaping out of gardens into post-cultural fallows. Effect estimates were extracted from GLM models. Ecological and biological traits were species location in gardens (a), vegetative reproduction (b), tolerance to humidity (c), and soil pH preferences (d). *P*-values are indicated as follows: *ns* no significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

(Milbau and Stout 2008) would be particularly interesting here as this may also strongly influence the species probability of escaping. However, our study provides new insights into the key mechanisms that may allow ornamental plants to escape out of cultivation: we found that planting practices have a strong impact on species probability of escaping, probably because they may cause propagules pressure to increase at the landscape level.

Our results confirm that the ornamental alien species pre-adapted to the abiotic conditions prevailing in habitats surrounding their introduction zone have a better chance of escaping than other planted alien species (Richardson et al. 2000a; Prinzing et al. 2002). Most plant species are adapted to restricted soil conditions and may be unlikely to overcome barriers of unsuitable soils. Here we found that the probability of species escape was higher when their edaphic tolerance matched soil conditions of surrounding natural habitats, here Mediterranean old fields. In the Mediterranean region, predominantly calcareous, but also shallow and dry soils can be considered limiting factors for numerous plant species (Debussche and Isenmann 1990). Alien introduced plants were more likely to have escaped if they had a preference for dry soils and were high-pH or pH-indifferent. These findings show that the establishment processes of ornamental alien species in abandoned agricultural land sites strongly depend on their edaphic requirements. This is consistent with Cadotte et al. 2006a who found that successful invaders in the flora of Ontario were tolerant to a larger range of soil moistures relative to non invasive species. Besides, although we analysed the influence of hardiness and drought tolerance on probability of species' escape, we found no significant correlation. This contrasts with previous studies that showed an effect of species pre-adaptation to local climatic conditions on their colonization success. For instance, Hanspach et al. 2008 show that introduced species tolerances to low temperature improved their chance of becoming naturalized in Germany and increased their area of occupancy. Our results thus suggest that the main environmental features that determine the escape of ornamental species to old fields are edaphic factors (moisture, pH) in Mediterranean regions.

Propagule pressure has been proposed to have major impacts on the success of species colonizations (Mulvaney 2001; Lockwood et al. 2005; Dehnen-Schmutz et al. 2007a, b; Hanspach et al. 2008). We found that the more often an ornamental plant was grown and the closer it was planted to garden margins, the more likely the species had expanded to surrounding landscapes. Since, propagule pressure is difficult to measure and express quantitatively, several proxies of propagule pressure have been used in the literature, such as the number of visitors to nature reserves (Lonsdale 1999), economic activity (Taylor and Irwin 2004), the number of administrative units in which a species is planted and total planting area (Krivánek and Pyšek 2008), availability and prices in horticultural trade (Dehnen-Schmutz

Table 4 Results of standard and phylogenetic logistic regressions (GLM and GEE, respectively) of species probability of escaping outside cultivation as a function of predictive variables (abbreviations given in Table 1)

	GLM			GEE		
	df	F	P	df	F	P
Single models						
HARD	1	1.0973	NS	1	0.2499	NS
RESI	1	8.8546	**	1	2.2257	NS
HUMI	1	30.201	***	1	14.552	***
FERT	1	11.638	***	1	5.6914	*
VEGR	1	4.172	*	1	3.215	NS
FLOP	2	0.0239	NS	2	0.7231	NS
FLOS	1	3.0136	NS	1	0.7827	NS
POLL	3	0.9466	NS	1	0.6882	NS
ABUN	1	13.422	***	1	10.918	**
SREP	1	0.0192	NS	1	0.8208	NS
REPT	2	0.9775	NS	1	0.0282	NS
FRUP	2	1.503	NS	1	0.2788	NS
FRUS	1	0.0301	NS	1	1.2554	NS
GARL	1	4.3659	*	3	12.456	***
SEES	3	1.7128	NS	1	1.0497	NS
SEEC	4	3.273	*	1	0.3761	NS
Stepwise selection						
HUMI	1	32.857	***	1	14.0575	***
ABUN	1	15.903	***	1	8.5154	**

Analyses done with the sample of zoochorous study species. Results concern single-variable models and results of stepwise selection in order to reduce the entire set of predictive variables to the minimum adequate model for zoochorous species. Significance of variables was assessed with a Fisher test

Degrees of freedom (*df*), Fisher test statistics (*F*) and associated *P*-value are given. *P*-values indicated as follows: *NS* no significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

et al. 2007a) or the number of botanical gardens in which a species is cultivated (Hanspach et al. 2008). What distinguishes our study from these other multispecies comparative studies is the inclusion of variables on propagule pressure as measured by the abundance of species in private domestic gardens, and the location of alien species in gardens. Our results revealed that the abundance of ornamentals species in gardens predict the probability of escaping out of cultivation and establishing in surrounding old fields, particularly for zoochorous species. Zoochorous species planted in high abundance provide a high fruit density which affects bird fruit choices (Denslow

1986; Sargent 1990; Stanley and Lill 2001). Garden shrubs (*Pyracantha* sp., *Cotoneaster* sp.) which are frequently planted in hedges of the gardens (Marco et al. 2008a) are particularly attractive for generalist frugivorous birds. *Pyracantha* offers a great density of fruits (several millions per ha) and the seeds are dispersed by vertebrates, especially birds which can occur in very high numbers during migration periods (Debussche and Isenmann 1990). Moreover, the location of cultivated alien plants in gardens also appears critical for their probability of dispersing out of cultivation. Species planted in margins of gardens (lawns or hedges) were more likely to escape outside cultivation likely because growing near abandoned agricultural land sites reduces dispersal distance between introduction and potential establishment sites. This may increase the risk of alien species spread in the Mediterranean countryside by helping them to overcome dispersal barriers. Thus, the planting practices of gardeners may strongly influence the success of alien species outside cultivation and could be modified to reduce the risk of invasion by ornamental plants. An important factor which can also influence garden plant dispersal is the dumping of garden waste (Sullivan et al. 2005; Foxcroft et al. 2008). Garden refuse can effectively form important sites from which plants may spread. Here, we found no dumping in adjacent old fields studied. Seed of exotic plants are also likely to be inadvertently carried into old fields by human or animals (Mack and Lonsdale 2001). However, abandoned agricultural land sites in rural areas are not visited unlike forest fragments and reserves, which are more popular recreational areas where the visitors create disturbance and facilitate dispersal of alien plant species.

When local conditions do not allow species to produce seeds, the ability to spread vegetatively may be of major importance. Among the reproductive characteristics tested in our study, vegetative reproduction best enhanced species ability to escape out of gardens. This is in accordance with previous studies which showed that invasion success heavily depends on vegetative propagation (Reichard and Hamilton 1997; Lloret et al. 2005). Indeed, vegetative spread will facilitate establishment, rapid expansion and persistence within suitable habitats, and enhance competitive ability and resource-use efficiency (Pyšek et al. 1995). For species invading semi-natural areas, vertebrate and wind dispersal could also be important (Lloret et al. 2005) but we found no
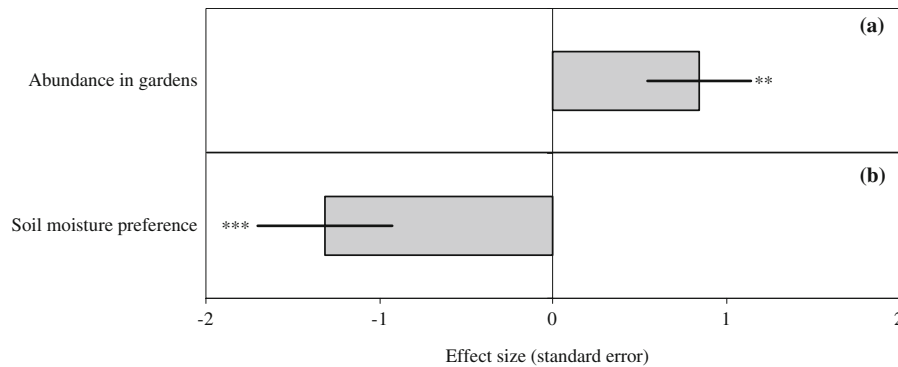
Fig. 3 Histogram depicting the estimated effects and their standard errors (*error bars*) of each class of ecological and biological traits on the probability of alien zoochorous cultivated species escaping out of gardens into post-cultural fallows. Effect estimates were extracted from GLM models. Ecological and biological traits were species abundance in garden (a) and soil moisture preference (b). *P*-values are indicated as follows: *ns* no significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

significant effect of dispersal-related traits. A possible reason for this is that in our study, the close contact between gardens and abandoned agricultural land sites will only require short dispersal distances in order to escape from cultivation (Marco et al. 2008b); thus bird or wind dispersal only give a limited advantage for the probability of species escaping out of cultivation, and both local and long distance dispersal determine spatial patterns of garden escapees (Pyšek and Hulme 2005). For other reproductive traits, period and duration of flowering were surprisingly not significant variables for species ability to escape to abandoned agricultural lands. These findings are consistent with Milbau and Stout (2008) who used an approach similar to ours, but contrast with other studies which identified these traits as important for the invasion process (Lloret et al. 2005; Goodwin et al. 1999; Cadotte and Lovett-Doust 2001; Lake and Leishman 2004; Cadotte et al. 2006a). We also identified no fruit traits that could explain escape probability of zoochorous species', which may be due to the low number of zoochorous escaped plants in our sample which reduced our statistical power. This result highlights the conceptual limitations of comparative approaches based on a limited subset of species, sampled from a particular habitat type (Cadotte et al. 2006b).

Conclusion

Our study provides interesting insights into the factors that may allow ornamental plants to escape out of cultivation and potentially become invaders. Alien species cultivated in gardens which exhibit pre-adaption to local environmental constraints, especially edaphic ones, and potential for vegetative reproduction have more chance to escape out of the gardens. We also demonstrated that species abundance within gardens, especially for zoochorous species, and species occurrence towards gardens margins increased their probability of escaping to surrounding landscapes. This highlights the importance of gardening practices regarding both pre-selection and propagule pressure on the establishment success of ornamental plants. Therefore, it may be possible to mitigate risks of establishment of ornamental plants in abandoned agricultural land sites by modifying gardening practices, at least in Mediterranean regions. It is important to encourage gardeners to plant native species as these species are also naturally adapted to local environmental constraints. Planting of pre-adapted aliens should be reduced to be occasional and or far from garden margins. Furthermore, local ornamental nurseries and the ornamental market should develop the cultivation and trade of native species. Gardeners should also avoid planting zoochorous monospecies hedges, which are an important source of escaped zoochorous alien species in abandoned agricultural land sites. Special attention must be given to the positioning of these species in gardens because this may affect the chance of species dispersal outside of gardens. Our study thus shows that it is important to conduct research on the transition phase from plant cultivation to plant naturalization outside of

cultivation because this may produce useful data for the implementation of adequate management policies. We also encourage the development of large databases probing characteristics of ornamental species as well as the cooperation with horticulture companies which may provide useful biological information on the ecological and biological features of ornamental plants. This will allow us to better understand the processes by which ornamentals become invaders and affect natural biodiversity, as this phenomenon is expected to increase in the years to come.

Appendix

See Table 5.

Table 5 List of the perennial alien plant species escaped (=1) and not escaped (=0) in abandoned agricultural lands of Lauris village

Species	Family	Not escaped/escaped
x Cupressocyparis leylandii	Cupressaceae	0
Abelia schumannii	Linnaeaceae	0
Abelia x grandiflora	Linnaeaceae	0
Abies nordmanniana	Pinaceae	0
Abies sp.	Pinaceae	0
Abutilon sp.	Malvaceae	0
Acacia dealbata	Fabaceae	0
Acanthus mollis	Acanthaceae	0
Acca sellowiana	Myrtaceae	0
Acer campestre	Sapindaceae	0
Acer negundo	Sapindaceae	1
Acer palmatum	Sapindaceae	0
Acer platanoïdes	Sapindaceae	0
Acer pseudoplatanus	Sapindaceae	0
Achillea sp.	Asteraceae	0
Acorus gramineus	Acoraceae	0
Actinidia chinensis	Actinidiaceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Aesculus hippocastanum	Sapindaceae	0
Agapanthus sp.	Agapanthaceae	0
Agave americana	Agavaceae	0
Ailanthus altissima	Simaroubaceae	1
Akebia sp.	Lardizabalaceae	0
Albizia julibrissin	Fabaceae	0
Albizia ombrella	Fabaceae	0
Alcea rosea	Malvaceae	0
Allium ascalonicum	Alliaceae	0
Allium cepa	Alliaceae	0
Allium sativum	Alliaceae	0
Allium schoenoprasum	Alliaceae	0
Alocasia macrorrhiza	Araceae	0
Aloe arborescens	Asphodelaceae	0
Aloe grandidentata	Asphodelaceae	0
Aloe sp.	Asphodelaceae	0
Aloysia triphylla	Verbenaceae	0
Althaea sp.	Malvaceae	0
Amaranthus caudatus	Amaranthaceae	0
Amaryllis belladonna	Amaryllidaceae	0
Ampelopsis robusta	Vitaceae	0
Anthemis sp.	Asteraceae	0
Aporocactus flagelliformis	Cactaceae	0
Aptenia cordifolia	Aizoaceae	0
Aquilegia alpina	Ranunculaceae	0
Arabis caucasica	Brassicaceae	0
Arbutus unedo	Ericaceae	0
Armeria sp.	Plumbaginaceae	0
Artemesia sp.	Asteraceae	0
Artemisia dracunculus	Asteraceae	0
Arum sp.	Araceae	0
Asparagus densiflorus	Asparagaceae	0
Aspidistra elatior	Ruscaceae	0
Aster novi-belgii	Asteraceae	0
Aubrieta sp.	Brassicaceae	0
Aucuba japonica	Garryaceae	0
Aurinia saxatilis	Brassicaceae	0
Begonia sp.	Begoniaceae	0
Bellis perennis	Asteraceae	0
Berberis x ottawensis	Berberidaceae	0
Berberis thunbergii	Berberidaceae	1
Bergenia cordifolia	Saxifragaceae	0
Betula sp.	Betulaceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Bougainvillea sp.	Nyctaginaceae	0
Bracteantha bracteata	Asteraceae	0
Broussonetia papyrifera	Moraceae	1
Brugmansia sp.	Solanaceae	0
Buddleja davidii	Scrophulariaceae	1
Buxus sempervirens	Buxaceae	0
Caesalpinia gilliesii	Fabaceae	0
Callistemon citrinus	Myrtaceae	0
Callistemon sp.	Myrtaceae	0
Calluna vulgaris	Ericaceae	0
Calocedrus decurrens	Cupressaceae	0
Caltha palustris	Ranunculaceae	0
Camellia japonica	Theaceae	0
Campanula carpatica	Campanulaceae	0
Campsis grandiflora	Bignoniaceae	0
Carpobrotus acinaciformis	Aizoaceae	0
Caryopteris sp.	Lamiaceae	0
Caryopteris x clandonensis	Lamiaceae	0
Catalpa bignonioides	Bignoniaceae	0
Ceanothus sp.	Rhamnaceae	0
Ceanothus x delileanus	Rhamnaceae	0
Cedrus deodara	Pinaceae	0
Centaurea montana	Asteraceae	0
Cerastium tomentosum	Caryophyllaceae	0
Ceratostigma plumbaginoides	Plumbaginaceae	0
Cercis siliquastrum	Fabaceae	0
Chaenomeles x superba	Rosaceae	0
Chamaecyparis lawsoniana	Cupressaceae	0
Chamerion fleischeri	Onagraceae	0
Chlorophytum comosum	Agavaceae	0
Choisya ternata	Rutaceae	0
Chrysanthemum sp.	Asteraceae	0
Cistus salviifolius	Cistaceae	0
Cistus sp.	Cistaceae	0
Cistus x purpureus	Cistaceae	0
Citrus aurantium	Rutaceae	0
Citrus clementina	Rutaceae	0
Citrus limon	Rutaceae	0
Citrus mitis	Rutaceae	0
Citrus paradisi	Rutaceae	0
Citrus sp.	Rutaceae	0
Clematis sp.	Ranunculaceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Clivia miniata	Amaryllidaceae	0
Commelina coelestis	Commelinaceae	0
Convallaria majalis	Ruscaceae	0
Cordyline australis	Laxmanniaceae	0
Coreopsis sp.	Asteraceae	0
Cornus alba	Cornaceae	0
Cornus sanguinea	Cornaceae	0
Coronilla glauca	Fabaceae	0
Cortaderia selloana	Poaceae	1
Corylus avellana	Betulaceae	0
Corylus maxima	Betulaceae	0
Cotinus sp.	Anacardiaceae	0
Cotoneaster franchetii	Rosaceae	0
Cotoneaster horizontalis	Rosaceae	1
Cotoneaster lacteus	Rosaceae	1
Cotoneaster microphyllus	Rosaceae	0
Cotoneaster salicifolius	Rosaceae	0
Cotoneaster sp.	Rosaceae	0
Crambe maritima	Brassicaceae	0
Crassula ovata	Crassulaceae	0
Crassula perforata	Crassulaceae	0
Crataegus monogyna	Rosaceae	0
Crocus sp.	Iridaceae	0
Cucurbita pepo	Cucurbitaceae	0
Cupressus arizonica	Cupressaceae	0
Cupressus macrocarpa	Cupressaceae	0
Cycas revoluta	Cycadaceae	0
Cyclamen sp.	Myrsinaceae	0
Cydonia oblonga	Rosaceae	0
Cymbidium sp.	Orchidaceae	0
Cyperus longus	Cyperaceae	0
Cyperus papyrus	Cyperaceae	0
Cytisus nigricans	Fabaceae	0
Dahlia sp.	Asteraceae	0
Delosperma cooperi	Aizoaceae	0
Deutzia sp.	Hydrangeaceae	0
Dianthus barbatus	Caryophyllaceae	0
Dianthus plumarius	Caryophyllaceae	0
Dianthus sp.	Caryophyllaceae	0
Dicentra spectabilis	Papaveraceae	0
Diospyros kaki	Ebenaceae	0
Echeveria elegans	Crassulaceae	0
Echinocereus sp.	Cactaceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Echinopsis sp.	Cactaceae	0
Eichhornia crassipes	Pontederiaceae	0
Elaeagnus angustifolia	Elaeagnaceae	0
Elaeagnus x ebbingei	Elaeagnaceae	1
Epiphyllum sp.	Cactaceae	0
Erigeron karvinskianus	Asteraceae	0
Erysimum cheiri	Brassicaceae	0
Escallonia sp.	Escalloniaceae	0
Eucalyptus gunnii	Myrtaceae	0
Eucalyptus sp.	Myrtaceae	0
Euonymus fortunei	Celastraceae	0
Euonymus japonicus	Celastraceae	0
Euphorbia candelabrum	Euphorbiaceae	0
Euphorbia myrsinites	Euphorbiaceae	0
Euphorbia sp.	Euphorbiaceae	0
Euryops chrysanthemoides	Asteraceae	0
Fagus sp.	Fagaceae	0
Felicia amelloides	Asteraceae	0
Festuca glauca	Poaceae	0
Ficus benjamina	Moraceae	0
Ficus carica	Moraceae	0
Ficus elastica	Moraceae	0
Foeniculum vulgare	Apiaceae	0
Forsythia x intermedia	Oleaceae	0
Fortunella japonica	Rutaceae	0
Fragaria vesca	Rosaceae	0
Fraxinus excelsior	Oleaceae	0
Fuchsia sp.	Onagraceae	0
Gaillardia sp.	Asteraceae	0
Gaura lindheimeri	Onagraceae	0
Gazania sp.	Asteraceae	0
Geranium maculatum	Geraniaceae	0
Geranium sanguineum	Geraniaceae	0
Geranium sp.	Geraniaceae	0
Ginkgo biloba	Ginkgoaceae	0
Gleditsia triacanthos	Fabaceae	0
Graptopetalum bellum	Crassulaceae	0
Graptopetalum paraguayense	Crassulaceae	0
Grevillea sp.	Proteaceae	0
Haworthia sp.	Asphodelaceae	0
Hebe sp.	Plantaginaceae	0
Hebe x franciscana	Plantaginaceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Hedera colchica	Araliaceae	0
Hedera helix	Araliaceae	0
Heliotropium arborescens	Boraginaceae	0
Helleborus niger	Ranunculaceae	0
Hemerocallis sp.	Hemerocallidaceae	0
Heuchera sp.	Saxifragaceae	0
Hibiscus sp.	Malvaceae	0
Hippuris vulgaris	Plantaginaceae	0
Hosta sp.	Agavaceae	0
Hyacinthus orientalis	Hyacinthaceae	0
Hydrangea macrophylla	Hydrangeaceae	0
Hydrangea quercifolia	Hydrangeaceae	0
Hypericum sp.	Hypericaceae	0
Hypoestes phyllostachya	Acanthaceae	0
Ilex aquifolium	Aquifoliaceae	0
Impatiens balfourii	Balsaminaceae	0
Incarvillea sp.	Bignoniaceae	0
Ipomoea sp.	Convolvulaceae	0
Iris sp.	Iridaceae	1
Jasminum nudiflorum	Oleaceae	0
Jasminum officinale	Oleaceae	0
Juglans regia	Juglandaceae	1
Juniperus chinensis	Cupressaceae	0
Juniperus communis	Cupressaceae	0
Juniperus horizontalis	Cupressaceae	0
Juniperus sp.	Cupressaceae	0
Juniperus squamata	Cupressaceae	0
Juniperus x media	Cupressaceae	0
Kalanchoe blossfeldiana	Crassulaceae	0
Kalanchoe daigremontiana	Crassulaceae	0
Kerria japonica	Rosaceae	0
Kniphofia sp.	Asphodelaceae	0
Kolkwitzia amabilis	Linnaeaceae	0
Lagerstroemia indica	Lythraceae	0
Lantana camara	Verbenaceae	0
Lathyrus sp.	Fabaceae	0
Lavandula x intermedia	Lamiaceae	0
Lavandula dentata	Lamiaceae	0
Lavatera sp.	Malvaceae	0
Lavatera thuringiaca	Malvaceae	0
Leontopodium alpinum	Asteraceae	0
Leucanthemum vulgare	Asteraceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Ligustrum jonandrum	Oleaceae	0
Ligustrum ovalifolium	Oleaceae	1
Ligustrum sinense	Oleaceae	0
Lilium sp.	Liliaceae	0
Linum perenne	Linaceae	0
Liquidambar styraciflua	Altingiaceae	0
Lobelia splendens	Campanulaceae	0
Lonicera japonica	Caprifoliaceae	0
Lonicera nitida	Caprifoliaceae	0
Lonicera pileata	Caprifoliaceae	0
Lonicera sp.	Caprifoliaceae	0
Lonicera x heckrottii	Caprifoliaceae	0
Magnolia grandiflora	Magnoliaceae	0
Magnolia x soulangeana	Magnoliaceae	0
Mahonia aquifolium	Berberidaceae	0
Malus domestica	Rosaceae	0
Mandevilla sp.	Apocynaceae	0
Melia azedarach	Meliaceae	0
Melissa officinalis	Lamiaceae	0
Mentha viridis	Lamiaceae	0
Mespilus germanica	Rosaceae	0
Mirabilis jalapa	Nyctaginaceae	0
Miscanthus sinensis	Poaceae	0
Monstera deliciosa	Araceae	0
Morus kagayamae	Moraceae	0
Musa basjoo	Musaceae	0
Myosotis sp.	Boraginaceae	0
Nandina domestica	Berberidaceae	0
Narcissus sp.	Amaryllidaceae	0
Nicotiana sp.	Solanaceae	0
Opuntia microdasys	Cactaceae	0
Opuntia sp.	Cactaceae	1
Opuntia spinosior	Cactaceae	0
Osteospermum sp.	Asteraceae	0
Oxalis articulata	Oxalidaceae	0
Paeonia sp.	Paeoniaceae	0
Paeonia suffruticosa	Paeoniaceae	0
Paliurus spina-christi	Rhamnaceae	0
Papaver croceum	Papaveraceae	0
Parthenocissus quinquefolia	Vitaceae	1
Parthenocissus tricuspidata	Vitaceae	0
Passiflora caerulea	Passifloraceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Passiflora violacea	Passifloraceae	0
Paulownia tomentosa	Paulowniaceae	0
Pelargonium lierre	Geraniaceae	0
Pelargonium zonale	Geraniaceae	0
Pennisetum villosum	Poaceae	0
Perovskia sp.	Lamiaceae	0
Petunia sp.	Solanaceae	0
Phalaris arundinacea	Poaceae	0
Philadelphus coronarius	Hydrangeaceae	0
Phlox subulata	Polemoniaceae	0
Phormium tenax	Hemerocallidaceae	0
Photinia serratifolia	Rosaceae	0
Photinia x fraseri	Rosaceae	0
Phyllostachys aurea	Poaceae	1
Physocarpus opulifolius	Rosaceae	0
Picea abies	Pinaceae	0
Picea glauca	Pinaceae	0
Picea pungens	Pinaceae	0
Pieris sp.	Ericaceae	0
Pinus mugo	Pinaceae	0
Pinus nigra	Pinaceae	1
Pinus sylvestris	Pinaceae	0
Pittosporum tenuifolium	Pittosporaceae	0
Pittosporum tobira	Pittosporaceae	0
Platanus x hispanica	Platanaceae	0
Plectranthus coleoides	Lamiaceae	0
Plumbago auriculata	Plumbaginaceae	0
Polygala myrtifolia	Polygonaceae	0
Polygonatum sp.	Ruscaceae	0
Populus nigra	Salicaceae	0
Portulaca grandiflora	Portulacaceae	0
Portulaca umbraticola	Portulacaceae	0
Potentilla fruticosa	Rosaceae	0
Primula auricula	Primulaceae	0
Primula groupe Polyanthus	Primulaceae	0
Prunus armeniaca	Rosaceae	0
Prunus avium	Rosaceae	0
Prunus cerasifera	Rosaceae	0
Prunus domestica	Rosaceae	0
Prunus dulcis	Rosaceae	0
Prunus laurocerasus	Rosaceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Prunus persica	Rosaceae	0
Prunus sp.	Rosaceae	0
Ptelea trifoliata	Rutaceae	0
Punica granatum	Lythraceae	0
Pyracantha sp.	Rosaceae	1
Pyrus communis	Rosaceae	0
Quercus ilex	Fagaceae	0
Quercus pubescens	Fagaceae	0
Ranunculus flammula	Ranunculaceae	0
Rheum rhaponticum	Polygonaceae	0
Rhododendron sp.	Ericaceae	0
Rhus typhina	Anacardiaceae	0
Ribes nigrum	Grossulariaceae	0
Ribes sp.	Grossulariaceae	0
Robinia pseudoacacia	Fabaceae	1
Rosa sp.	Rosaceae	0
Rubus idaeus	Rosaceae	0
Rudbeckia sp.	Asteraceae	0
Rumex acetosa	Polygonaceae	0
Rumex arifolius	Polygonaceae	0
Ruscus aculeatus	Ruscaceae	0
Russelia equisetiformis	Plantaginaceae	0
Salix sp.	Salicaceae	0
Salvia microphylla	Lamiaceae	0
Salvia nemorosa	Lamiaceae	0
Sambucus nigra	Adoxaceae	0
Sanvitalia procumbens	Asteraceae	0
Saponaria officinalis	Caryophyllaceae	0
Saponaria sp.	Caryophyllaceae	0
Sarcococca confusa	Buxaceae	0
Satureja montana	Lamiaceae	0
Scaevola aemula	Goodeniaceae	0
Schefflera actinophylla	Araliaceae	0
Schlumbergera truncata	Cactaceae	0
Sedum acre	Crassulaceae	0
Sedum aizoon	Crassulaceae	0
Sedum album	Crassulaceae	0
Sedum oreganum	Crassulaceae	0
Sedum palmeri	Crassulaceae	0
Sedum reflexum	Crassulaceae	0
Sedum sieboldii	Crassulaceae	0
Sedum sp.	Crassulaceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Sedum spathulifolium	Crassulaceae	0
Sedum spectabile	Crassulaceae	0
Sedum spurium	Crassulaceae	0
Sedum telephium	Crassulaceae	0
Sempervivum arachnoideum	Crassulaceae	0
Sempervivum montanum	Crassulaceae	0
Sempervivum sp.	Crassulaceae	0
Sempervivum tectorum	Crassulaceae	0
Skimmia japonica	Rutaceae	0
Solanum pseudocapsicum	Solanaceae	0
Solanum rantonnetii	Solanaceae	0
Solanum tuberosum	Solanaceae	0
Sophora japonica	Fabaceae	0
Spathiphyllum wallisii	Araceae	0
Spiraea japonica	Rosaceae	0
Spiraea sp.	Rosaceae	0
Spiraea x vanhouttei¨	Rosaceae	0
Stachys byzantina	Lamiaceae	0
Stipa tenuissima	Poaceae	0
Strelitzia reginae	Strelitziaceae	0
Symphoricarpos sp.	Caprifoliaceae	0
Syringa vulgaris	Oleaceae	1
Tamarix ramosissima	Tamaricaceae	0
Tamarix tetrandra	Tamaricaceae	0
Taxus baccata	Taxaceae	0
Teucrium chamaedrys	Lamiaceae	0
Thuja occidentalis	Cupressaceae	0
Thuja orientalis	Cupressaceae	1
Thymus x citriodorus	Lamiaceae	0
Tilia cordata	Malvaceae	0
Tilia tomentosa	Malvaceae	0
Trachelospermum jasminoides	Apocynaceae	0
Trachycarpus fortunei	Arecaceae	0
Tradescantia pallida	Commelinaceae	0
Tropaeolum sp.	Tropaeolaceae	0
Tulbaghia violacea	Alliaceae	0
Tulipa sp.	Liliaceae	0
Vaccinium myrtillus	Ericaceae	0
Verbena bonariensis	Verbenaceae	0
Verbena x hybrida	Verbenaceae	0
Viburnum carlesii	Adoxaceae	0

Table 5 continued

Species	Family	Not escaped/escaped
Viburnum opulus	Adoxaceae	0
Viburnum rhytidophyllum	Adoxaceae	0
Viburnum sp.	Adoxaceae	0
Viburnum x bodnantense	Adoxaceae	0
Viola tricolor	Violaceae	0
Weigela sp.	Diervillaceae	0
Westringia fruticosa	Lamiaceae	0
Wisteria sinensis	Fabaceae	0
Yucca aloifolia	Agavaceae	0
Yucca elephantipes	Agavaceae	0
Yucca filamentosa	Agavaceae	0
Yucca sp.	Agavaceae	0

Each species was assigned to its proper systematic family according to the Angiosperm Phylogeny Group (2003)

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