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NATURALIZATION AND IMPACT OF A HORTICULTURAL SPECIES, *COTONEASTER HORIZONTALIS* (ROSACEAE) IN BIODIVERSITY HOTSPOTS IN BELGIUM

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ABSTRACT. — Cultivation of ornamental plant species has been recognized to foster plant naturalization of exotics by counteracting environmental stochasticity and continuously providing propagules. As a preliminary attempt to describe the invasion status of *C. horizontalis*, we gathered information on the occurrence of the species in Belgium by compiling various databases. We assessed the naturalization status of *C. horizontalis* in Belgian calcareous grasslands, high-value habitats recognized as biodiversity hotspots, by characterizing its occurrence, population status, preferred habitats, invaded communities, growth rate and fruiting capacity. We also assessed the impact of the species on calcareous grasslands communities and on individual species.

Cotoneaster occurred in seven of the nine investigated sites, with densities varying from 0.34 to 10 individuals/ha. In the most invaded sites, the high proportion of small individuals suggests an important ongoing colonization process, emphasized by the fact that fruiting capacities were demonstrated for 3-year-old individuals. Invaded habitats were typically Mosan Xerobromion habitats, which are priority Natura 2000 habitats. The presence of *C. horizontalis* was associated with changes in both the structure and composition of the community by decreasing species richness and diversity, and affecting grassland specialist species. These impacts are expected to intensify over time with population age and increasing propagule pressure due to close urbanization.

KEY WORDS. — *Cotoneaster horizontalis,* biodiversity hotspots, calcareous grasslands, impact, naturalization.

INTRODUCTION

Invasions by exotic species represent a major challenge to biodiversity conservation as they are now considered as being one of the major causes of biodiversity loss worldwide (D'ANTONIO & KARK 2002, D'ANTONIO & MEYERSON 2002). In many areas, ornamental horticulture has been recognized as the main pathway for plant invasions (GROVES 1998, REICHARD & WHITE 2001, KÜHN & KLOTZ 2002, PYSEK *et al.* 2002). Importation and cultivation of ornamental species are highly relevant in plant invasion processes as they directly affect the propagule pressure (DEHNEN-SCHMUTZ *et al.* 2007), by influencing both the number of individuals involved in one release event and the number of discrete release events. Moreover, despite the fact that only a small fraction of introduced populations become invasive, cultivation has been recognized to foster plant naturalization by counteracting environmental stochasticity and by continuously providing propagules, thereby contributing to the persistence of the species and the increase of its range (MACK 2000, KOWARIK 2003).

Some exotic species are known to invade hotspots of native plant diversity worldwide (STOHLGREN *et al.* 1999, STOHLGREN *et al.* 2001, PYSEK *et al.* 2003). The importance of the phenomenon in such valuable habitats is somehow controversial but in a survey performed in the U.S, STOHLGREN *et al.* (2001) demonstrated on large spatial scale that hotspots of native plant diversity have been far more heavily invaded than areas of low plant diversity. They argued that such hotspots cannot be expected to repel invasions. Exotic plant invasions often have impacts on the resident vegetation by modifying its composition and structure (LEVINE *et al*. 2003) and on the ecosystem functioning (EHRENFELD *et al*. 2001). Given the variety of possible impacts of exotic species on native vegetation (e.g., competition for light and/or nutrients, and allelopathic effects), such high-value habitats might be threatened by the phenomenon of plant invasion. Moreover, comparative studies on impacts at the community level are surprisingly rare (but see ALVAREZ & CUSHMAN 2002, JÄGER *et al.* 2007).

Belgium (Western Europe) and neighboring countries have suffered from invasion by exotic plants, some of which have dramatically increased their range in the last 30 years (MULLER 2000, VERLOOVE 2002). Among the exotic species introduced in Belgium, *Cotoneaster horizontalis* (Rosaceae) is a shrubby species originating from western China (LAMBINON *et al*. 2004). The introduction date of *C. horizontalis* as an ornamental species in Belgium is unknown but the first observation in the wild dates back to 1982 (*HARMONIA* DATABASE 2007). *C. horizontalis* is prostrated, has a rapid lateral expansion and can grow on very thin soils or rocks and on steep slopes. Those characteristics, as well as its red color in the fall, make the species of particular interest for horticulture, as a cover species for walls or embankments. In a recent survey, we found that 52% of the plant nurseries (n = 102) sell *C. horizontalis* in southern Belgium (VANDERHOEVEN, unpubl. data). Once established, expansion of local colonies may result in extensive smothering of native communities, altering their structure and composition (CROFTS & JEFFERSON 1999). Ledge, crevice, and scree communities may be affected, as well as a range of calcareous grassland communities. Root systems are highly pervasive, often penetrating deeply into crevices in the bedrock. Moreover, *C. horizontalis* is known for causing contact dermatitis (WELLER & ORMEROD 1996) and might potentially become problematic in case of increased occurrence. In different parts of England and Wales, *C. horizontalis* induced alterations in the composition and structure of different calcareous grassland communities (CROFTS & JEFFERSON 1999). Infestations have been reported from a variety of substrates including chalk as well as harder Jurassic and Carboniferous limestone. *C. horizontalis* is included in the black list of invasive species in Belgium (category A2, *HARMONIA* DATABASE 2007) and is reported to be present in calcareous grasslands.

Calcareous grasslands are among the most species-rich habitats in Western Europe, on both local and regional scales (WILLEMS 2001, WALLIS DEVRIES *et al.* 2002) and are considered as biodiversity hotspots in temperate countries (PRENDERGAST *et al.* 1993, WALLISDEVRIES *et al.* 2002). This richness confers them a major conservation interest. Formerly widespread, calcareous grasslands have strongly decreased since the end of the nineteenth century. This phenomenon was particularly dramatic in Belgium (see ADRIAENS *et al.* 2006). The major causes for this decrease are the destruction and the fragmentation of habitats due to the abandonment of traditional agro-pastoral practices, to pine plantation, and to urbanization. As a result of the increasing urbanization and subsequent ornamental activities in their vicinity, a new pressure might threaten calcareous grasslands in the next few years: invasion by exotic plant species. Given the great interest of calcareous grasslands for nature conservation, we argue that there is a need for a first investigation on the naturalization of *C. horizontalis* in this habitat in Belgium and on possible impacts of the species.

Data on the distribution of the species were fragmented. Therefore, as a first attempt to give a complete overview, we gathered information on the occurrence of the species in Belgium by compiling various databases and field data. On the local scale, we assessed the naturalization status of *C. horizontalis* in calcareous grasslands by characterizing its occurrence, population status, preferred habitats, invaded communities, growth rate and fruiting abilities. Finally, we considered the impacts of the species on high-value calcareous grasslands both at the plant community level and on individual species by comparing species composition and cover in invaded and uninvaded plots. Perspectives for management and control are discussed.

MATERIAL AND METHODS

Study species

Cotoneaster horizontalis (Rosaceae) is a 0.1-0.6 m high shrubby species. It produces many rose to purple flowers all along the stems. It is insect-pollinated, although self-pollination is possible in other *Cotoneaster* species (East 1940). The fruit is a red, 3-4 mm in diameter pome that is dispersed by birds. *Cotoneaster* berries are highly attractive to blackbirds and other thrushes, which readily disperse them by defecation (Crofts & Jefferson 1999).

Study area

A first assessment of the occurrence of *C. horizontalis* in Belgium was performed by compiling different databases: (i) the monitoring of quarries in the Walloon Region (southern Belgium), observations starting from 1997 (Remacle 1997-2007); (ii) the inventory of High Biological Interests Sites (HBIS) of the Walloon Region (data from 1993; Dufrêne 2005); (iii) the atlas flora of Flanders (northern Belgium) and the Brussels region that holds observations from 1972 to 2004 (Van Landuyt *et al.* 2006); (iv) personal field observations since 2002 (Laboratoire d'Ecologie FUSAGx, unpubl. data).

Secondly, an extensive survey was carried out in calcareous grasslands in the vicinity of Dinant (50°15'30''N – 4°55'E) in southern Belgium (Fig. 1). This region is known for the presence of numerous calcareous grasslands and *C. horizontalis* had been recorded in different sites of the region (Dufrêne 2005 and pers. obs.). Nine sites were selected in the study area. Some of them were chosen because *C. horizontalis* had previously been recorded ("Montagne de la Croix" and "Champalle") while the others were chosen because of their large area and their high conservation value in the region. All sites were situated on gentle to steep South to West-facing slopes in the Meuse valley or some of its tributaries (Fig. 1). In the region, several plant species, like *Helianthemum apenninum, Artemisia alba, Draba aizoides,* reach the northern boundary of their distribution range. The region is moderately urbanized. Most of the investigated grasslands were close to small towns or villages, so the propagule pressure of exotic species might be quite strong because of their presence in private gardens (Fig. 1).

Data collection and analyses

A first field survey took place in mid-November 2006. At that time, *C. horizontalis* had a typical deep red color, making it very easy to locate. In each site, *C. horizontalis* individuals were counted. Two size classes were considered: small individuals (diameter < 100 cm) and large individuals (diameter > 100 cm). In accessible sites, counting was carried out by covering the whole grassland area. In the "Leffe" site, for less accessible areas, individuals were counted from the nearest easily reachable position. On the "Fonds de Leffe West" site, sixteen stem samples were collected from individuals just above ground. Individuals were selected in order to cover habitat and size variability. For each of them, the presence of fruits was noted and the diameter was measured (largest and smallest diameters). Age rings were counted on stem sections.

In order to estimate the growth rate, the relationship between the diameter (dependent variable) and the age (number of rings, independent variable) was tested with linear regression. Normality of the residuals was tested by Levene's test and their homoscedasticity by Breuch-Pagan's test. Box-Cox transformation was applied on the dependent variable using a minitab ver. 14.20 macro (Minitab Inc., State College, Pennsylvania; Palm 2002). In October 2007, another field survey was performed in order to characterize the community and the impact of *C. horizontalis*. As proposed by Walker & Smith (1996) and commonly used (Vanderhoeven *et al.* 2005, Dassonville *et al.* 2007), the most realistic way to measure the impact of an invader is to compare invaded plots with nearby control plots with similar vegetation, soil, geology, climate and land-use history. For this reason, at three heavily invaded sites ("Montagne de Sosoye", "Fonds

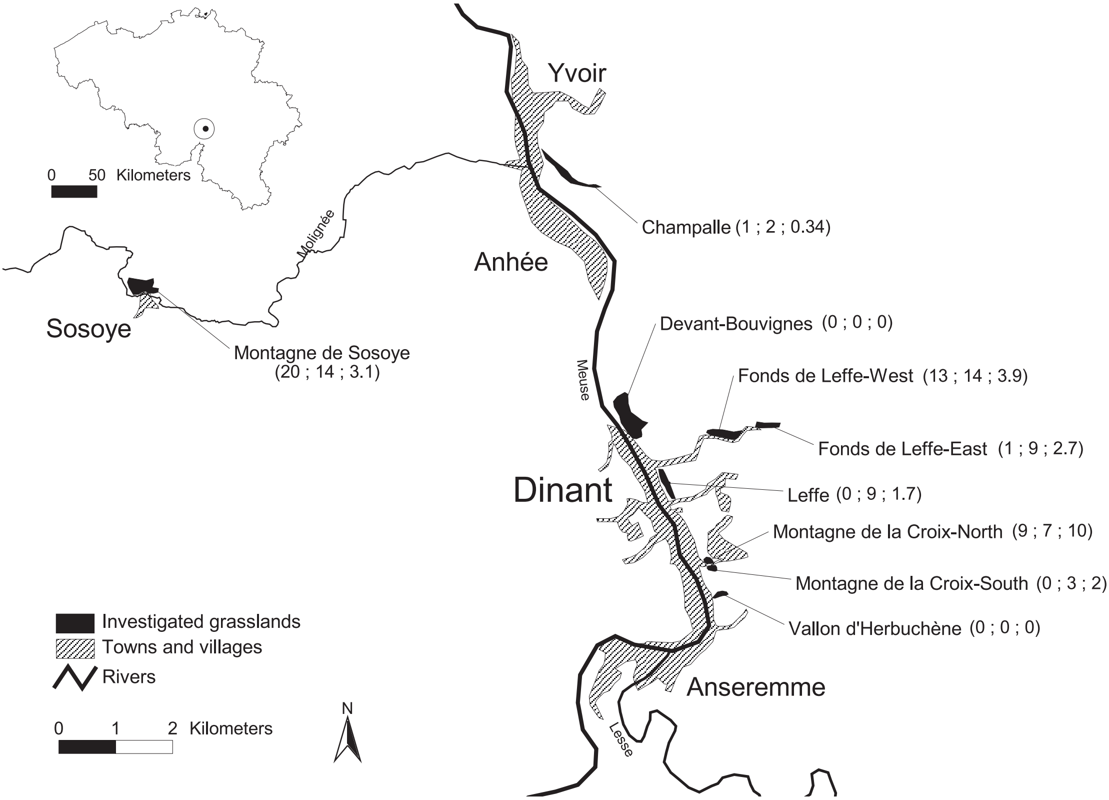

Fig. 1. Investigated sites. *Cotoneaster* counts are given between brackets: number of small individuals, number of large individuals, density (number of individuals/ha), respectively.

de Leffe East" and Montagne de la Croix North"), five *Cotoneaster* individuals were selected. Each of them was used as the center of a vegetation relevé ("invaded plots", n = 15). In the near vicinity of each of those individuals, one or two relevés were realized ("control plots", n = 28). In order to test differences in vegetation between invaded and uninvaded sites, ten relevés were made ("uninvaded plots", n = 20) in each of the two uninvaded sites ("Vallon d'Herbuchenne" and "Devant-Bouvignes"). All the relevés had an area of 1 m² (1 m × 1 m). In each relevé, we recorded the presence of all visible vascular plants as well as their cover [%], cover of rocks [%], bare soil cover [%], moss cover [%], slope [°], and aspect (eight classes). For each relevé, we estimated the species richness (number of species per m^2) and Shannon's equitability (SHANNON & WEAVER 1949). In order to ensure that the three plot types did not differ significantly as to their abiotic conditions, we tested the equality of slope and soil depth by ANOVA as well as the distribution of the aspects by a χ^2 test. Slopes were log-transformed and soil depths were square root-transformed in order to meet normality and homoscedasticity requirements. Two correspondence analyses were carried out on vegetation data. The first was performed using the cover values of the plant species and the second using only the presence-absence matrix. This provided both quantitative and qualitative approaches to vegetation data.

For each variable (cover of rocks, bare soil cover, moss cover, species richness and Shannon's equitability), the paired t-test was used to compare invaded plots and the corresponding control plots of invaded sites. When two control plots were available, their mean was considered in the paired t-test. Fischer's exact test was used to determine whether a species showed a different occurrence in invaded and control plots. For the variables cited above, the invaded sites (control plots) and uninvaded sites were compared using the Mann-Whitney test.

RESULTS

Distribution area

The analysis of the different databases revealed the wide occurrence of *C. horizontalis* in Belgium (Fig. 2). In the northern part of the country, an important incidence of the species was observed especially in large urban entities (Brussels, Ghent), as well as in the western sandy dunes, another high value habitat (Van Landuyt, pers. com.). In southern Belgium, the most affected zone was the upper Meuse valley, a deep valley showing a high occurrence of steep slopes and rocks. It is worth noting that *C. horizontalis* was less frequent in the eastern part of the country, which is characterized by more acidic soil conditions.

Local invasion status and population structure

A total of 102 *C. horizontalis* individuals were found in the nine calcareous grasslands investigated. Detailed results of observations are given in Fig. 1. Only two sites were free of *C. horizontalis*: "Vallon d'Herbuchenne" and "Devant-Bouvignes", despite their closeness to invaded sites (less than 1 km). In sites colonized by *C. horizontalis*, the individual density (individuals/ha)

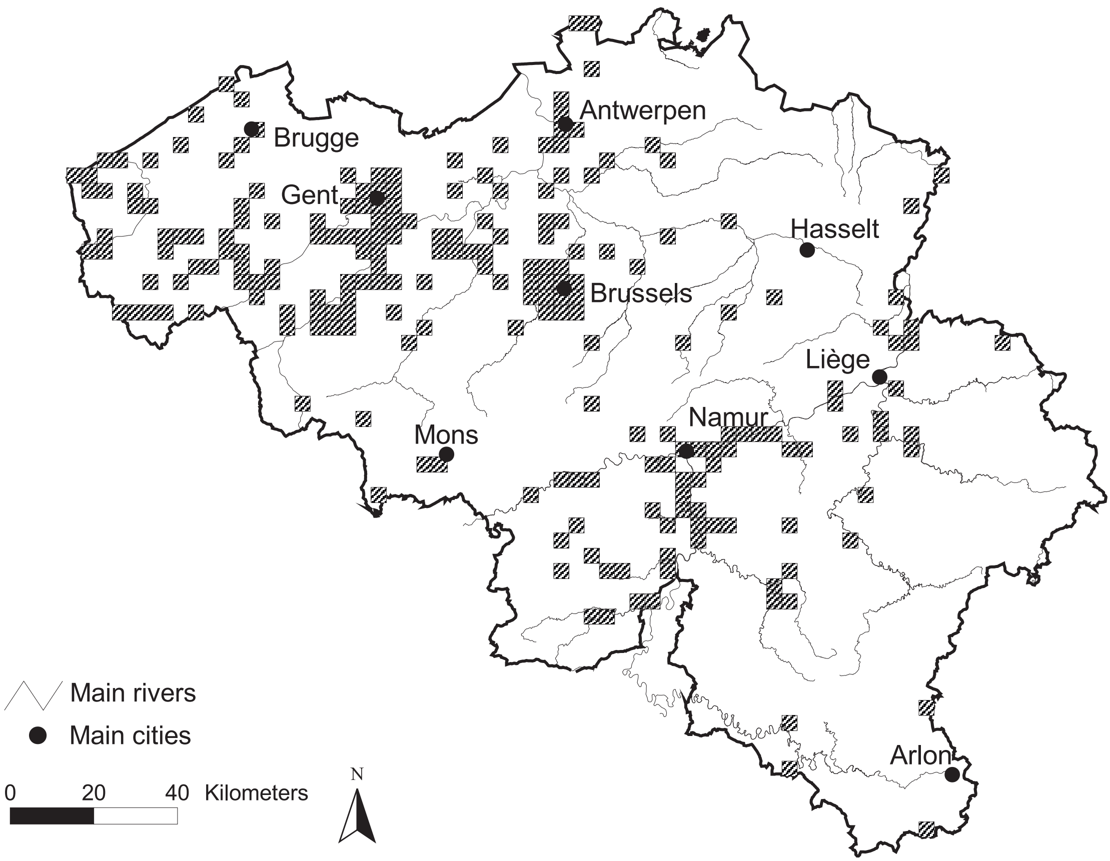

Fig. 2. Occurrence of naturalized *Cotoneaster horizontalis* in Belgium. Striped squares exhibited at least one naturalized individual. Sources: Remacle 1997-2007, Dufrêne 2005, Van Landuyt *et al.* 2006, Gembloux Agricultural University-Laboratory of Ecology: unpubl. data.

was variable, ranging from 0.34 (“Champalle”) to 10 (“Montagne de la Croix”). Considering all the sites, the mean proportion of small individuals (diameter < 100 cm) was 43% and exhibited an important variation among sites, ranging from 0 to 58.8%. We observed a significant correlation between the number of small individuals and the number of large individuals within a site ($R^2 = 0.578$; $P = 0.047$): sites exhibiting the largest number of small individuals (“Montagne de Sosoye” = 20; “Fond de Leffe-West” = 13) were also those showing the greatest number of large individuals (“Montagne de Sosoye” = 14; “Fond de Leffe-West” = 14).

The 16 individuals collected in “Fond de Leffe West” were from 2- to 14-year-old and their diameter ranged between 0.3 and 3.25 meters. The largest individual was the oldest one, and the smallest was the youngest. Only two individuals (two- and four-year-old) did not exhibit fruits. Fruiting was observed on individuals from three years old and on every individual more than four years old. Diameter was found to be a good predictor of age ($R^2 = 0.813$, $P < 0.001$). The intercept of the regression was not significant ($P = 0.663$), indicating a constant annual growth from germination. The estimated annual diameter growth (slope of the regression) was 21 cm.

Vegetation and habitat description

Species most frequently observed close to *Cotoneaster*-invaded plots (i.e., in control plots) were *Allium sphaerocephalon, Brachypodium pinnatum, Bromus erectus, Festuca lemanii, Globularia bisnagarica, Helianthemum apenninum, Helianthemum nummularium, Hieracium pilosella, Hippocrepis comosa, Lactuca perennis, Pimpinella saxifraga, Potentilla neumanniana, Sanguisorba minor, Scabiosa columbaria, Sedum album, Seseli libanotis*, and *Teucrium chamaedrys*. This indicated that *Cotoneaster* mostly occurred in complexes of xeric grasslands and calcareous rocks, along a gradient of rock cover and soil depth (Fig. 3). However, a few individuals were found at the edges of grasslands or under

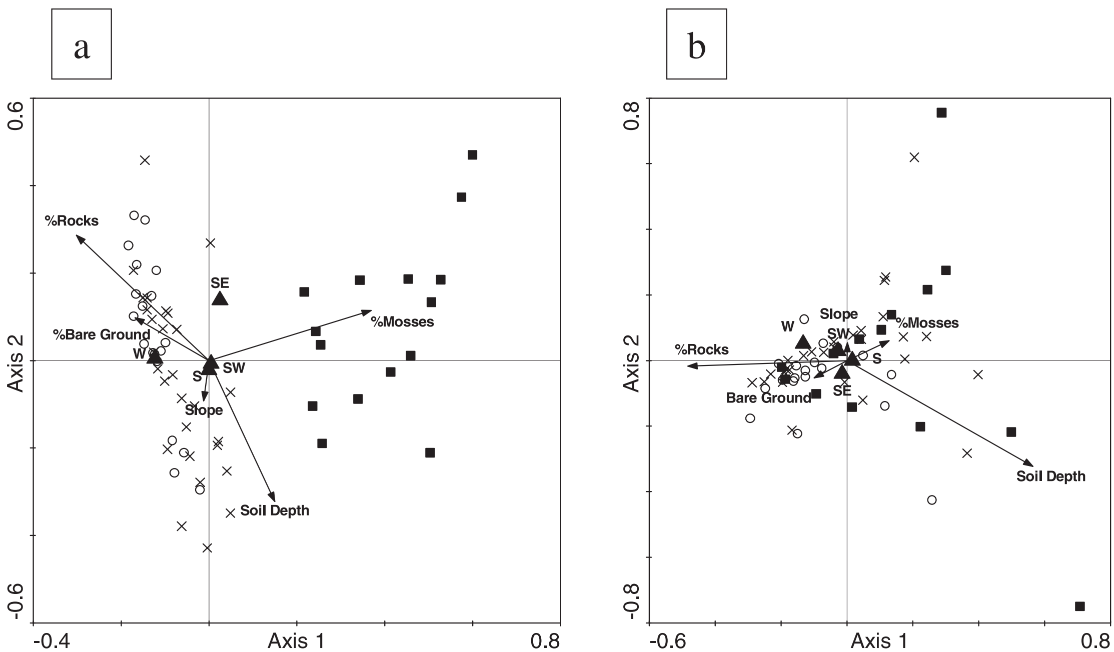

Fig. 3. Correspondence analysis ordination graph of plots realised from (a) species abundance data, and (b) presence-absence data. ○: uninvaded plots; x: control plots; ■: invaded plots; →: environmental variables; ▲; aspects.

scrubs with *Prunus spinosa, Salix caprea, Viburnum lantana, Corylus avellana*, and the herbaceous species *Helleborus foetidus, Origanum vulgare, Geranium robertianum*, and *Picris hieracioides*. No individuals were found in mesophilous grasslands located on gentle slopes, although such habitats were widespread in some investigated sites, notably at the "Montagne de Sosoye" where *C. horizontalis* was present on steep slopes.

The ANOVA did not show any significant difference between invaded plots, control plots of invaded sites, and plots of uninvaded sites for slope ($F = 0.01$, $df = 2;60$, $P = 0.994$) or soil depth ($F = 0.08$, $df = 2;60$, $P = 0.928$). The mean values for those variables were 26° and 4cm, respectively. About 87% of the plots were facing South or Southwest. The distribution of the aspect did not differ either ($\chi^2_{obs.} = 5.99$; $df = 6$; $P = 0.424$).

Impact on the community composition and on the presence of individual species

The correspondence analysis showed a high differentiation of the invaded plots along the first axis when species abundance was taken into account (Fig. 3a). However, this differentiation completely disappeared when only their presence/absence was considered (Fig. 3b). This suggests that species cover rather than species composition differed in invaded plots.

Comparisons between invaded and control plots showed that where *C. horizontalis* was present, rocky and bare ground cover was significantly lower, and moss cover was significantly higher. Both species richness and diversity (Shannon's equitability) were also lower (Table 1). Four species were significantly individually affected

Table 1. The impact of *C. horizontalis* on vegetation: comparison between control and invaded plots (paired t-test). Mean values are given for both plot types.

Tested parameter	Control plots(n = 15)	Invaded plots (n = 15)	*t*	*P*
Rocks cover	23.1	12.0	-2.57	0.022
Bare soil cover	13.8	5.5	-2.35	0.034
Moss cover	21.2	43.3	2.66	0.019
Species richness	11.9	8.2	-5.91	<0.001
Shannon's equitability	0.65	0.28	-7.92	<0.001

Table 2. The impact of *C. horizontalis* on individual native species: comparison of native species occurrence between invaded and control plots (Fischer's exact test).

	Proportion of occupied patches		Comparison invaded/uninvaded plots
	Invaded n = 15	Control n = 28	
Allium sphaerocephalon	0.00	0.36	**
Bromus erectus	0.60	0.89	*
Festuca lemanii	0.33	0.89	***
Globularia bisnagarica	0.13	0.39	°
Lactuca perennis	0.00	0.43	**
Sanguisorba minor	0.60	0.86	°
Sedum album	0.07	0.36	°
Seseli libanotis	0.13	0.39	°

Notes. ***: $P < 0.001$; **: $0.001 < P < 0.01$; *: $0.01 < P < 0.05$; °: $0.05 < P < 0.1$, n is the number of plots considered. Species with P-values > 0.1 are not shown.

($P < 0.05$) by the presence of *C. horizontalis* and four other species only marginally ($0.1 < P < 0.05$) (Table 2). All those species are dry grassland specialist species.

Comparison between invaded and uninvaded sites

Correspondence analyses (Fig. 3) did not allow detection of any difference between control plots and uninvaded plots, suggesting similar vegetation. Mann-Whitney tests performed on vegetation parameters (cover of rocks, bare soil cover, moss cover, species richness and Shannon's equitability) did not either permit to detect significant differences between invaded and uninvaded sites. Those results did not explain the absence of *C. horizontalis* at "Vallon d'Herbuchenne" and "Devant-Bouvignes".

DISCUSSION

Examples of ornamental species able to become naturalized and becoming invasive in Belgium are numerous as illustrated in the *Harmonia* database (2007), which currently lists 65 species. Nevertheless, relevant descriptions of the naturalization status of these species are notably missing in the literature. The compilation of the different databases allowed us to highlight that the ornamental *C. horizontalis* is widely distributed in Belgium. Moreover, considering that our results do not arise from a complete systematic survey across Belgium, the occurrence is probably still underestimated. Its presence was recorded in urbanized zones like Brussels or Ghent but also in priority habitats for conservation like coastal sandy dunes or dry calcareous grasslands.

The field survey performed during the autumn 2006 confirmed the occurrence of *C. horizontalis* in calcareous grasslands of the Belgian Meuse Valley, with seven invaded sites out of the nine investigated. The density of individuals as well as the proportion of small (and young) individuals varied considerably from site to site, suggesting different histories and dynamics of colonization that will be worth investigating in the future. Particular attention should be paid to the dynamics of populations with a large number of individuals that also showed a relatively high proportion of small individuals, because such a demographic structure suggests an important ongoing colonization process. As those small individuals are growing and fruiting, the colonization process is expected to speed up in the following years. On the contrary, sites with a lower occurrence only presented few small individuals, probably resulting from a sporadic rather than an early ongoing colonization process. It should be noted that at the site 'Leffe', the number of small individuals was certainly underestimated because this site was observed from a distance. In addition, we observed that some three-year-old individuals already reproduced successfully. Fruits are dispersed by birds, which allows long distance dispersal of the species towards uninvaded grasslands. Our data stress that the naturalization process of the species in Belgian calcareous grasslands is effective and that there is a risk of *Cotoneaster* spreading.

The importance of human factors in the invasion process has recently been renewed. Biological mechanisms are mostly used to explain exotic species expansion and naturalization processes (Trepl 1984, Pysek & Prach 1993) but as underlined by Kowarik (2003), cultivation, as other anthropogenic mechanisms, should be considered as an important driving force. As stressed by Mack (2000), cultivation counteracts the impact of environmental stochasticity, with the latter impeding the development from casual to naturalized populations of exotic species. By growing the species with care under protected conditions, cultivated individuals are indeed sheltered from environmental hazards. Secondary releases resulting from gardens therefore act as a key factor in naturalization processes but also foster population expansion by significantly contributing to long-distance dispersal and consequently overcoming spatial isolation (Kowarik 2003). In the present case, the proximity of gardens and cultivated individuals (pers. obs.) will most probably intensify the spread of *C. horizontalis* in the studied calcareous grasslands. The comparisons we performed between invaded and uninvaded sites did not indicate differences in the community or in abiotic conditions limiting the establishment of *C. horizontalis* in some grasslands. This suggests that differences in invasion history or propagule pressure would explain the absence of *C. horizontalis*.

Habitats invaded by *C. horizontalis* are typically Mosan Xerobromion (Eunis Code E1.2721), which are priority Natura 2000 habitats. Those habitats are biodiversity hotspots on both regional and European scales. They are rare in Belgium, confined to south-facing steep slopes with shallow soils and shelter numerous rare species (Butaye *et al.* 2005, Piqueray *et al.* 2007). A great number of native species observed in the close vicinity of *C. horizontalis* are threatened in Belgium; seven have a legal protection status: *Allium sphaerocephalon, Festuca pallens, Globularia bisnagarica, Helianthemum apenninum, Juniperus communis, Lactuca perennis*, and *Orchis spp*. At Champalle, two other protected plant species, *Aster linosyris* and *Geranium sanguineum*, were also observed in the vicinity of the species though they were not found in the vegetation relevés. Those observations probably even underestimated the potential impact of *C. horizontalis* on the native flora because the period of investigation did not permit to fully appreciate the floristic conservation value of the sites. Numerous species were not visible anymore in October, among which orchid species [e.g., 15 orchid species known in the very invaded site "Montagne de Sosoye" (Dufrêne 2005)]. Impact assessment indicated that the presence of *C. horizontalis* is associated with changes in both the structure and the composition of the community by decreasing species richness and diversity, and directly affecting individual grassland specialists. These impacts are expected to intensify over time with changing population structure.

It is worth noting that none of the vegetation relevés included other invasive plant species, although the invasive *Senecio inaequidens* was occasionally observed in recently restored areas, and the naturalized species *Cheiranthus cheiri* was observed in some rock cracks of investigated sites (pers. obs.). The occurrence of these two species is currently very low but should be monitored in the future.

In addition, an indigenous congeneric species, *Cotoneaster integerrimus* also grows on south-facing calcareous rocks in this region. This species shows affinities with numerous species that we found in the vicinity of *C. horizontalis* (Butaye *et al.* 2005, Piqueray *et al.* 2007). The distribution area of *C. integerrimus* in Belgium, provided by Van Rompaey & Delvosalle (1979), shows many similarities with that of *C. horizontalis*. The sympatry of both species is thus very probable, which implies that hybridization between those two species cannot be excluded. Both species have a basic chromosome number of 17. In Germany, *C. horizontalis* shows triploid and tetraploid individuals while *C. integerrimus* is reported to have di-, tri- and tetraploid individuals (Oberdorfer 1983). To our knowledge, cytotypes have not been identified for these two species in Belgium. Hybridization potential would be worth investigating in the future.

Up till now, the description of exotic species invading biodiversity hotspots in Belgium is limited, except for *Rosa rugosa* Thunb. Both *Rosa rugosa* and *Cotoneaster horizontalis* are ornamental shrubby Rosaceae species that are widely cultivated close to priority habitats for nature conservation. Their dispersal by animals allows for rapid colonization of nutrient-poor habitats with low competition. Indeed, *Rosa rugosa* is another Asiatic shrub that has invaded numerous coastal habitats in NW Europe in recent decades (Bruun 2006, Kollman *et al.* 2007), including sandy dunes of the Belgian littoral where it forms dense impenetrable thickets. In Belgium, the first observation of this species in the wild dates back from 1934 (*Harmonia* database 2007). In Denmark, the Netherlands, and Germany, its distribution and local abundance have markedly increased in the past four decades (Bruun 2005) because of, among others, its high reproductive capacity and seed dispersal by frugivorous birds (Kollman *et al.* 2007). As a result, species richness and biodiversity of German open dune grasslands were shown to be affected (Grootjans *et al.* 2002, Isermann 2007, Kiehl & Isermann 2007). Restoration measures included, among others, reintroduction of traditional management techniques in dunes, such as mowing, grazing and sod cutting, or construction of artificial habitats to compensate for biodiversity loss elsewhere (Grootjans *et al.* 2002). Although occurring in another kind of high-value habitat, this example highlights the potential rapidity of invasion and the necessity to act at early stages of the invasion process to avoid such alarming situations.

In regard of the naturalization and the expansion potential of the exotic horticultural *C. horizontalis* in biodiversity hotspots in Belgium, our results suggest that this species should no longer be commercialized and that it would be worth undertaking intensive management in high-value habitats. Alternative species exhibiting the same characteristics of value for gardeners (covering and color) should be promoted. Nevertheless, because of its large distribution in plant nurseries and its high attractiveness to the public, the feasibility of definitively stopping commercialization is probably low. It should be combined with campaigns in high-risk areas (biodiversity hotspots) to raise public awareness and early management of invasion in calcareous grasslands.

The species forms a very outspread root and rhizome system, so that pulling up individuals could induce serious damage to the neighboring plants (that were shown to be of conservation value) and should therefore be proscribed. Cutting individuals would probably not allow the eradication of *Cotoneaster*, but, if done regularly (every 3 years), it would limit the development of fruiting individuals. However, resprouting capacity and other biological and phenological traits of the species should be studied further before developing and undertaking coherent and efficient management strategies.

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