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The behaviour of *Ailanthus altissima* weed and its effects on natural ecosystems

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Abstract

Ailanthus altissima is an invasive species for the native flora of Greece and it could pose a serious threat to the biodiversity and the functioning of ecosystems. The purpose of this study was to investigate the spreading of *Ailanthus altissima* in urban and non urban areas of North and Central Greece and also to evaluate the effects of its spreading on species composition and floristic diversity in natural ecosystems. The spreading of *Ailanthus altissima* in urban areas is very intense, mainly in abandoned places (35.29%). It is commonly found in non urban areas of Greece, especially in hedgerows of arable lands (36%) and adjacent wetlands (17%). It is less common in forests (4%), shrublands (11%) and grasslands (9%). The spread of *Ailanthus altissima* in urban and natural ecosystems is relatively recent. Although it has been recorded at altitudes of up to 640 m, it usually appears at low altitudes of up to 200 m. Floristic diversity was found to be higher in the stands that it dominated (H´=1.574, H´=1.890) in comparison to stands that were dominated by *Quercus pubescens* (H´=1.468) or *Q. coccifera* (H´=1.716). This may be contributed to the fact that in those stands synanthropic species, which are usually found in regions of intense human activity, were present together with typical forest vegetation species.

Key words

Invasive species, *Ailanthus altissima,* Floristic diversity, Mediterranean area

Introduction

Primary among crucial ecological issues are the land-use and cover change, and the ecosystem changes that result (Vitousek, 1994). Land-use and cover change deals with alterations made by humans upon the land (land-use) and its biotic cover (land cover) and the resulting effects upon the natural environment (Meyer and Turner, 1992). Exotic plant invasion into regions that were previously separated by biogeographic barriers is a key problem of land use and cover change (D'Antonio and Vitousek, 1992). Frequently, plant species are introduced into new areas because of their economic value as crop species, timber trees, forage plants or for ornamental use (Heywood, 1989). Lately, there is a dramatic increase in the introduction of non-native species as a result of the more global human movements and the increased international trade (McNeely *et al.* 2001).

Invasive species compete with native species and may render them extinct (Mooney and Drake, 1989). Therefore, biotic invasions can cause an ecosystem to become homogenized and can decrease regional diversity by accelerating the extinction of native species (D'Antonio and Vitousek, 1992). It has been well documented that invasion by non-native species represents one of the greatest threats to biodiversity worldwide (Mack *et al*. 2000). Thus, invasion of non-native species could pose a serious threat to natural ecosystems. For instance, Wilcox and Thurow (2006) reported that invasive species is one of the most important drivers for rangeland degradation. For these reasons the competition between invasive and native species is an important issue that merits attention.

Ailanthus altissima (Miller) Swingle is a species of the Simaroubaceae family. It can grow up to 9-18 m tall, has alternately arranged compound leaves, heart-shaped leaf scars, and a

disagreeable smell when leaves are crushed and is sometimes called the "stink tree". It is native to China and North Vietnam (Basnou and Vila, 2009) and it has been introduced to Europe, Australia and America (Weber and Gut, 2004). The species was introduced from Beijing to Europe in the 1740s from the collection of a Jesuit priest who had mistaken it for a lacquer tree (*Toxicodendron vernicifluum*). In 1751, the seeds were sent to Philip Miller in England when it was discovered that a silkworm, *Samia cythia*, produced a high quality silk when grown on *A. altissima* leaves and that the tree exhibited rapid growth and beautiful foliage. *A. altissima* has been examined for its uses as an ornamental plant, a reforestation tree for disturbed sites, fuel wood production, potential use as fodder for domestic animals, afforestation and as a cure for dysentery (Hu, 1979).

A. altissima is known for its fast occupation of highly disturbed sites (Call and Nilsen 2003). It is found along roadways, in parks, alleys and even through cracked walls and roofs. It is also capable of invading natural vegetation like riparian forests, shrublands as well as mesic and xeric woodlands (Kowarik and Saumel 2007). It has been reported by Castro-Diez *et al*. (2009) that in Central Spain this species is growing side by side with *Ulmus minor* Mill in habitats formerly dominated by elms, as a result of the reduction of its populations due to the vascular wilt disease. According to Hadjikyriakou and Hadjisterkotis (2002) and Hulme (2004), *A. altissima* spreading threatens natural habitats by invading forests and maquis in the Mediterranean islands.

Today, *A. altissima* is considered a "weed" tree because of its rapid growth (Delgado *et al*., 2009). The rapid spread of this species is due to its wide-spreading shallow root system, its high seed production (350,000 seeds individual^{-1} yr^{-1}), its capability to reproduce by thin papery samaras, stump sprouts, and suckers, its high tolerance in polluted environments and the secretion of chemicals from the roots and stems which can negatively affect the growth of nearby plants (Kowarik, 1995; Vilà *et al.,* 2006).

The purpose of this study was to investigate the spreading of *A. altissima* weed in urban and non urban areas and also to evaluate the effects of its spreading on species composition and floristic diversity in natural ecosystems of North and Central Greece.

Materials and Methods

Spreading of *Ailanthus altissima* in urban and non urban areas: The study was conducted in 2008 in 10 towns and cities (Thessaloniki, Veroia, Serres, Drama, Orestiada, Lamia, Karpenissi, Ioannina, Trikala, Karditsa) of continental Greece. Urban landscapes where *A. altissima* plants existed were recorded. Simple random sampling was used (Mendenhall *et al.,* 2005) among all the blocks in all of the urban areas. The sample was 5% of the total number of blocks in each city. A total of 1082 blocks were investigated. In every position longitude, latitude, altitude and urban habitat were recorded. Urban habitats were distinguished as follows: alleys, cracked walls, roofs, abandoned areas and road edges.

The study was conducted in parts of Central and Northern Greece in 2005 and 2006. Non urban landscapes where *A. altissima* plants existed were recorded. A total of 800 positions with the presence of *A. altissima* were recorded. Floristic and phytosociological data on the study areas were also investigated, in order to record the possibility of *A. altissima* appearance (Athanasiadis *et al*., 1993; Hanlidou and Kokkini, 1997; Karagiannakidou and Raus, 2001; Vlachos *et al*., 2002; Tsiripidis and Athanasiadis, 2003; Fotiadis and Athanasiadis, 2008; Karousou *et al*., 2008; Papadimitriou and Ispikoudis, 2008; Fotiadis *et al*., 2009).

For every position of *A. altissima* appearance longitude, latitude, altitude, the natural vegetation habitat and anthropogenic interventions were recorded. Natural vegetation habitats were distinguished as follows: wetlands (lakes, rivers, streams where willows and plane trees are dominant), grasslands, arable land, forests, shrublands, reforestations and road edges. These data contributed to the determination of the environmental conditions that encourage the spreading of *A. altissima*.

Effects of *Ailanthus altissima* on natural ecosystems: The study was conducted in 2006, in *Quercus pubescens* and *Q. coccifera* stands, on the Mountain Beles (North Greece) and on the Mountain Timfristos (Central Greece) respectively, where *A. altissima* is widely spread.

Mountain Beles is located in the north-northeast of Greece. The mean elevation of the study area is 300 – 400 m a.s.l. The climate is characterized as humid Mediterranean with cold winters. Gneiss is the parent rock material and soils are of high fertility. The area is mostly forested with oaks and beech (Fotiadis and Athanasiadis, 2008). Mountain Timfristos is located in Central Greece. The mean elevation of the study area is 600 m a.s.l. The climate is characterized as humid Mediterranean with cold winters. Limestone is the parent rock material and soils are of medium to low fertility. The area is mostly forested with firs. The continuity of the landscape is disrupted by kermes oak and *Juniperus* shrublands as well as by grasslands (Dimitrellos and Christodoulakis, 1995). Wild fires on Mountain Beles and Mountain Timfristos are rare and do not spread easily. As a result they do not have a serious impact on the vegetation.

Number of species and plant density per species were measured in quadrats (1X1 m) in stands where *A. altissima* was dominant and in adjustment stands where only natural vegetation existed. Each stand was replicated seven times (total of 28 replications). Collected plant material was taxonomically identified by using Flora Hellenica (Strid and Tan, 1997; 2002) and Flora Europaea (Tutin *et al*., 1968-1980).

Floristic diversity was evaluated by the Shannon-Weiner index of α-diversity (H′), evenness of the Shannor-Weiner index of diversity (E), Berger-Parker index of dominance (d), and species richness (N). The formulae of the indices are given below (Henderson, 2003):

$H' = -\sum_{i=1}^{S} p_i \ln p_i$ (1), $E = \frac{H'}{H_{max}} = \frac{H'}{\ln S}$ (2), $d = \frac{N_{max}}{N}$ (3), N (4),

where, S is the maximum recorded number of taxa, p^i is the proportional abundance of the i^{th} taxa, N^{max} is the number of records of the dominant taxon and N is the number of taxa.

Results and Discussion

Spreading of *Ailanthus altissima* in urban and non urban areas: The collected data indicated that *A. altissima* is found in almost all urban areas of altitude up to 600 m. It does not however appear in Karpenissi where the altitude is 900-1100 m (Fig. 1). The species prefers open abandoned urban areas and roadway sides. It is also present in parks, where former individuals were planted for ornamental purposes, invaded or expanded in alleys and appears even through cracked walls and roofs, especially in abandoned, roof-tiled houses (Fig. 2). It is usually found in small stands, with 1-2 trees and many juveniles. The ornamental use of *A. altissima* has been recorded as early as the 1900s in urban areas such as in the city of Thessaloniki where it is now fully established naturally (Krigas *et al.,* 1999).

A. altissima is mainly spread in arable land (36%), usually in hedges or in hedgerows, in a huge variety of cultivations (such as cotton, olive trees, peach trees and cereals). It also spreads in road edges (21%) and wetlands (17%) located close to arable land, in mixture with *Platanus orientalis* and *Salix alba.* Its spreading is not very common in natural ecosystems (shrublands 11%, grasslands 9% and forests 4%) (Fig. 3).

According to consulted floristic or phytosociological data (Athanasiadis *et al*., 1993; Hanlidou and Kokkini, 1997; Karagiannakidou and Raus, 2001; Vlachos *et al*., 2002; Tsiripidis and Athanasiadis, 2003; Fotiadis and Athanasiadis, 2008; Karousou *et al*., 2008; Papadimitriou and Ispikoudis, 2008; Fotiadis *et al*., 2009) no presence of the species has been recorded in natural ecosystems of the study areas. This suggests that the spread of *A. altissima* in natural ecosystems is relatively recent.

All the observations of the *A. altissima* spreading were recorded at altitudes of up to 640 m (Fig. 4). The majority of these observations were at very low altitudes of up to 100 m (42%) (Fig. 4). This indicates that lower winter temperatures constrain its expansion. It has been reported for various parts of Central Europe, as well as for some Mediterranean islands, that warm climates shown to favor the spread of *A. altissima* (Kowarik and Samuel 2007; Traveset *et al.*, 2008). Its presence has been found in the *Quercetalia ilicis* vegetation zone and in the lower sub-zone of *Quercetalia pubescentis* vegetation zone.

Knapp and Canham (2000), who studied the invasion of an old-growth forest, reported that the spreading of this invasive species in New York, USA follows a similar pattern. As it is a pioneer species, intolerant to shade (Bernetti, 1995) it commonly dominates forest edges where there is no competition. Its recent spread to the edges of forests and shrublands, as well as to grasslands might pose an important threat to these ecosystems especially after a disturbance to

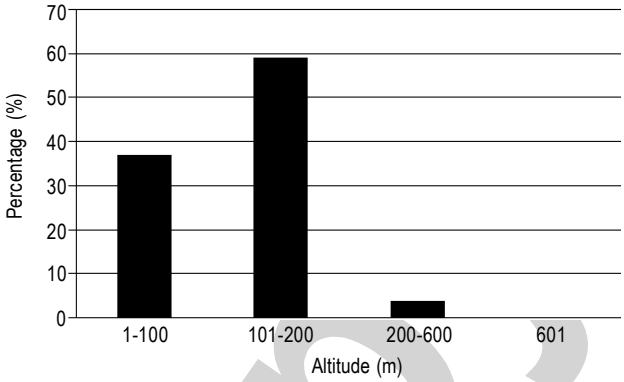

Fig. 1: Altitude of urban areas where *Ailanthus altissima* was found

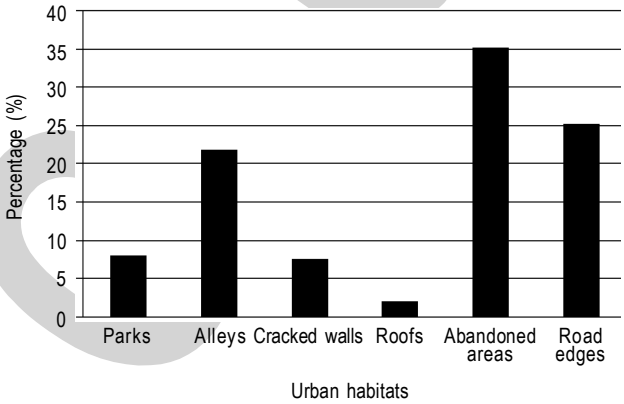

Fig. 2: Urban habitats where *Ailanthus altissima* was found

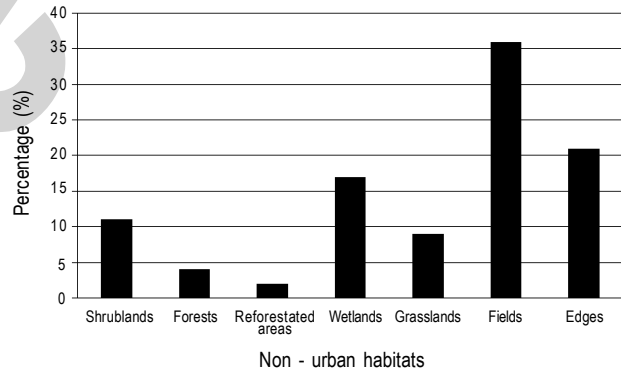

Fig. 3: Presence of *Ailanthus altissima* in non - urban habitats

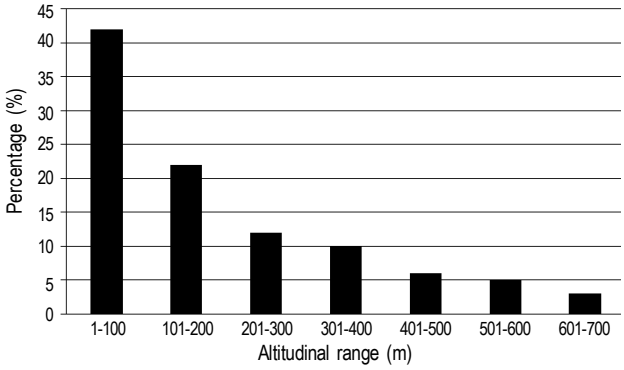

Fig. 4: Altitudinal range of *Ailanthus altissima* presence

Table - 1: Main components of floristic diversity in stands where *Ailanthus altissima* was dominant and in stands where *Quercus pubescens* or *Quercus coccifera* were dominant

Dominant species	N	H´	*E* (H´)	*d*
Ailanthus altissima in proximity to stands of *Q. coccifera*	9.428	1.890	0.412	0.342
Quercus coccifera	7.714	1.716	0.374	0.358
Ailanthus altissima in proximity to stands of *Q. pubescens*	12.714	1.574	0.357	0.505
Quercus pubescens	9.714	1.468	0.333	0.478

Table - 2: Diversification of species (total constancy in 28 replications) in stands where *Ailanthus altissima* was dominant and in stands where *Quercus pubescens* or *Quercus coccifera* were dominant

	Stability of species (Number of stands) where *Ailanthus* dominated*	Stability of species (Number of stands) where *Quercus* dominated*
Synanthropic species		
Ailanthus altissima	14	-
Galium aparine	4	-
Conyza canadensis	2	-
Taraxacum officinale	2	-
Chenopodium murale	1	-
Sonchus asper	1	-
Species found on arable land and waste places		
Medicago minima	5	-
Vicia hirsuta	5	-
Myosotis ramosissima	4	-
Sherardia arvensis	4	-
Sanguisorba minor	3	-
Geranium molle	3	-
Bromus sterilis	2	-
Bromus squarrosus	1	-
Torilis arvensis	1	-
Tragopogon porrifolius	1	-
Rhagadiolus stellatus	3	1
Characteristic species of forest vegetation		
Brachypodium sylvaticum	3	2
Carpinus orientalis	2	4
Celtis australis	5	3
Crataegus monogyna	1	4
Dactylis glomerata	3	7
Cyclamen hederifolium	1	2
Quercus coccifera	1	7
Quercus pubescens	1	8
Thymus sibthorpi	2	7
Satureja vulgaris	2	3
Veronica chamaedrys	2	2
Cistus creticus	-	3
Hedera helix	-	2
Phillyrea latifolia	-	6
Phleum pratense	-	5
Poa nemoralis	-	2
Viola alba	-	3

*** Total constancy**

the natural vegetation. Traveset *et al*. (2008) found that this species has the potential to significantly alter the functioning of ecosystems in the Mediterranean islands. There is a possibility that this pioneer species could withdraw from these ecosystems when the disturbance of the natural vegetation ceases to exist. However, recent researches (Kowarik and Samuel, 2007) reported higher shade tolerance in *A. altissima* root suckers than in true seedlings. This will possibly allow the species to invade shadier areas via its root system and thus to remain in the disturbed woody ecosystems.

Effects of *Ailanthus altissima* on natural ecosystems: Floristic diversity was higher in stands dominated by *A. altissima* (Table 1). Species richness (N), Shannon-Weiner index of α-diversity (H´) and evenness of Shannon-Weiner index of diversity (E) were higher in the *A. altissima* stands compared with stands where *Quercus pubescens* or *Q. coccifera* were dominant. However, the Berger Parker index of dominance was slightly lower only in the case of *A. altissima* when in proximity to stands of *Q. coccifera* compared to the stands where *Q. coccifera* was dominant. These results are in contrast with those reported by Kowarik (1995), Knapp and Canham (2000) and Merriam (2003) who found reduced species richness in plant communities dominated by this species. The results of this study could be attributed to the fact that *A. altissima* is intolerant to shade, its invasion in these regions was relatively recent and intense human activity favor the presence of other species that are usually present in arable land, anthropogenic and ruderal habitats.

The above results are also verified by the special floristic composition of the *A. altissima* forest stands (Table 2) where light-demanding species were found in the understorey such as *Myosotis ramosissima, Sanguisorba minor, Sherardia arvensis*. These species are common in grasslands and arable lands (Mucina, 1997). Species typical of forest vegetation (Mucina, 1997) were found in the understorey (such as *Brachypodium sylvaticum, Cyclamen hederifolium, Veronica chamaedrys* etc.); these species were also present in the understorey of *Quercus pubescens* forests or *Q. coccifera* shrublands. Furthermore, some synanthropic species were found (*Geranium molle, Galium aparine, Torilis arvensis* etc.); these species are usually found in regions of intense human activity and were not present in analyzed stands of *Quercus pubescens* or *Q. coccifera.* Although most of the species, found in *A. altissima* stands, were represented by a huge number of individuals, their constancy was very low. This is most likely a result of the disturbance of the ecosystem.

The presence of a relatively high number of synanthropic species could imply an intense disturbance of ecosystems. Mucina (1997) has reported a variety of herb rich disturbed communities such as *Stellarietea mediae* and *Artemisietea vulgaris*. Consequently, the higher floristic diversity in stands dominated by *A. altissima* could also be a result of the disturbance of the natural ecosystems.

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