



Chapter

5

Fraxinus angustifolia
(narrow-leaved ash)



Photo 5.1.- Dense *F. angustifolia* forest at Ploiesti, Romania.

Distribution and systematics

F*raxinus angustifolia* Vahl (narrow-leaved ash) is found throughout southern and eastern Europe. Its distribution extends from Spain and Portugal in the west, northwards to Slovakia and southern Moravia, and eastwards to Turkey (Mediterranean and Black Sea region), Syria, Caucasus, Iran and southern Russia (see distribution map on page 11: Figure 1.2). In Central Europe, the Pannonian Basin and the Balkans it occurs mainly in riparian and floodplain forests (Photo 5.1). These forests are found along the large rivers and their tributaries (such as the Drava, Sava, Danube, Váh, Morava, Tisa, Nester, Maritza, Tundja and Iantra), or associated with lakes and wetlands (e.g. Lake Balaton, Burgas and Varna). In the Mediterranean region (Spain, France, Italy, Greece, southern Turkey), *F. angustifolia* can be found on drier sites at higher altitudes (500m-2000m), as well as on riverine and wetland sites. Mixed stands of *F. angustifolia* and *F. excelsior* are also found (e.g. in Romania and Moldova) on the banks of large rivers, where *F. excelsior* seeds have been transported downstream by the water.

Fraxinus angustifolia is closely related to *F. excelsior*. Its morphology is quite variable, and several **TAXA** have been described based on differences in the **SAMARA** and leaf morphology. *Fraxinus angustifolia* has three subspecies, restricted by geographical region:

- ssp. *angustifolia* (western Mediterranean);
- ssp. *oxycarpa* (Bieb. ex Willd.) Franco & Rocha Afonso (east Central Europe and southern Europe from NE Spain eastwards);
- ssp. *syriaca* (Boiss.) Yalt. (Turkey and eastwards to Iran).

Apart from these geographical criteria, the three subspecies differ from one another in the number of leaflets and the shape of the samara, but there are many intermediate forms that make subspecies determination difficult. There are also different phenotypic forms of *F. angustifolia* (form *parviflora*, form *rotundifolia*), which are not considered as separate taxa. The form *rotundifolia*, with wide leaves like those of *F. excelsior*, is common in Moldova and the eastern part of Romania.

Distinguishing *F. excelsior* and *F. angustifolia*

Fraxinus angustifolia is sometimes confused with *F. excelsior*, although there are several characters that distinguish them (see Figure 5.1):

The clearest distinction is in the **INFLORESCENCE** type. *F. excelsior* has a compound inflorescence (panicle), whereas *F. angustifolia* has a simple, unbranched raceme.

There are many more flowers in the large inflorescences of *F. excelsior* than in the smaller inflorescences of *F. angustifolia*.

This can also easily be seen on trees bearing fruits or fruit remnants: there are many branches in a *F. excelsior* fruit cluster, but only one branch in *F. angustifolia*.

Although bud colour is variable, *F. excelsior* has black terminal buds whereas *F. angustifolia* buds are usually brown.

The leaflets of *F. angustifolia* are usually narrower than in *F. excelsior*.

N.B. One should not rely on leaf and bud characters alone to distinguish the two species, since these vegetative characters are quite variable in both species. Seedlings of the two species, as well as **HYBRIDS**, may therefore be indistinguishable.

















Fraxinus pallisiae, a hairy variant common in the Danube Delta

Synonyms

The name *F. pallisiae* Willmott, and its synonym *F. holotricha* Koehne, is also treated in this book as a synonym of *F. angustifolia* (although some practitioners, in its natural range in southeastern Europe, consider it as a distinct species in afforestation programmes). This variant is similar to "normal" *F. angustifolia* ssp. *oxycarpa* in most characters, but is distinguished by its pubescent (hairy) or partly pubescent leaves and branchlets, especially when young. The samaras may be pubescent too. It is usually found on wet sites (such as the Danube Delta), flood plains and streams, but more or less pubescent individuals occur elsewhere too, often mixed with intermediate forms and "pure" *F. angustifolia*. The variant is found in various proportions in the eastern part of Romania (from 10-15% in Ploiesti district and Oltenia region, to more than 80% in the Danube Delta), and also in Moldova.

Figure 5.1.- Practical guide for the differentiation of *Fraxinus excelsior* and *Fraxinus angustifolia*

Species Criteria	<i>Fraxinus excelsior</i>	<i>Fraxinus angustifolia</i>	Validity of criteria
Buds	 <p>Colour: black to dark brown. Terminal buds with flattened node, forming a "snake-head"</p>	 <p>Colour: brown (variable). Flattened node does not form a "snake-head"</p>	 <p>Weak: because of the variation of bud colour in <i>F. angustifolia</i></p>
Shoots / Stem	 <p>Non-hairy¹</p>	 <p>Mostly non-hairy¹</p>	Indifferent, but see comments ¹
Leaflets	 <p>Oval-shaped to spear-shaped</p>	 <p>Narrower, spear-shaped</p>	Slightly discriminative: because of a large variation in leaflet shape and atypical forms (see comments ²)
Gender	 <p>Pure male trees and hermaphrodite or female trees</p>	 <p>Hermaphrodite trees only³</p>	 <p>Powerful only in the case of pure male <i>F. excelsior</i> trees</p>
Inflorescences and fructifications	 <p>Branched (Panicle with 50-150 flowers/fruits)</p>	 <p>Unbranched (Raceme with 15-20 flowers/fruits)</p>	Very powerful with the exception of male <i>F. excelsior</i> trees that may form some fruits (see comments ⁴)
Fruits (samaras)	 <p>Flattened, distally winged</p>	 <p>Flattened, distally winged</p>	Indifferent ⁵

(see Comments overleaf...)

Figure 5.1.- (...continued)

Comments

1. The subspecies *F. excelsior* ssp. *coriariifolia* (occurring in eastern Romania) is densely hairy on shoot, buds, leaves and samaras but the more widespread *F. excelsior* ssp. *excelsior* is always non-hairy.

The hairy variant of *F. angustifolia* (sometimes distinguished as the separate species *F. pallisiae* and *F. holotricha*) is hairy on shoots, buds, leaves and samaras. Intermediate forms which are more or less hairy, or partly hairy, exist in some populations mixed with non-hairy individuals. The hairy ash is mainly found in eastern Europe, and is especially common in the Danube Delta where some *F. angustifolia* populations consist of only hairy individuals.

2. The narrow-leaved *F. excelsior* (f. *acuminata*), with leaves like those of *F. angustifolia* is found in large areas in the eastern part of Romania (forest district Iasi) and also in Moldova Republic. The wide-leaved *F. angustifolia* (f. *rotundifolia*) is present in 10-50% of the individuals of the population in almost all *F. angustifolia* forests in Romania, more frequent in the eastern part of country.



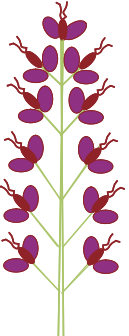
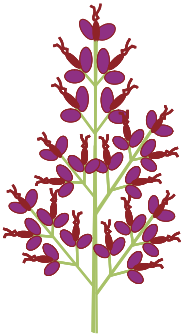

Narrow-leaved *F. excelsior*







Leaflet variation in *F. angustifolia*

3. Female trees of *F. excelsior* can have flowers with reduced **STAMENS**. The hermaphrodite trees of *F. angustifolia* can have hermaphrodite inflorescences (usually with some pure male flowers at the base) and some pure male inflorescences.

4. The mixed inflorescences of some *F. excelsior* trees, with hermaphrodite flowers only on the main axis and male flowers on the secondary branches, can be mistaken in the fruit stage because of the appearance of a raceme after the fall of male flowers.

<i>F. angustifolia</i>	<i>F. excelsior</i>	<i>F. excelsior</i>
Unbranched inflorescence with hermaphrodite flowers	Branched inflorescence with hermaphrodite flowers	Branched inflorescence with hermaphrodite flowers on the main axis and branches with male flowers that have fallen off
		

5. Another dangerous mistake: common ash versus American ash

Species	<i>Fraxinus excelsior</i>	<i>Fraxinus americana</i>	Validity of criteria
Criteria			
Fruits (samaras): seed cavity	Flattened 	Cylindrical 	Very powerful
Other	 Hermaphrodite or unisexual flowers in a panicle	 Unisexual flowers only (male or female) in dense panicles on separate male and female trees	

Ecology and silviculture

F*raxinus angustifolia* is commonly found in riparian forests, sometimes in pure stands but more commonly mixed with other broadleaves including *Quercus*, *Carpinus*, *Ulmus*, *Acer*, *Alnus*, *Populus*, *Salix*, *Platanus*, *Juglans*, *Tilia*, *Sorbus* and *Prunus* species, as well as various small trees and shrubs including *Pyrus*, *Malus*, *Corylus*, *Tamarix*, *Cornus*, *Crataegus*, *Ligustrum*, *Ramnus*, *Viburnum*, *Sambucus* and *Rosa* species^{6; 22; 24; 37}. In contrast to *F. excelsior*, *F. angustifolia* tolerates wet and flood-prone sites.

Soil and climate

Fraxinus angustifolia grows well on moist, rich clays in bottomlands and moist, well-drained soils in uplands. It does best on rich soils at lower altitudes and will withstand temporary flooding. It prefers aerated or only moderately compacted sandy clays. It also grows well on loams, sandy loams and sandy clay loams with pH in the range 5.0–8.0 (but usually 6.0–8.0). The optimum soil depth is between 40 and 100 cm, with a soil volume of 0.45 to 0.9 m³/m². Sub-soils are usually alluvial, with various textures.

Fraxinus angustifolia requires a mild climate and precipitation between 400 and 800 mm. Such conditions ensure a growing season of 6 to 7 months. *Fraxinus angustifolia* is a light-demanding species, requiring 60–100 % of total direct light.

Silvicultural characteristics

Riverine mixed forests (Photo 5.2), including those containing *F. angustifolia*, represent very stable ecosystems, rich in species diversity. In these forests, most of the hardwoods forming the canopy layer have valuable timber. Silvicultural management of these forests can be achieved using continuous cover methods (shelterwood or group systems) in which natural regeneration of *F. angustifolia* and *Quercus robur* is achieved by regeneration cuttings in small areas (strips or groups) in years with abundant seed crops. Secondary fellings are repeated several times in the same stand, allowing a regeneration period of 15 to 25 years. Another option is to encourage stands of one or two species by selective cutting at long intervals (as practised in Austria, Croatia and Romania). In stands dominated by *F. angustifolia* where the soil is temporarily flooded in spring and autumn, natural regeneration from seed is limited. In such cases, coppicing is carried out on a cycle of 25 to 35 years.

The proportion of *F. angustifolia* to plant in mixed forests depends on the site and on the target mixture. On typical oak sites, the proportion of other hardwoods (e.g. ash, cherry, black alder) should be around 30–40 %, whereas on wetter sites (typical riverine forests, or those subject to temporary flooding) the proportion of *F. angustifolia* should increase to 70–80 %. The remainder is typically a mixture of black alder, willows and poplars. In southern Europe and the Mediterranean, the most productive natural stands are usually found in valley forests. However, due to the patchy distribution of *F. angustifolia* in the lowlands and to human pressures such as deforestation, farming and water extraction in these areas, many stands are left simply for conservation purposes. Silvicultural regimes for *F. angustifolia* on drier sites in southern Europe (Photo 5.3) are usually not so intensive and are linked with coppicing and/or mixed coppicing and planting.

For a hardwood, *F. angustifolia* grows rapidly when young, but its growth slows after 50–60 years. In general, it is considered a fast-growing species: the mean annual increment can reach 12–15 m³ ha⁻¹ in natural stands and 20–25 m³ ha⁻¹ on good plantation sites. The suggested rotation is 40–60 years to achieve 40–60 cm DBH, though site and wood quality objectives must also be taken into account. The rotation time for a larger target size varies in different parts of the natural range. In Central Europe it is around 60–80 years, and in Croatia and Serbia about 60 years, though in the riverine forests of northern Turkey, where growth rates are particularly high, it may be as short as 40 years. Continuous cover forestry can be applied in mixed stands of *F. angustifolia* and *Quercus robur*, using 60–80 year rotations for *F. angustifolia* and 120–140 years for *Q. robur*. As with most broadleaved trees, harvesting of *F. angustifolia* should be in winter.

Drainage to remove excess soil water is important when establishing new plantations in riparian forests on gleyed soils. On alluvial soils, it is important to thin the seedlings and control competing vegetation, as *F. angustifolia* does not tolerate heavy competition from weeds. In plantations, the number of plants established per hectare is usually about 5000 (i.e. 1m x 2m spacing) if the seedlings are small. Intensive plantations now tend to use fewer, larger (2–3 year old) plants at spacings of 2m×2m to 3m×3m. Although more expensive, this gives higher survival by reducing the effect of weed competition.

As with all tree species, a major issue in *F. angustifolia* plantations for wood production is the planting spacing. Wide spacing adversely affects both stem and wood quality. Narrow spacing (e.g. 2m x 2m, 2.5m x 2.5m, 2m x 3m, 3m x 3m) is recommended for high quality wood production. Ash plantations are generally established from nursery-

grown seedlings and rarely from rooted cuttings. Regeneration by direct seeding is not recommended for *F. angustifolia* because its slow initial growth results in high weeding and tending costs. Intimate mixtures of oaks (*Quercus*) with *F. angustifolia* and other fast-growing species (e.g. *Acer*, *Tilia*, *Alnus*, *Salix*, *Populus*) should be avoided since the fast-growing species out-compete the oaks.

Traditional and modern uses

F*raxinus angustifolia* is an important timber species with similar wood properties to *F. excelsior* (see p. 32). There have been many studies to compare the wood quality of the two species. *Fraxinus excelsior* has a higher proportion of heartwood (52-74%) than *F. angustifolia* (30-56%)²³. In trees grown on comparable sites, the width of annual growth rings of *F. angustifolia* is 1-3 mm, while in *F. excelsior* the rings are 15-30% narrower. The wood of *F. excelsior* is denser (665–728 kg.m⁻³) than that of *F. angustifolia* (645–684 kg.m⁻³)²³, but its volumetric shrinkage is higher. The mechanical properties of *F. angustifolia* are slightly inferior, in terms of compression strength and tensile strength along the grain, bending strength, impact bending strength, and the bending modulus of elasticity.

The wood properties of *F. angustifolia* vary according to the growing site. In southern and south-western Europe (Photo 5.4) the wood quality tends to be higher on the relatively dry sites preferred by the species. In other areas, *F. angustifolia* tends to grow faster, and its yield on optimum sites in northern Turkey is comparable to that of poplars⁵. The leaves, both fresh and dried, are palatable and nutritious to animals, and were used as fodder in southern Europe, where pollarded ash trees can still be seen. The fodder is also favoured by red and roe deer, which frequently damage young trees in plantations and natural regeneration, initially by browsing and later (in the case of red deer) by bark stripping. *Fraxinus angustifolia* has also been widely used in central and southern Europe as an ornamental tree along roads and city streets.



Photo 5.2.- Riverine *F. angustifolia* population along the Morava river at the Austrian/Slovakian border (near Hohenau, Austria).



Photo 5.3.- *F. angustifolia* planted around Castelbuono, Sicily, Italy.



Photo 5.4.- Remnant tree of *Fraxinus angustifolia* in an open field at Melia, Greece.

Research under FRAXIGEN

In FRAXIGEN, we have studied genetic variation in *F. angustifolia* in laboratories in three countries (Greece, Romania and Spain), looking at populations from Bulgaria, Croatia, Greece, Hungary, Italy, Moldova, Romania, Slovakia, Slovenia, Spain, and Turkey. The level of genetic variation was studied using nuclear and **CHLOROPLAST** microsatellite markers. The methods used in all these studies are described in Chapter 3. Each laboratory used a different method for the visualisation of microsatellite markers (because different laboratory equipment was available in each country), so standardisation of the data between laboratories is necessary and was still in progress when this book was printed. The results on nuclear **MICROSATELLITES** (from Spain and Greece) are therefore presented separately here, whereas the chloroplast data (from all three laboratories) has been standardised. Data on nuclear genetic variation from Romania was not available at the time of writing.

The molecular studies of genetic variation have been complemented, in Greece, by a **RECIPROCAL TRANSPLANT EXPERIMENT** (RTE) established at the same sites which were sampled for the molecular studies (Figure 5.7). This trial network was designed to examine the extent of local adaptation and the scale over which it operates, as described in Chapter 3.

The flowering and leafing **PHENOLOGY** of *F. angustifolia* was studied in Spain, Greece, Slovakia and Romania, giving a broad east-west geographic coverage. The studies of pollination biology and **GENE FLOW** described for *F. excelsior* and *F. ornus* in Chapters 4 and 6 were also replicated for *F. angustifolia* in Spain and Greece, but did not give any results because the developing seed was killed by frost in two consecutive years. The implications of the frost sensitivity of *F. angustifolia* are discussed further in the section on reproductive biology.

Genetic variation

Background

No molecular genetic data has previously been published on *F. angustifolia*. An Italian research group¹ has been working on chloroplast microsatellites, and kindly provided unpublished data on the distribution of *F. angustifolia* **HAPLOTYPES** across most of Europe. We have assigned numbers to our haplotypes which correspond to this larger study.

FRAXIGEN findings on long term migration (chloroplast haplotypes)

Thirty-four populations of *F. angustifolia* were studied in FRAXIGEN and eight different haplotypes were identified (Figure 5.2). The haplotypes matched those reported in an earlier European-wide study of chloroplast variation in *F. excelsior*¹⁵, which has the same haplotypes as *F. angustifolia*.

One dominant haplotype (H4) was identified within Spain, which was also present in single populations from Croatia and Moldova. The results from Italy showed the existence of two haplotypes (H3 and H5). The earlier European-wide study¹⁵ reported that H5 was the dominant haplotype in *F. excelsior* in southern and central Italy, whilst haplotype H3 was common in northern Italy and southern France.

Haplotype H1 was the most dominant in Greece and the Balkan Peninsula. The second most dominant haplotype in Greece (H3) seems to have migrated northwest to the Mediterranean area (Italian Peninsula and southern France). Haplotype H5 was also found in one population.

Haplotype H2 was found to be dominant in the populations studied in Slovakia, Hungary and Slovenia, whilst haplotypes H6, H7 and H9 were found in Romania, Moldova and Turkey.

¹ Dr GG Vendramin, Istituto di Genetica Vegetale, Consiglio Nazionale degli Ricerche, Via Atto Vannucci 13, 50134 Firenze, Italy.

The majority of haplotypes were found in populations from the Balkans, suggesting that this was a glacial refugium, i.e. an area where *F. angustifolia* survived the last Ice Age. However, both the Iberian and Italian peninsulas may have been additional refugia, as they contain haplotypes poorly represented in the Balkans.

FRAXIGEN findings on genetic variation (nuclear diversity)

The thirty-four populations of *F. angustifolia* sampled in FRAXIGEN were analysed using the same microsatellite markers used previously in a European-wide study of *F. excelsior*⁶ so that our results would be comparable. In each population, **DNA** from leaf material was extracted from 30 adult trees separated by 50 to 100m, depending on the size of the woodland. Mixed stands of *F. angustifolia* and *F. ornus* were found in Italy (IT_17A, IT_18A, IT_19A), Greece (GR_12A) and Spain (ES_04A).

We can only present in this chapter the results from 19 populations (Greece, Italy and Spain), since the analysis of the remaining populations was still in progress at the time of writing. For each marker we recorded the total number of **ALLELES** found in each population (**ALLELIC RICHNESS**; Figure 5.3), and also calculated **HETEROZYGOSITY**, which takes into account the evenness of the distribution of different alleles. Both indicated overall high, and similar, levels of **GENETIC DIVERSITY** across all the populations. In Greece, however, the most southern populations tended to have lower diversity. This may be explained by increased relatedness (crossing between relatives) in these populations, caused by various factors (e.g. isolation, southern distribution limits, human influence). The overall levels of diversity did not differ among pure and mixed stands.

The differences between populations (**GENETIC DIFFERENTIATION**) were small. The Spanish and Italian populations formed two separate groups. Exceptions were population IT_18A, from southern Italy, which appears to be more similar to Spanish populations. In contrast, population ES_06 from eastern Spain is more similar to the Italian populations. The Greek populations showed little differentiation, suggesting that there may be high gene flow between them.

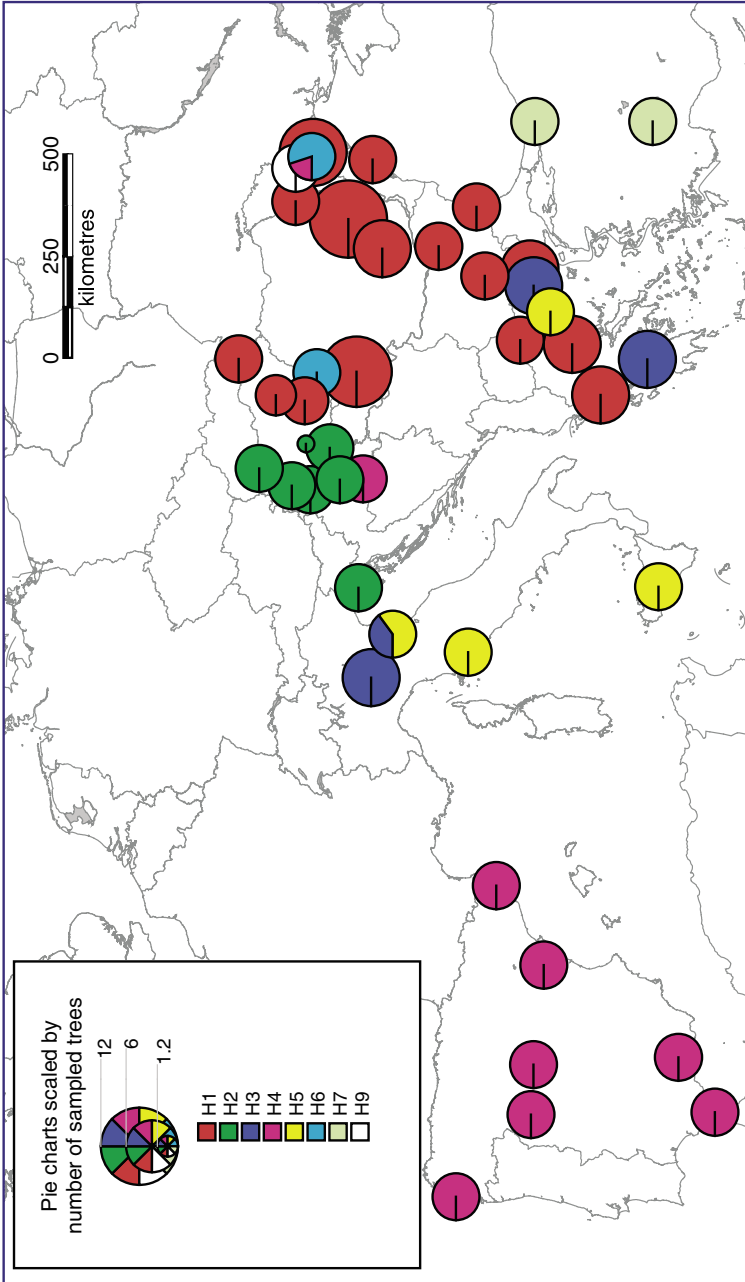


Figure 5.2.- Chloroplast haplotypes in 34 populations of *Fraxinus angustifolia* from Bulgaria, Croatia, Greece, Hungary, Italy, Moldova, Romania, Slovakia, Slovenia, Spain and Turkey. The size of the pies is scaled to show the number of individuals sampled in each population.

Figure 5.3.- Allelic richness in 19 populations of *Fraxinus angustifolia* from Greece, Italy and Spain. The size of the circles is scaled to show the total number of alleles found at five nuclear microsatellite loci. Each pie is divided into slices showing the proportion of alleles found at each locus. The number of alleles in each population is corrected for differences in sample size between populations.

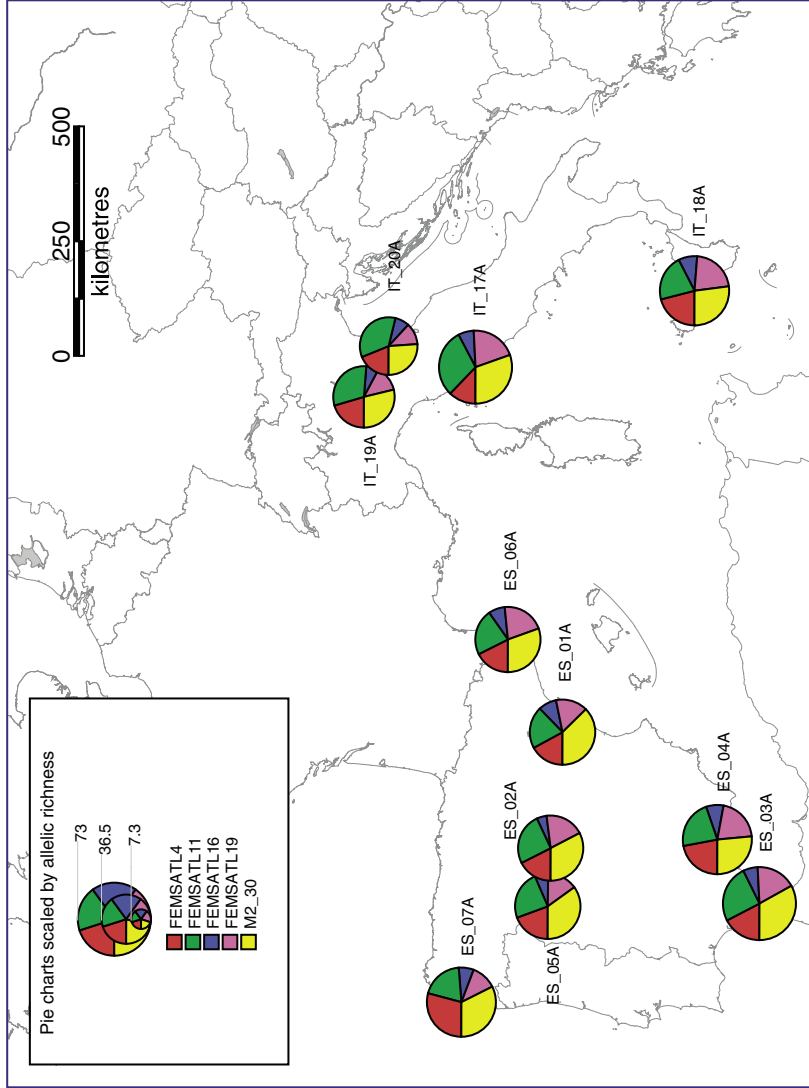


Figure 5.3a.- Allelic richness of *Fraxinus angustifolia* in populations from Italy and Spain; data from Spanish laboratory.

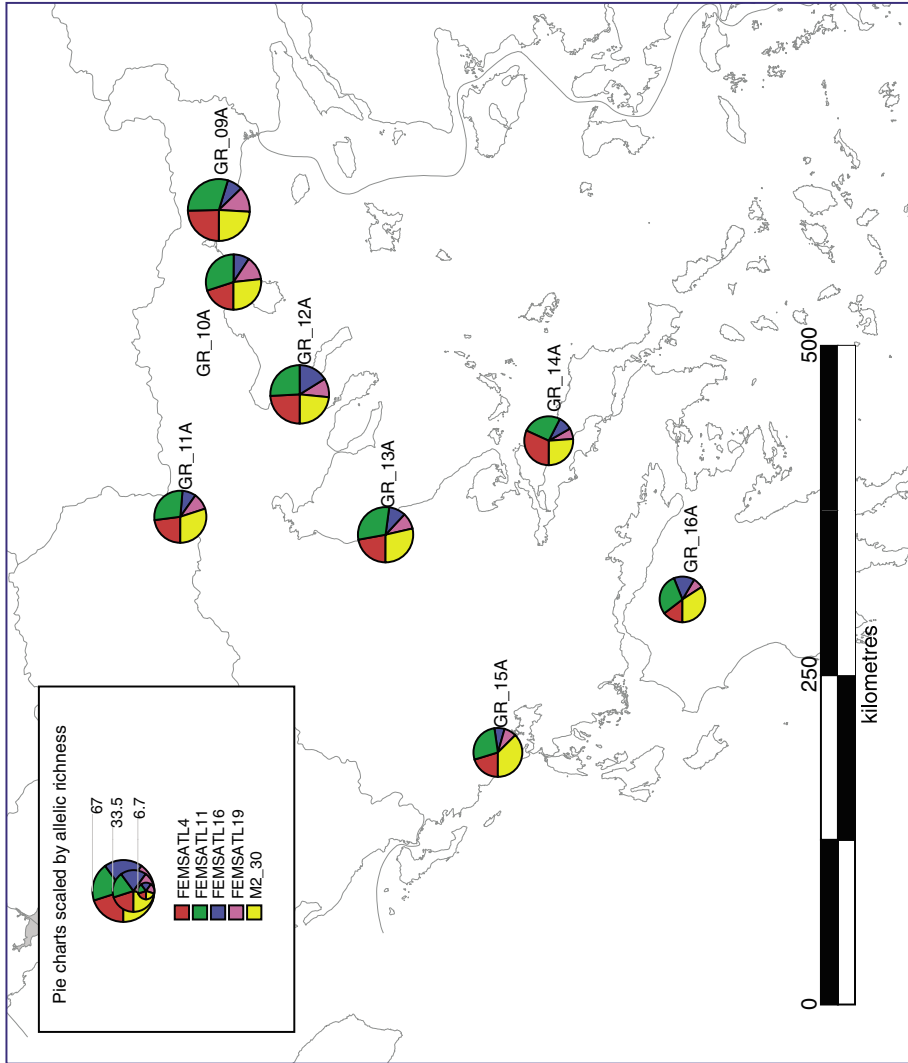


Figure 5.3b.- Allelic richness of *Fraxinus angustifolia* in populations from Greece; data from Greek laboratory.

Reproductive biology

F*raxinus angustifolia* is a wind-pollinated tree up to 30 m tall. It is closely related to *F. excelsior*, to the extent that they are able to hybridise^{33,34}. Inflorescences can be male, **HERMAPHRODITE** or mixed male and hermaphrodite. No female inflorescences (with pure female flowers or female with rudimentary stamens) have been found in the study populations (or in any reports to date). The male and hermaphrodite flowers of *F. angustifolia* occur on all individuals, i.e. all trees are functionally hermaphrodite.

The start of flowering of *F. angustifolia* varies with latitude, but it always starts before *F. excelsior* in the same area. The inflorescences emerge from lateral buds in the spring, 2–11 weeks before the leaves expand from the terminal buds. The difference between flowering and leaf flushing is much more apparent in the Mediterranean than in central Europe (Figure 5.4).

Hermaphrodite inflorescences have 15 flowers on average. Although the mean size of mixed (hermaphrodite + male) inflorescences is slightly larger (17.3 flowers on average), the total number of flowers in the racemes of *F. angustifolia* is always much lower than in the panicles of *F. excelsior*. Therefore, the type and size of inflorescence is considered the best morphological **TRAIT** for the separation of these two closely related species.

In Mediterranean countries (Spain, Greece), the phenological observations in 2003 and 2004 revealed a flowering period between January/early February and February/early March. At higher latitudes (Romania, Slovakia), flowering usually starts in the second half of March and may last till the second half of April. Over two years of investigations, the time of flowering varied by up to 18 days. Although *F. angustifolia* is **PROTOGYNOUS**, i.e. the start of the stigma receptivity precedes the start of the opening of **ANTHERS** and the release of **POLLEN**, there is a marked overlap of the male and female phases within individuals, making self-pollination possible (Figure 5.4).

Occasionally, depending on the autumn and winter temperatures, flowering starts in autumn (mostly in late November, after leaf fall). This happens not only in the Mediterranean area but also in central Europe. In such cases, the inflorescences are extremely vulnerable to winter frosts. Another consequence is that the flowering and fruiting intensity are not correlated, owing to the frequent damage to developing seeds by spring frosts. The overall result of this vulnerability is that seed production is often

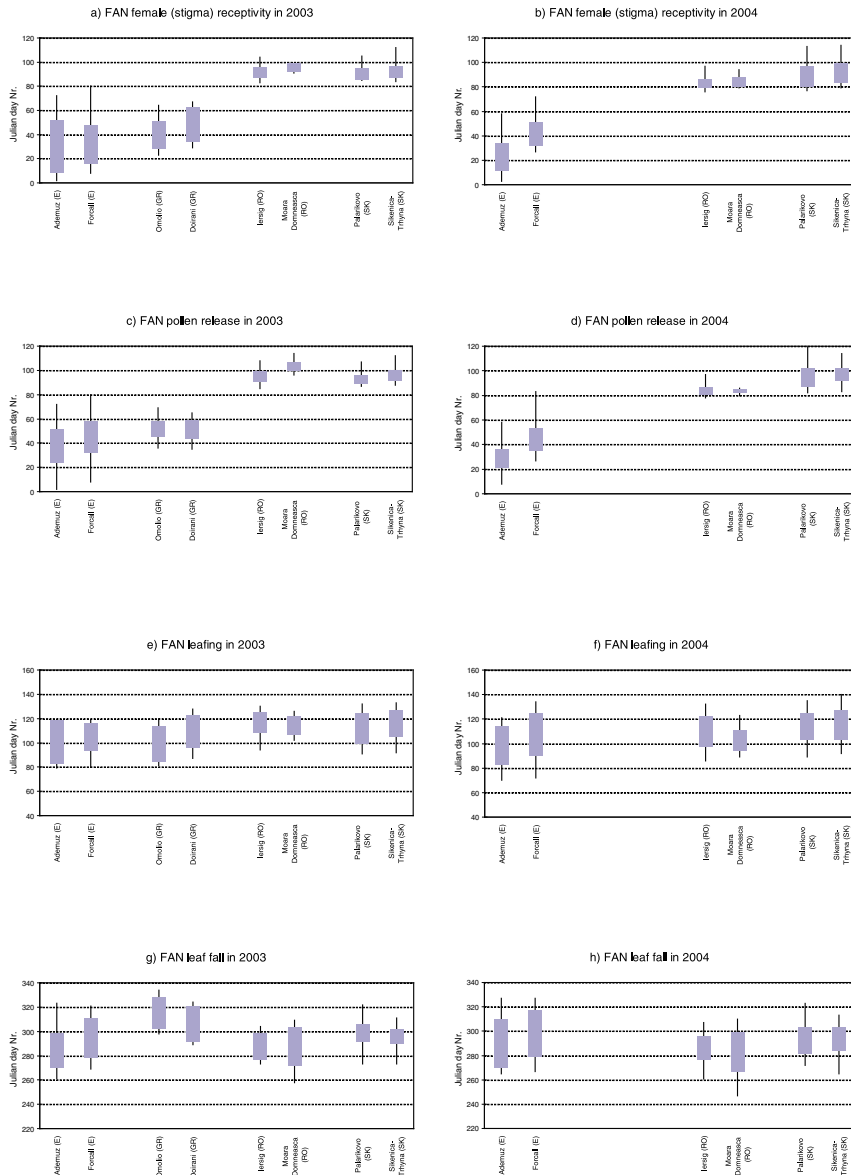


Figure 5.4.- Phenological observations of *F. angustifolia* (FAN) in populations in the Mediterranean and Central Europe in 2003 and 2004.

low or non-existent in *F. angustifolia*, and frost is likely to be a major factor limiting the species' distribution. It is therefore a species which might be expected to increase its range if the European climate becomes warmer.

Leaf flushing shows similar trends to flowering, although there is less difference between regions. Leafing starts earlier in the Mediterranean countries (mid March to early May) compared to the countries in central Europe (late March to mid May). The opposite occurs in autumn, where the most frequent date for complete defoliation falls on the turn of October and November in Romania and Slovakia, in early November in Spain, and in the second half of November in Greece (Figure 5.4). As a result, the vegetative period of *F. angustifolia* is longer in the Mediterranean region and shorter in Central Europe.

One of the most important aspects of phenological studies is to assess the chances of natural hybridisation between *F. excelsior* and *F. angustifolia*. *Fraxinus excelsior* always starts flowering after *F. angustifolia*, but in some years the end of *F. angustifolia* flowering may overlap with the beginning of *F. excelsior* flowering. In a young mixed seed orchard in southern Slovakia (Figure 5.5), and in natural mixed stands of the two species in Romania (Figure 5.6), we found a marked overlap in flowering duration which would make natural hybridisation possible. It is important to note that hybrid seed would be more likely to be found on *F. excelsior* than on *F. angustifolia* trees, because there is more overlap between *F. excelsior* female receptivity and *F. angustifolia* pollen release than between *F. angustifolia* female receptivity and *F. excelsior* pollen release.

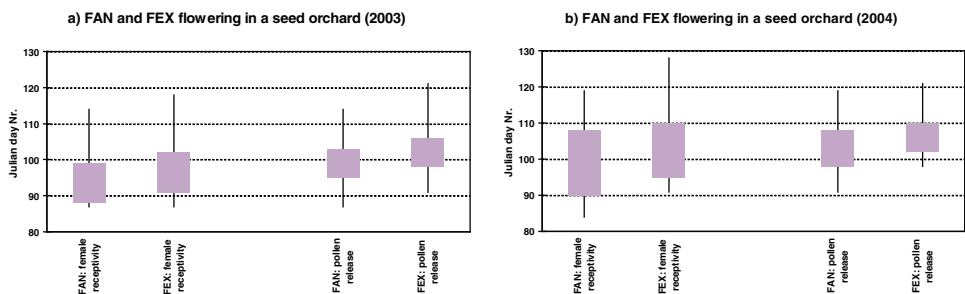


Figure 5.5.- Phenological observations of *F. angustifolia* (FAN) and *F. excelsior* (FEX) in a seed orchard in Southern Slovakia in 2003 and 2004.

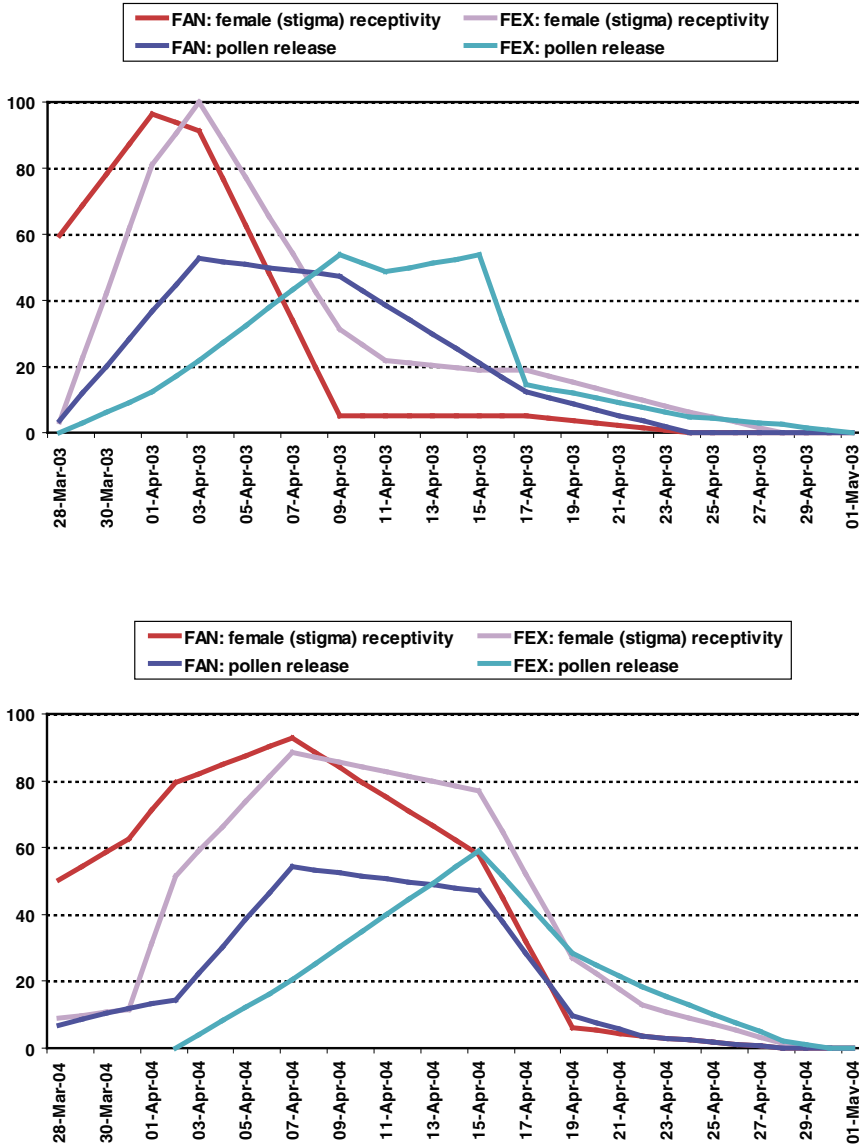


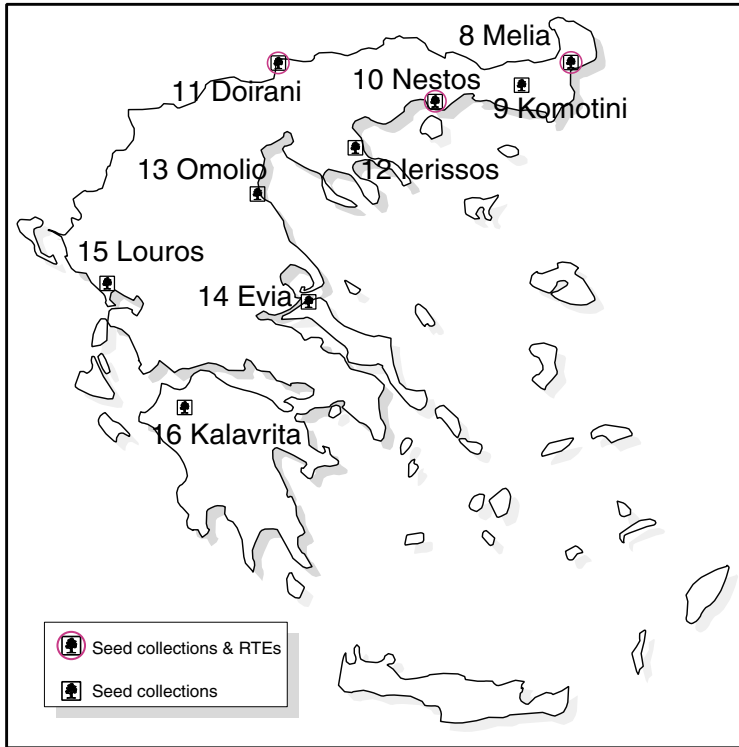
Figure 5.6.- Phenological observations of *Fraxinus angustifolia* and *F. excelsior* in a natural mixed stand in Romania in 2003 and 2004.

Local adaptation

The assumption that locally sourced seed is preferable, because it is more likely to be well adapted to the planting site, is central to current European policies on forest reproductive material (see Chapter 2). The concepts of localised adaptation, and of reciprocal transplant experiments (RTEs) to examine the extent and scale of local adaptation, are discussed in Chapter 3.

In FRAXIGEN we established an RTE for *F. angustifolia* at nine sites in Greece. Poor survival at six of the sites has meant that the experiment is not fully reciprocal, but we have been able to compare the nine seed sources at three of the sites (Figure 5.7). Survival and growth of two year old seedlings were assessed in the field. The results show that survival rates were not significantly different between provenances, but were between planted sites. There were significant differences between seed sources for height increment (at all three sites). Height increments were also significantly different among the sites (probably due to different site conditions - climate and soil). The interaction between seed sources and planted sites (often called **GENOTYPE** by environment interaction) was significant for height growth, showing that the relative performance of the seed sources was different at different sites. There was however, little indication of home site advantage. At the Melia site the local seed source and the closest other site (57km away) are performing best, but there is no overall correlation between height growth and geographic distance. In contrast, at Doirani, a high correlation was found between height and geographic distance, but poorer performance was only apparent in material from sites more than 200 km away. There was no apparent relationship between seed source location and performance at the third site, Nestos.

After only two years growth it is hard to draw firm conclusions about the performance and extent of any local adaptation in the seed sources evaluated. The results so far suggest that if there is any local adaptation at this life stage it is at a very broad scale (more than 100 km) and not restricted to within a few km. Genetic analysis using neutral molecular markers^{28;38} showed low differentiation among tested populations, which may equate with the low level of **ADAPTIVE VARIATION** found. Longer term evaluation may be required for the genotypes' expression to show in the different environments. When seed is needed for regeneration and ecological restoration purposes it should be collected from relatively local populations and from as many trees as possible (more than 20; see box 7.1 Chapter 7). This would ensure seed collections maintain the high levels of genetic variation found within *F. angustifolia* populations^{28;38}.



Site number	Site name	Latitude (°)	Longitude (°)	Altitude (m.a.s.l)
8	Melia *	40.58.3 N	26.07.4 E	155-170
9	Komotini	40.59.5 N	25.23.3 E	10-15
10	Nestos *	40.53.7 N	24.46.5 E	18-20
11	Doirani *	41.14.7 N	22.46.4 E	50
12	Ierissos	40.27.6 N	23.49.0 E	10-20
13	Omolio	39.53.6 N	22.37.2 E	16-20
14	Evia	38.49.1 N	23.25.3 E	120
15	Louros	39.09.2 N	20.45.8 E	50
16	Kalavrita	37.56.3 N	22.04.1 E	870

Figure 5.7.- Location of seed collection sites and *reciprocal transplant experiments for *F. angustifolia* in Greece.