A comparison of the growth and morphology of native and commercially obtained continental European *Crataegus monogyna* Jacq. (Hawthorn) at an upland site

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ABSTRACT

1. The growth and morphology of native *Crataegus monogyna* Jacq. (Rosaceae) obtained from an upland population in mid-Wales was compared with that of commercially obtained material of Hungarian provenance in an upland trial.
2. Six months after planting, the native plants were 35% taller, 70% more branched and had twice the total stem length and four times as many thorns per thorny plant than the commercial material. 91% of native plants were thorny compared with only 20% of commercial plants. Commercial plants had larger leaves, longer petioles and a greater severity of powdery mildew attack than the natives.
3. It was possible, using vegetative characters, to separate 88% of the natives from 80% of the commercial plants on the basis of their growth and morphology using discriminant analysis. Native seed was significantly smaller in size than the commercial seed which suggests that the measurement of reproductive characters would allow further discrimination between the two groups.

KEYWORDS: invasive species, amenity plantings, alien species, hedges.

INTRODUCTION

Crataegus monogyna Jacq. (Hawthorn) is the most commonly planted shrub species in new hedges and in the repair of derelict hedges in Britain (Brooks 1980). For the purposes of hedge-planting, whips are bought from nurseries where they are propagated from seed. There is circumstantial evidence that for commercial purposes seed has been obtained in many cases and from at least the early 1970s from the continent and especially eastern Europe (Dunball 1982). This is motivated by costs as foreign seed is often less than half the price of British collected seed.

Continental *C. monogyna* (henceforth referred to as alien) is a common constituent of hedges which have been planted along new roads and motorways and following recent road-widening operations. It can be identified by its habit of early bud-burst, often in early February when it contrasts with the unopened buds of native *C. monogyna* in neighbouring old hedges. This may indicate a phenology in the aliens which is poorly adapted to the British oceanic climate with its mild winters and a lack of rapid and reliable temperature increases more typical of spring in a continental climate. *C. monogyna* as a species has low bud dormancy (Murray *et al.* 1989) and is responsive to spring temperature increases. It is possible that natives have a higher dormancy than the aliens.

There is prima facie evidence that the use of alien *C. monogyna* material is inappropriate in British upland or exposed sites as it shows poor growth, is swamped by grasses and is susceptible to dieback both by wind scorching and powdery mildew. In contrast, it may be expected that native upland populations of *C. monogyna* would have a high degree of adaptation to exposure, poor soils and possibly grazing. A comparison of the growth and morphology of native and continental material at a worst-scenario upland site might identify whether locally obtained material is more suitable for upland planting than continental material.

MATERIALS AND METHODS

In November 1989, seed collections were made from a hawthorn population in mid-Wales that is unlikely to have been planted in recent decades because of its remote location, natural appearance and great age. This population forms a woodland scrub at an altitude of 350 m on the southern side of Cader Idris (SH/746.713), the second highest mountain in mid-Wales. The site is extremely exposed, as the valley runs to the coast in a south-westerly direction, the most frequent wind direction. Near the population the valley narrows and wind is funnelled through a pass to the east. Part of the population covers large block scree derived from a neighbouring cliff, which may have given some protection from grazing. The hawthorn trees at the site differ in size and probably age, some of the multi-stemmed trees appearing very old. Good *et al.* (1990) working in upland North Wales found the age of single-stemmed hawthorn bushes to be from ten to 115 years and also found suckering in some individuals. The trees at the mid-Wales site would be expected from their size to be at least as old as the oldest at the former site although suckering was not apparent.

Native seed was cleaned of fleshy covering by fermenting in water at room temperature. It was then placed in seed-trays at a depth of 1 cm in a 50:50 mixture of grit and compost outdoors. Alien seed that had been chitted (treated with concentrated sulphuric acid for 30 minutes, thoroughly rinsed in water and then mixed with compost and kept in polythene bags at 5°C for three months in order to break dormancy) was obtained from Forestart Ltd, Hadnall, Gloucester, who stated that it was of Hungarian provenance.

Samples of clean native seed (n = 121) and chitted alien seed (n = 25) were measured for length and width with calipers. Following germination in March 1991, seedlings were pricked out into individual cells of compartment seed trays. In July the plants were potted into 9 cm diameter pots containing John Innes compost no. 2. In March 1992 the material was planted at an exposed site at Pwllpeiran Experimental Husbandry Farm at an altitude of 330 m in well-drained soil. The site was on a small level area on a steep (30°) south-facing slope.

A total of 192 plants, comprising 63 aliens and 129 natives, were planted at a spacing of 0.5 m between seedlings in a rectangular plot of cultivated ground measuring 7 m by 10.5 m. In order to minimise the effect of environmental variation on the inter-group comparison, the plot was divided into four blocks within each of which 15–16 alien seedlings and 32–33 native seedlings were planted in completely random order. Seedlings were planted through a landscape fabric mulch (Tensar) which suppresses weeds but is permeable to rain.

Measurements of morphology, growth and powdery mildew score (Table 1) were made after shoot extension had finished in August 1992. The mildew infecting the plants is hawthorn powdery mildew (*Podosphaera clandestina* Lev.), a common disease causing dieback of the growing points which can reach epidemic status (Khairi & Preece 1978).

TABLE 1. MORPHOLOGICAL CHARACTERS, GROWTH AND DISEASE OF *CRATAEGUS MONOGYNA* SEEDLINGS STUDIED
(all measurements were made to the nearest mm)

1. Height
2. No. of branches
3. Total branch length including main stem
4. Stem diameter (single measurement at base)
5. Petiole length (mean of three petioles)
6. Leaf width (mean of three leaves)
7. Leaf length (mean of three leaves)
8. Bract length (mean of three bracts which are situated at the base of the petiole)
9. Total no. of thorns
10. Mildew incidence score:
    1) no disease,
    2) < three mature leaves with infection (silver and/or red blotches),
    3) mature leaves with or without infection and with at least two immature leaves and stem apex infected,
    4) as 3 above but with some length (> 1 cm) of stem affected.

N.B. Characters 5, 6, 7 and 8 above were sampled on the main stem at as near as possible to half-plant height.

Data were analysed using the multivariate statistical technique, discriminant analysis (DA) available in the Genstat statistical package (Genstat 5 Committee 1987; Digby 1989). DA is a statistical technique based on canonical variate analysis (Mardia *et al.* 1979) and finds the best linear combination of variables that discriminate between prior groupings. The resulting discriminant function has the greatest variable between-group variation relative to within-group variation. DA can be used to examine the validity of an a priori classification or to allocate new members to an existing classification. DA has been used in taxonomy, particularly at the intraspecific level, e.g. to examine the taxonomic groupings within *Hordeum vulgare* L. (Baum & Bailey 1983) and hybridisation between native and alien cultivar forms of *Lotus corniculatus* L. (Bonnemaison & Jones 1986). Using DA it is possible to determine how morphologically distinct the native and alien hawthorn groups are from each other. The analysis also determines which characters make major contributions to any discrimination between the two groups.

RESULTS

Alien seed was significantly larger (ANOVA, $p \leq 0.001$) than native seed with mean dimensions for width 5·0 mm and length of 6·4 mm compared with 4·4 mm and 5·5 mm for native seed. There was no significant difference in the shape of seeds (ratio of length to width) between the two groups.

The native and alien groups exhibited different morphology and growth characteristics (Table 2) at the upland site. The native plants showed overall greater growth than the alien plants. Native plants were on average 35% taller, had twice the total stem length and 70% more branches than the alien plants. Mean stem diameter was also greater in native plants. The alien plants had larger leaves and longer petioles than the native plants but bract size was similar in both groups.

Of the native plants, 91% were thorny compared with only 20% of alien plants. Native plants also had a greater number of thorns per thorny plant so that mean thorn density per unit length of stem was approximately three times greater than in the aliens. The mean powdery mildew score for the aliens indicates a higher incidence of disease of the stem apex than the natives.

Some morphological characters were highly and significantly positively correlated (Table 3): leaf width with leaf length (indicating a uniform leaf outline shape), leaf width with petiole length, and leaf length with petiole length. Some growth characters were also significantly and positively correlated: stem diameter and total stem length, stem diameter and branch number, and branch number and total stem length. The regular spacing of thorns, where they occurred, was indicated by the high correlation of thorn number per plant with total stem length. Powdery mildew score was significantly positively correlated with petiole length.

In the discriminant analysis the natives and aliens were introduced as separate groups. This

TABLE 2. MEAN VALUES AND THEIR STANDARD DEVIATIONS FOR MORPHOLOGICAL CHARACTERS AND GROWTH PARAMETERS OF NATIVE (N = 129) AND ALIEN (N = 63) MATERIAL OF *CRATAEGUS MONOGYNA*
(all measurements in mm)

	Native		Alien	
	mean	s.d.	mean	s.d.
Height	107·0	37·5	79·3	34·0
No. of branches	3·1	1·7	1·8	1·4
Total stem length	235·6	134·7	129·8	84·0
Stem diameter	4·2	1·4	3·6	1·5
Petiole length	4·3	1·7	6·3	3·1
Leaf width	12·7	3·5	15·3	5·1
Leaf length	15·4	3·9	19·5	6·7
Bract length	3·4	1·3	3·5	1·8
No. of thorns	10·6	13·1	0·6	1·5
Thorn number +	12·4	13·3	3·0	1·8
Mildew score	1·5	0·8	2·0	1·1

N.B. Thorn number + indicates the mean of only the thorny plants; s.d. = standard deviation.

TABLE 3. CORRELATION COEFFICIENTS BETWEEN VEGETATIVE CHARACTERS OF *CRATAEGUS MONOGYNA*

Height (ht)									
No. of branches (n.b.)	0·377 ***								
Stem diameter (s.d.)	0·416 ***	0·381 ***							
Petiole length (p.l.)	0·139	0·003	0·168						
Leaf width (l.w.)	0·135	0·067	0·275 **	0·706 ***					
Leaf length (l.l.)	0·132	0·068	0·218 *	0·719 ***	0·893 ***				
Bract length (b.l.)	0·306 **	0·147	0·264 **	0·386 ***	0·485 ***	0·445 ***			
No. of thorns (n.t.)	0·312 **	0·425 ***	0·387 ***	−0·162	−0·037	−0·074	0·071		
Mildew score (m.s.)	0·083	−0·004	−0·182	0·194 *	0·113	0·186	0·017	−0·075	
Total stem length	0·609 ***	0·656 ***	0·522 ***	0·015	0·148	0·129	0·233 *	0·819 ***	0·001
	ht	n.b.	s.d.	p.l.	l.w.	l.l.	b.l.	n.t.	m.s.

N.B. significance levels for the correlations coefficients are as follows: * = $p \leq 0.05$; ** = $p \leq 0.01$; *** = $p \leq 0.001$.

analysis reclassified 88% of the natives into the initial native group and 80% of the alien plants into the initial alien group. The natives and aliens are, therefore, reasonably distinct in terms of their growth and morphological characteristics, but there was an overall 15% overlap of the two groups (Fig. 1), i.e. 12% of the natives and 20% of the aliens were classified incorrectly. Some of this overlap might have been due to the effect of the harsh environment on growth and establishment. Most of the alien plants classified by the analysis as natives had small leaves and short petioles compared with those classified correctly as alien plants.

Those characters which are positively correlated with the discriminant function (Table 4), i.e. high values correlated with the native group are, in decreasing order of importance, number of thorns per plant, total stem length and branch number per plant. Characters that are negatively correlated with the discriminant function, i.e. high values correlated with the alien group are, in decreasing order of importance petiole length, leaf width, leaf length and mildew score.

DISCUSSION

In this study, the native *Crataegus monogyna* plants were discriminated from the aliens on the basis of higher stem length, a higher number of branches, higher thorn number and lower powdery mildew score. It would be expected that the relatively high mildew score and low growth rates in the aliens would be associated with low establishment rates following hedge-planting. If sufficient growth is not made, especially as a result of dieback due to mildew, then there is often the danger of planted hawthorn quickly becoming overgrown and shaded by grasses in a fenced situation.

The above would suggest that the natives are more suited to hedge-planting in upland situations than the alien material and because of their thorniness combined with a bushy habit, they may also be more grazing tolerant where fencing is insufficient to provide protection from grazing animals. The natives have smaller leaves and shorter petioles than the aliens and thus at nodes where thorns are present there is less unguarded leaf to graze. Certainly, from the degree of variation present in the natives, it would be possible to select for bushy, fast-growing, thorny plants, e.g. a plant which had shown the most growth in the experiment also had 109 thorns at a density of one thorn every 9 mm of stem. From the significant differences in seed size of the two groups, the gathering of

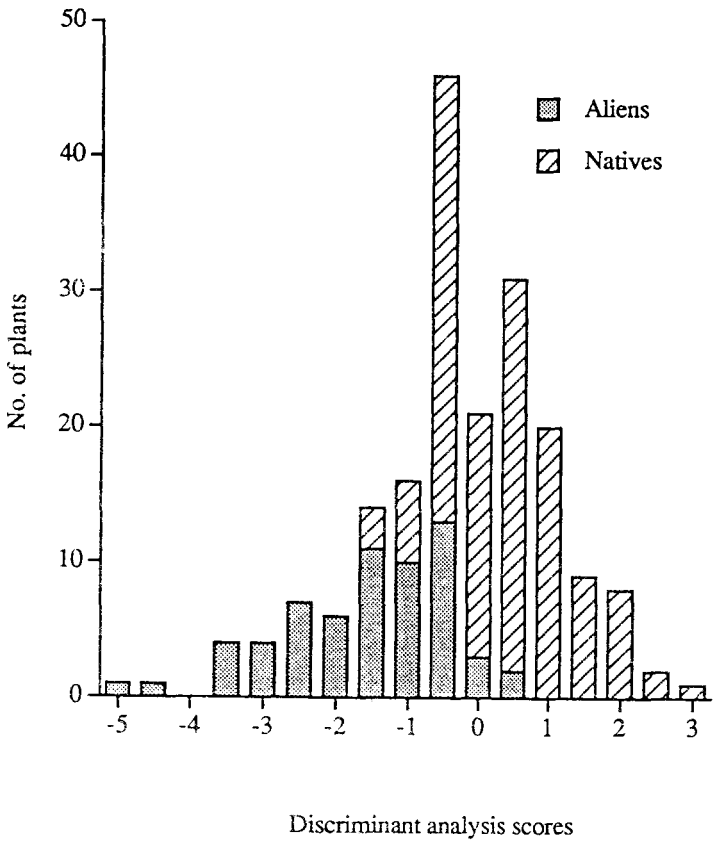

FIGURE 1. Bar chart of discriminant analysis scores for alien and native groups of *Crataegus monogyna*.

TABLE 4. CORRELATION BETWEEN DISCRIMINANT FUNCTION SCORES AND CHARACTER SCORES FOR *CRATAEGUS MONOGYNA*

Character	Correlation coefficient	Probability
No. of thorns	0·594	***
Total stem length	0·560	***
No. of branches	0·535	***
Height	0·494	***
Stem diameter	0·269	**
Petiole length	−0·582	***
Leaf length	−0·541	***
Leaf width	−0·440	***
Mildew score	−0·362	***
Bract length	−0·083	

N.B. Significance levels for correlation coefficients are as follows: ** = $p \leq 0.01$; *** = $p \leq 0.001$.

reproductive data may enable a further separation of the native and alien material on morphological grounds.

The escape and spread of exotic plant species following their movement by man across geographical boundaries is a potential danger to many endemic vegetation types (Salisbury 1961). Examples include the South American *Lantana montevidensis* (K. Spreng.) Briq. which is invading natural vegetation across the tropics (Ridley 1930) and *Rhododendron ponticum* L. from Turkey which is infiltrating oak woodland in the British Isles (Cross 1974). A much more insidious threat is the spread of material which is of alien provenance though conspecific with or closely related to an indigenous species and thus able to hybridise and potentially introgress. The planting of alien *Crataegus monogyna* represents such a threat. Across Europe there are six recognised subspecies of *C. monogyna* (do Amaral Franco 1968) and 22 species within the genus, at least four of which commonly hybridise with *C. monogyna*. A hybrid of *C. monogyna* and *C. laevigata* (Poiret) DC. (Midland Hawthorn) which naturally occurs in the south of England, *Crataegus* × *media* (Bradshaw 1971) and which may occur in imported seed, would probably be unsuitable for hedge planting. *C. laevigata* is typically an understorey species of lowland woodland and would be expected to be intolerant of exposed sites. There is always the possibility that importations of seed may contain alien subspecies, hybrids and even other species of the *Crataegus* genus which are then sold as common Hawthorn.

The natives sampled in this trial may represent an extreme locally adapted ecotype of *Crataegus monogyna* subsp. *nordica* franco (do Amaral Franco 1968) but the taxonomy of this species has yet to be completely resolved. However, as alien material continues to be planted in hedges from where it is highly likely that bird dispersal will take place, further taxonomic investigation of the British forms will be difficult to progress.

At upland sites in the British Isles, it can be argued that native *C. monogyna* should be planted for two reasons, namely that it has a higher growth performance than the aliens and also that it is more appropriate for conservation purposes to use native provenances as these represent a component of local biodiversity. Grant awarding bodies should ensure that in hedge-planting, British provenance is used at the very least.

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