Natural regeneration of Corsican pine (Pinus nigra subsp. laricio) in Great Britain

G. KERR

Forestry Commission Research Agency, Alice Holt Lodge, Wrecclesham, Farnham, Surrey GU10 4LH, England

Summary

Factors affecting the natural regeneration of Corsican pine (Pinus nigra subsp. laricio (Poir.) Maire) are reviewed and, based on this, a preliminary set of guidelines is offered. Satisfactory natural regeneration of Corsican pine is generally more difficult to achieve compared with that of Scots pine (Pinus sylvestris L.). However, it is possible if a patient approach is adopted. Good seed years occur every 3–5 years and it is important to initiate operations which will take advantage of these ‘mast’ years. The main aim should be to produce > 5000 seedlings ha⁻¹ of advance regeneration at least 50 cm tall before commencing fellings. This bank of advance regeneration can be developed by: (1) increasing seed supply (e.g. by including coning as a selection criteria when thinning and using rotations in excess of 70 years); (2) preparing a seedbed before seed fall by disturbing organic matter on the soil surface and controlling vegetation; and (3) protecting the seedlings from browsing mammals.

Introduction

Corsican pine (Pinus nigra subsp. laricio (Poir.) Maire) (nomenclature according to Farjon (1998)) is an important species in lowland Britain, at the last census in 1979 it occupied 47 251 ha (Locke, 1987). It grows best on warm sunny sites in the south of Britain (Fourt et al., 1971) and is not planted on elevated sites with a cool, wet climate because it is liable to attack by Brunchorstia pinea (Gremmeniella abietina) (Read, 1967; Lines, 1985).

Many foresters believe that Corsican pine does not regenerate in Britain. This impression is probably caused by the contrast with Scots pine (Pinus sylvestris L.), the other major lowland pine, which regenerates freely. In addition, the fact that most Corsican pine is managed on short rotations of 55–65 years does not provide suitable conditions for the species to regenerate. However, evidence from field observations and the literature suggests that Corsican pine does have the capacity to regenerate naturally in Britain. This was noted by Brown (1967) who summarizes the problems as ‘much seed is destroyed by squirrels, in the full cone on the tree; more is doubtless devoured on the ground by squirrels, pigeons, pheasants, finches or mice; some may survive till germination time, but fail then because of unsuitable temperature, moisture, or ground cover’. There are many accounts of successful natural regeneration of Pinus nigra throughout Europe (Parde, 1962; Cucchi, 1965; Paci and Romoli, 1992; Menguzzato, 1994; Vallauri et al., 1997).
At a time of growing interest in the use of silvicultural systems other than clear felling in Britain, the use of natural regeneration could help to form more diverse stand structures (Kerr and O’Hara, 2000).

The objective of this paper is to bring together evidence from the literature and a series of field observations on factors which influence natural regeneration of Corsican pine. Based on this a preliminary set of guidelines is offered for foresters undertaking natural regeneration in stands of Corsican pine.

**Flower, cone and seed production**

The cycle of flower and cone development has been described in detail by Fletcher (1992) and Philipson (1997). The reproductive cycle spans from initiation of seed cones in late summer of year 1 to seed shedding in February to June of year 4. Flowering and pollination occur in year 2 and the climate during this period is important for later seed production. For example, Brown (1966) stated that abundant yield of seed in 1961/62 was probably due to the brilliant summer of 1959. The different stages of cone development can usually be observed on single trees giving rise to the capacity for some seed production every year; however, good seed years only occur every 3–5 years (Seal et al., 1962).

As with all trees the amount of coning on individual trees can vary between none and heavy, and the cones can have variable amounts of viable seed. The age of the first good seed year is commonly quoted as 25–30 years old but it can be as early as 16 (Brown and Neustein, 1972). The age of maximum seed production is usually quoted as 60–90 years (Gordon and Faulkner, 1992) but the upper limit has probably not been verified in Britain.

Assessment of cone crops is not easy and requires a certain amount of skill and experience (Gordon and Faulkner, 1992). If time is required to plan operations for seedbed preparation, potential seeding can be assessed in semi-mature cones in July of year 3. If this is not necessary, developing embryos in December (year 3) to January (year 4) can be observed. Generally seed viability is very good, and average germination for commercially tested seed is 80 per cent, based on data from seed tests over a 30-year period (Gordon, 1992).

It is commonly understood that one way of increasing the amount of seed produced in a stand is to carry out preparatory thinnings which aim to build large crowns on the best trees. This has been practised in stands of Corsican pine in Corsica as a component of shelterwood regeneration (Brown, 1960b). The effect has not been verified for Corsican pine but the relationship between spacing and seed production has been investigated on stands of *Pinus elliottii* by Florence and McWilliam (1956). The stands were 14 years old and about 20 m tall, ranging in density from 123 to 176 trees ha⁻¹. The density giving maximum cone production per tree (123 trees ha⁻¹) was much lower than that giving maximum total cone production (296 trees ha⁻¹). Another finding was that pollen production was greater at wide spacings and was reflected in a higher number of viable seeds per cone. Hence there is some evidence that thinning to increase crown size will result in more seed production.

Cone production in *Pinus nigra* is under strong genetic control (Matziris, 1993). Therefore if a stand is likely to be naturally regenerated in the future, evidence of coning should be considered, as well as form and growth characteristics, when thinning.

**Seed loss in the cone**

Evidence from the literature suggests that seed loss in the cone can be heavy for pines. For example, Dormont et al. (1996) estimated that the potential seed crop decreased by 84 per cent for *Pinus cembra* L. Mortality was mainly by abiotic factors in the first year of cone development, while cone insects caused most damage to second year cones. Similar losses have also been recorded by Shearer and Schmidt (1970) for *Pinus ponderosa* Doug. Brown (1967) indicated that grey squirrels were major predators of Corsican pine seed in Britain. The seed is more than twice as heavy as that of Scots pine and is therefore an attractive food source (Brown and Neustein, 1972). In areas where red squirrels are absent grey squirrels can be controlled using warfarin (Pepper, 1998). However, where red squirrels are present more expensive methods,
such as cage trapping, must be used to control the grey squirrels. Shearer and Schmidt (1970) reduced problems of squirrel predation of Pinus ponderosa Dougl. seed in the cone by banding isolated seed trees with metal strips which prevented the squirrels from climbing the trees.

**Seed dispersal**

Brown and Neustein (1972) recorded that at Thetford in 1967, 1969 and 1970, cones opened in bright, dry weather in March and after this seed fall was fitful because the cones closed in dull, rainy weather. In 1967 when there was plenty of seed, 50 per cent of seed had been shed by 12 April and 92 per cent by mid-May.

The distance over which seed can travel is important; Johnson (1976) noted regeneration 100 m away from the nearest seed source. This may have been carried by birds but the site is on the north Norfolk coast and is open and windy, so this was likely to be a maximum distance. Detailed work on seed dispersal distances for a range of conifers by Farmer (1997) has shown that the majority of the seed falls 40–60 m from the mother trees or forest edge. For shortleaf pine (Pinus echinata Mill.), Yocom (1968) showed that 80 per cent of seed over two seed years fell less than 40 m away from their source.

**Seed loss after shedding**

The only published information on seed loss after shedding in the UK is from Brown and Neustein (1972) who describe an experiment in the West Tofts section of Thetford Forest. The experiment was in a part of the forest in which a recently cleared area of 3 ha adjoined 20 m tall Scots pine, with irregular, rather open canopy. Sixty quadrats each of 2 m² were distributed among five ground cover types, three under the Scots pine and two in the clearing, and given one of the four following degrees of protection by using suitable netting: (1) excluding mice and all larger animals; (2) admitting mice, excluding birds and larger mammals; (3) admitting mice and small birds; excluding pigeons, pheasants and rabbits; (4) admitting all fauna. Unfortunately the data from the experiment cannot be recovered and the only record of the results is in Brown and Neustein (1972). One thousand seeds of Corsican pine (germination 80 per cent) were sown on each quadrat on 15 April 1967 and three tallies were made of the resulting seedlings in 1967, and then a single assessment in 1968 and 1969.

In the wood the ground cover comprised a grass-herb mixture (mainly Holcus mollis) mossy pine litter, and clean tilled, very sandy soil. On this bare soil with exclusion of mice, seedlings appeared in great numbers (600 or more in a quadrat, out of a possible 800) and survival in the first summer was good. Unprotected quadrats alongside yielded no more than 20 seedlings. Where mice were admitted in the wood, little was evidently gained by exclusion of birds and larger mammals. The mossy litter carpet also provided a good germination bed, but subsequently many small seedlings withered in the dry weather of June and July.

In the clearing, protective treatments were the same as in the wood, and ground cover at germination time was either nil, or short grass-herb. Germination was again very good on the bare sand with full protection, though not quite as good as under trees: mice were less active there early in the summer, but small birds were more common, so that the intermediate protection (level 2) showed a significant effect. Seedlings which arose in the grass-herb mixture were seldom smothered as they were in the wood, where the protection treatments caused a marked stimulation of grass and herb growth. In later tallies the most obvious feature was the contrast between the sturdy pine seedlings in the open (most of them in the cultivated plots) and the weak, drawn seedlings under the trees, where light transmission was about 20 per cent of full daylight.

The results of this experiment clearly show that keeping out mice was important to the germination and survival of Corsican pine. However, it is difficult to generalize from the results, for example, variations in habitat and the dynamics of populations of small mammals may also have influenced the results. However, it does seem reasonable to conclude that, collectively, seed predators (mice, finches and other birds, ants and other insects) will ensure that much seed is consumed and that abundant masts are the most likely starting point for successful natural
regeneration. This is confirmed by Skulj and Krystufek (1991) who reported that mice are an important predator of seed and can prevent natural regeneration of Austrian pine (Pinus nigra Arnold var. nigra) in Slovenia.

Conditions for seed germination
There are few references which make observations on Corsican pine germination. Brown and Neustein (1972) refer to moisture and temperature as the 'two cardinal needs' for germination of seed; they do not discount light but believe it is much less important. In Britain, the main germination period (April–June) is commonly the driest and, in areas such as Thetford, always subject to frosts (Low and Greig, 1973).

There are even fewer laboratory studies aimed at identifying optimal germination characteristics; an exception is that of Gosling and Peace (1990). One of the things they looked at was whether a 3-week pre-chill (which is commonly applied to northern temperate conifer seeds as a dormancy breakage pretreatment) had any effect on subsequent germination. They showed that out of 42 seedlots, 70 per cent benefited from pre-treatment, 16 per cent were unaffected and 14 per cent harmed. However, no distinction was made between seedlots from abroad, or those collected in the UK. It is therefore not known whether the differing responses were caused by origin/provenance effects. They also looked at the influence of incubation temperature on germination. Constant temperatures between 10 and 25°C all appeared to permit maximum germination capacity. However, germination dropped from about 75 per cent at 25°C to only 10 per cent at 35°C. Further studies (e.g. observing the effects of daily alternating temperatures, light quality and quantity and cycles of wetting and drying) would also be useful in gaining an improved understanding of how these factors interact in conditions associated with natural regeneration.

Initial seedling survival and growth
Brown and Neustein (1972) described small groups of saplings, mostly about 10 years old, which were found in 1967 in Knightwood Inclosure in the New Forest under mature Corsican and Scots pines, but with side light from a south margin. It was certain that they did not come through the Pteridium or Molinia which then occupied the site, so they assumed that a small ground fire on the site near a busy main road gave them their chance. They also observed in the early summer of 1967, in spite of vast losses of seed to rodents, many young seedlings were noted in the New Forest and under 40-year-old Corsican pine in Thetford Forest. The thick loose litter was clearly a great barrier to early and effective root penetration of the sand and the seedlings all withered in hot dry weather in July. The importance of seedbed preparation for pine regeneration has been shown to be important for a wide range of pines (Liming, 1945; Grano, 1949; Pomeroy, 1949; Foiles and Curtis, 1965; Johnson, 1968; Shearer and Schmidt, 1970; Amorini and Gambi, 1976).

Recent observations in Corsican pine long-term retentions (stands retained beyond normal financial rotation) in Thetford were also useful. A range of stands, 70–80 years old, were visited and natural regeneration of Corsican and Scots pine was found on all sites. Young trees varied between germinants and established trees 2–3 m tall. The most dense regeneration was usually found near to forest edges, a pattern also observed by Preto (1983) in Pinus nigra plantations. The most likely explanation for this was a coincidence of timing between seed production, from trees being felled into the retention and/or trees in the retention, and disturbance caused by removing vegetation and exposing mineral soil. This latter effect would reduce predation of seed, because of burying, and increase the chances of survival as the radicle of the germinating seed would have access to water and nutrients in the mineral soil.

Johnson (1976) described prolific natural regeneration of Corsican pine at Holkham Nature Reserve, an area mainly of sand dunes on the north Norfolk coast. Two studies investigated the effect of topographic aspect on natural regeneration and the age structure of the existing regeneration. The first study showed that Corsican pine regeneration survived best on slopes with a northerly aspect, possibly due to summer moisture deficits being less acute on such slopes. Although the regeneration was 'prolific', the way
in which the data were presented does not allow conversion into seedling densities. The second study showed considerable variation in age of the regeneration between 2 and 43 years old. The variation in the data was explained by seed supply, fluctuations in rabbit and vole populations, rainfall distribution and the rate of dune formation. The ability of Corsican pine regeneration to remain suppressed was also noted, with two 19-year-old trees being 7.3 m and 1.2 m tall.

**Advance regeneration**

The term ‘advance regeneration’ is defined by Harmer and Kerr (1995) as seedlings that are present beneath the canopy before regeneration fellings occur. Advance regeneration is important because it is the most likely indicator of success when regenerating a stand. Brown and Neustein (1972) attempted to investigate the growth of advance regeneration of three pine species in differing degrees of shade. The artificial shades transmitted approximately 60, 35, 20 and 10 per cent daylight; results are shown in Table 1. In the weakest shade, transmitting about 60 per cent light, all three pines maintained the height gained in full daylight. Below 20 per cent daylight, there was a marked reduction in height. This pattern was also reflected in the data for dry weight, although the largest reduction occurred between 60 per cent and 35 per cent of full light. Twenty-four months in the strongest shade (10 per cent transmission) was not severe enough to kill any of the plants. The value of their data is limited by the fact that the initial sizes of the trees were not given and the important silvicultural characteristic of response to release from shading was not observed. However, it is clear that Corsican pine can survive and grow under moderate shade for up to 3 years.

Experience of managing other types of Pinus nigra is also of interest; Pintaric (1997) described the natural regeneration of Austrian pine (Pinus nigra Arnold var. nigra) in Bosnia-Hercegovina which had been managed using a single tree selection system. The youngest cohort of regeneration was found to be less than 10 years old. Genc (1994) described the use of advance regeneration of Pinus nigra subsp. pallasiana and stated that natural regeneration was more successful when the advance regeneration is < 10 years and 20–25 cm tall. Preto (1983) concluded that indirect light encouraged height and diameter development. Hence, although it has not been exactly defined for Corsican pine, there is evidence that advance regeneration of Pinus nigra can tolerate some shading but has difficulty surviving under very dense canopies (transmitting < 30 per cent of full light). In most of the long-term retention areas visited at Thetford the amount of light was judged to be very unlikely to be a constraint to the survival of advance regeneration of Corsican pine.

**Corsican pine in its native island**

J.M.B. Brown visited Corsica in June 1958 and many of his observations are relevant to the natural regeneration of Corsican pine (Brown, 1960a, b). In Corsica, it is the most important tree in the mountain forest, in which it commonly forms extensive pure stands, particularly between 1000 m and 1300 m. Below 1000 m it is often in mixture with maritime pine (Pinus pinaster Ait.) and above 1300 m in mixture with beech (Fagus sylvatica L.), birch (Betula verrucosa Ehrh.) and European silver fir (Abies alba Mill.). In 1958 plans were made that included control of grazing and fire in these forests. Brown speculated that control of grazing in the forests would favour the survival and growth of tree seedlings and may tip the balance towards the shade bearers (beech and silver fir); this was confirmed by his field observations.

Much of the winter precipitation in the mountains falls as snow and this provides insurance against water shortage in the early part of the growing season (an important difference from much of southern Britain). It is clear that there are about half the number of rain days (> 0.01 inches) and four times as many hot days (> 25°C) in a Corsican summer compared with lowland Britain; this could be important to flowering and seed production.

Brown (1960b) noted considerable areas of even-aged high forests which were reported to be 150–200 years old. The ‘old’ system of regeneration was a shelterwood system, although this had been changed at the turn of the century to a selection system. The main reason for the change
Table 1: Effect of shade on seedlings of three pines in the nursery (relative heights at 3 years and dry weights at 2 years)

<table>
<thead>
<tr>
<th></th>
<th>Full light</th>
<th>Three year height as percentage of value for full light</th>
<th>Two year dry weight as percentage of value for full light</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3-year</td>
<td>2-year dry wt</td>
<td>60 per cent</td>
</tr>
<tr>
<td></td>
<td>height (cm)</td>
<td>(g)</td>
<td></td>
</tr>
<tr>
<td>Pinus contorta</td>
<td>82.2</td>
<td>36.55</td>
<td>93</td>
</tr>
<tr>
<td>Pinus nigra subsp. laricio</td>
<td>46.3</td>
<td>13.45</td>
<td>98</td>
</tr>
<tr>
<td>Pinus sylvestris</td>
<td>63.8</td>
<td>20.25</td>
<td>98</td>
</tr>
</tbody>
</table>

Source: Brown and Neustein (1972).
was to reduce the risk of fire in extensive young pines of uniform age. With small groups of regeneration scattered in a framework of large trees (which are resistant to burning), control of fire was much easier. The method of conversion seems to be to have been to remove larger trees to encourage regeneration where it was already established. The application of either silvicultural system was handicapped by the fact that regeneration often failed to appear when it was wanted.

Brown noted that cones were produced every year but the quantity and quality of the seeds varied from year to year. He also commented that the quantity of cones and yield per cone were much lower in the dense, managed stands than the open stands of the community forests (cf. Florence and McWilliam, 1956). It was anticipated that the canopy of the selection system would favour more abundant coning of the mature trees. He also observed that with the shelterwood system a heavy preparatory thinning was practised to open up crowns of trees to encourage future seeding.

Brown observed Corsican pine regeneration in small groups or along rides and speculated this was due either to better seed supply, or to better conditions for germination and early growth in the warmer, often disturbed, ground of the gaps. He saw no very small seedlings under full canopy (which may indicate germination success and then failure to survive) but because of the dense bracken he noted that seedlings may have been missed. He also noted the beneficial influence of felling and extraction operations, which disturb the surface soil, bury the seeds and check the smothering influence of the bracken. There were no grey squirrels or wood mice in Corsica but there were abundant rodents and other animals which eat seeds and seedlings.

The role of fire

A question often asked about the regeneration of pines concerns the role of fire in promoting regeneration. Several authors have investigated this (Meyer, 1955; Crutchfield and Trew, 1961; Lotan, 1964; Trousdell and Langdon, 1967; Trabaud and Campanet, 1991) and depending on species, fire has been used as a method of encouraging seed release from cones and/or disposing of organic material on the forest floor. Brown (1960a) noted that maritime pine, and to a lesser extent Corsican pine, often regenerated with great freedom after a burn. However, little, if any, research has been done on the use of fire to promote natural regeneration of Corsican pine in Britain.

Conclusions and recommendations

Based on this information it is possible to draw some preliminary conclusions which may be helpful to foresters who wish to use natural regeneration of Corsican pine as part of their chosen silvicultural system.

1. Corsican pine does regenerate in Britain. However, the process does not appear to be as profuse or reliable as for Scots pine. With good seed years being every 3–5 years, patience will often be required and management plans will have to be flexible.

2. Natural regeneration is often more difficult on moisture-retaining, heavy and fertile soils than on those which are light, dry and infertile (Harmer and Kerr, 1995).

3. Seed production is one of the main factors limiting the natural regeneration of Corsican pine. It is unlikely that Corsican pine in even-aged plantation silviculture where canopies are kept tight and felling occurs at 55–65 years will maximize seed production. During the rotation, include evidence of coning as a selection criteria in thinning and use higher thinning intensities than marginal (Rollinson, 1988) to build large crowns on the chosen trees; this advice is similar to that given by Downs (1947) for loblolly pine (Pinus taeda L.). Rotations in excess of 70 years should provide enough opportunities for good seed years to commence the regeneration phase of the crop.

4. Either exclude browsing mammals from areas being regenerated or control them at levels below which damage to young trees will be acceptable. It is unrealistic to expect regeneration to survive without reducing the population of deer below five animals per 100 ha (Mayle et al., 1999). Squirrels, hares and rabbits are also a problem and must be controlled using appropriate measures for the site.
It is essential to monitor the coning patterns of the trees being regenerated. If a good seed year is likely, vegetation on the site must be controlled, preferably using herbicides. Once these have taken effect, a seedbed should then be formed by disturbing the ground to expose areas of mineral soil. This should be complete by early March at the start of the main seed fall in Corsican pine. In years when there is no heavy coning some seed will usually be produced and this can be used to increase the stocking of advance regeneration. To ensure the success of sufficient regeneration it is important to start the regeneration process with a good seed year (Meyer, 1955). If this turns out not to be the case, be patient and wait for the next one.

The amount and distribution of advance regeneration present is important in determining how and at what rate the overstorey is removed. If there is adequate advance regeneration (> 5000 seedlings ha⁻¹ at least 50 cm tall), which is evenly distributed, the canopy can be removed evenly in stages as in a uniform shelterwood. However, in the more likely scenario that advance regeneration is patchy, a judgement must be made which balances (a) the need of the advance regeneration to be released and (b) the need to retain overstorey trees as a seed source and to control light available for ground vegetation. If the advance regeneration is growing well, perhaps due to side light from a stand edge, there is no urgency to remove the overstorey. However, if increments are poor on the established natural regeneration then release fellings will be required. The evidence presented above suggests that Corsican pine seedlings can tolerate some shade but not less than 30 per cent of full light. When felling to release groups of advance regeneration, aim to fell in the Spring into areas where there is little, or no, advance regeneration. As well as protecting existing regeneration this may deposit seed and disturb the vegetation in the understocked areas. Managing the balance between advance regeneration, the overstorey and ground vegetation is perhaps one of the most difficult areas of the regeneration process (Murphy et al., 1999). However, there is no substitute for making observations and being in tune with the processes operating in the woodland.

To ensure rapid establishment of advance regeneration, prudent weed control using herbicides is recommended (Willoughby and Dewar, 1995). Dense advance regeneration will quickly form a canopy of its own and therefore the need for herbicide may be limited to one, or perhaps two, growing seasons.

In areas where there is a Scots pine seed source nearby, it is likely that regeneration of this species will also be present. In this case either aim to have a mixed woodland, or ensure that there are enough Corsican pine seedlings so that the Scots pine can be removed during thinnings. If Scots pine regeneration is too profuse and the species is not favoured then artificial regeneration of Corsican pine may be more appropriate.

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