Forest regeneration

There are two main mechanisms for the regeneration of forest species: **reproduction by seedlings and regeneration by resprouts**. Seeder species mainly reproduce by seedlings produced from seeds. **The success of their reproduction depends on the environment in which they are to germinate and the shade tolerance characteristics of the species**. Resprouting species regenerate by sprouts produced from buds located on the trunk, roots or stump. The resprouting characteristics depend on the site quality of the plot and the type of disturbance.

Types of species according to their main regeneration mechanism

The regeneration of forest species occurs mainly by two mechanisms: reproduction by seedlings and regeneration by resprouting (**Figure 1**). In the first case, new individuals are generated from propagules produced by existing ones, while in the second case, it is the pre-existing individuals themselves that maintain themselves after logging or a disturbance.

- **Reproduction by seedlings from seeds** is the most widespread reproduction mechanism among plants. It consists of the production of seedlings from seeds that germinate when environmental conditions are favourable. In the Iberian Peninsula, the **main seeder species** are of the coniferous genera *Pinus* or *Abies*, although many resprouting species such as *Quercus* can also produce large numbers of seedlings.

- **Resprouting, i.e. the production of sprouts from buds present in pre-existing organs** such as stumps or roots, is one of the most important mechanisms of plant regeneration against natural and anthropogenic disturbances. Resprouting is considered a mechanism by which a plant returns to a juvenile state after being disturbed. In the Iberian Peninsula the **main resprouting species** are of the genera *Quercus, Fagus, Corylus* and, to a lesser extent, *Populus* and *Betula*.

Figure 1. A) Aleppo pine (*Pinus halepensis*), a seeder species. Photo: iStock, seven75, **B**) Holm oak (*Quercus Ilex*), a resprouting species. Photo: MJ Broncano.

The regeneration of seeder species: the case of pines

Pines are the main group of seeder tree species in the Mediterranean. All of them **reproduce exclusively by seeds**, although there are some species that can produce sprouts, such as ***Pinus canariensis***, a rarity among pines. Pines **present a highly variable cone production**, with years of strong production and years of almost zero production, interspersed with years of medium production. Most of the species show similar phenology, with seed dispersal from late winter to spring and even summer.

Figure 2. *Pinus halepensis* young tree in an open area.

The seedlings of all **pines grow rapidly in open areas**, where the saplings outnumber the herbaceous vegetation and reach significant growth during the first years (**Figure 2**). In forest conditions the pattern is different. The seedlings of *P. nigra* are, among those of the peninsular pines, the ones that **best withstand certain shady conditions** (in fact, it could be said that they are the only ones). On the other hand, the seedlings of the rest of the pines need light to grow, so their regeneration is very low in the understory of a forest, even of the species itself.

Some species, such as *P. halepensis* or *P. pinaster*, only disperse part of their seeds stored in the crown and maintain a **bank of seeds inside cones called serotines** that remain closed for a long time. The seeds are released from these serotine cones by the heat and dryness induced by a severe forest fire or an extreme drought. This allows massive seed germination to occur in the autumn after the fire, creating a wave of pine regeneration during the first year after the fire (**Figure 3A**). **The remaining pines do not have serotine cones**, so in summer, which is the period when most forest fires occur, all the cones in the crown are empty and the soil seed bank is also exhausted. **Regeneration of these species after large fires is entirely dependent on the release of seeds** from unburned margins or from surviving tree islands, since seeds and seedlings do not survive the fire. For this reason, in a large part of the burned forests of these species, the presence of pine seedlings is very scarce or null (**Figure 3B**).

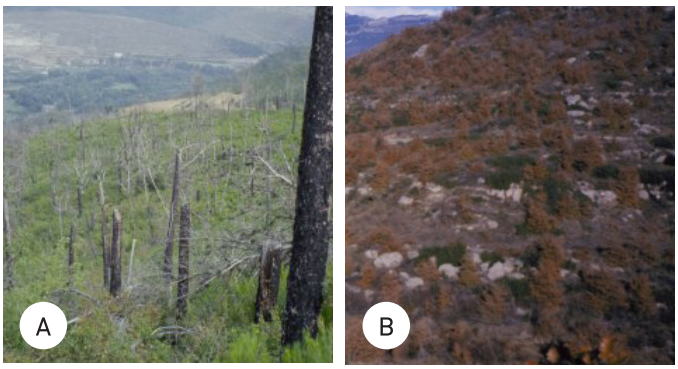

Figure 3. Regeneration of (**A**) *Pinus halepensis*, and (**B**) *Pinus nigra* in the first few years after a fire in a forest of the same species. The high density of *P. halepensis* seedlings and the virtual absence of *P. nigra* seedlings in the post-fire scenario can be seen.

Figure 4. Resprouting of an oak stool affected by a fire.

The regeneration of resprouter species: the case of holm oak

Holm oaks and downy oaks constitute the main group of resprouting tree species in the Mediterranean. **Holm oak (*Quercus ilex*) is a very clear case of a resprouting species**, since it sprouts vigorously after disturbances (**Figure 4**). The shoots are produced by the activation of dormant buds located at the level of the stump, the root crown or, to a lesser extent, the roots. The resprouting of holm oak after disturbances (both thinning, drought, herbivory or fire) is, in all cases, **higher than 85%.**

The **quality conditions** of the site (growth potential of a given stand), combined with the **intensity of management of the plot**, will determine the current state of the holm oak forest and its response to felling. **Intense thinning generates structures with many sprouts for both high and low site qualities**. As the thinning is of a lower intensity, the closing of the crowns generates a natural selection of sprouts, decreasing their density. This effect is more significant in high site qualities where greater growth allows a greater closure of the canopy. For low intensity thinning (irregular management) this selection effect means that in high site qualities the resulting structure has individuals with few or only one stem per stool. On the other hand, for low site qualities, where lower growth does not allow complete closure of the crowns (or this occurs very slowly), the effect of natural selection of resprouts is less, and we will find structures with many stems per stool.

Under the current management conditions and disturbance regime, **the regeneration of holm oak stands seems to be ensured through the resprouting of individuals**. It might be accepted that this type of regeneration is enough, but the oaks can also **reproduce sexually by acorns**. Normally, the annual production of acorns is rather low, although there are years with very strong production peaks. Acorns are large and heavy, so they have enough reserves to develop new seedlings, although they also have a high risk of being predated. All this makes **the presence of holm oak seedlings and saplings quite high in holm oak stands**. These young individuals cannot compete with the adult trees that sprout after a disturbance, but they can remain in the understory of the forest for many years as they have a high tolerance to shade. These individuals can live in canopies for a longer time, and therefore, also maintain the ability to respond to the release of competition when an opening occurs in the holm oak canopy.