Analele Universităţii din Craiova, seria Agricultură – Montanologie – Cadastru (Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series) Vol. 55/2025

CURRENT STATE OF KNOWLEDGE ON THE REGENERATION OF PEDUNCULATE OAK (*QUERCUS ROBUR* L.)

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Abstract

The paper investigates in detail the ecological, silvicultural and socio-economic processes involved in the regeneration of one of the most valuable native forest species. The pedunculate oak, which plays a major role in maintaining biodiversity, ecosystem stability and providing high-quality wood resources, is currently facing a number of difficulties in the regeneration process, especially in lowland areas affected by climate change and anthropogenic pressure.

The study compares natural and artificial regeneration methods applied in the forests of the Oltenia Plain, highlighting the influence of edaphic, climatic and biological factors on the success of regeneration. It addresses in detail competition with invasive or aggressive species, the effects of overgrazing, the fragmentation of forest habitats and changes in the local hydrological regime. It also evaluates various silvicultural interventions, innovative technologies and best practices used to stimulate the regeneration of natural seedling stands and oak crops.

The paper provides an integrated perspective on the dynamics of pedunculate oak regeneration, proposing a set of adaptive strategies aimed at both conserving local genetic resources and expanding the species range through sustainable afforestation and responsible forest management. The research results make significant contributions to the scientific basis for policies on the ecological rehabilitation of oak ecosystems in southern Romania and can serve as a model for other European regions in similar ecological contexts.

Key words: lowlands, pedunculate oak (Quercus robur L.), regeneration

INTRODUCTION

The pedunculate oak (*Quercus robur* L.) is a native tree of size I, which is particularly important in European deciduous forests due to its ecological and economic value. The pedunculate oak is a tree that can reach a height of up to 40 m and a diameter of up to 1 m, forming a broad crown with strong, knotty branches (Negulescu and Săvulescu 1965), with the maximum dimensions recorded being 58 m in height and 2 m in diameter (Constantinescu 1973). The pedunculate oak is found throughout Europe: in the north the British Isles, in the west the northern part of the Pyrenean Peninsula, in the south the Apennine Peninsula, the Balkan Peninsula, the northern coast of Asia Minor and in the east the Ural Mountains. As a species that is demanding in terms of soil mineral and organic composition, the pedunculate oak usually grows in lowland forest areas and less frequently on hills. It thrives on alluvial, reddish-brown forest soils, which are moist and especially wet. This species avoids growing on chernozems (Constantinescu 1973, Negulescu and Săvulescu 1965).

Good quality wood is used for veneer, in the furniture industry, stair construction, turning, carving and staves. Wood of ordinary quality is used in carpentry, construction (roof trusses, beams), parquet flooring, sleepers and posts. In the past, pedunculate oak was an irreplaceable wood for shipbuilding (Negulescu and Săvulescu 1965).

Due to harmful human activity, there has been a considerable reduction in the area covered by pedunculate oak forests, productivity has decreased and the protective functions of the forests have been weakened. Given the special economic value of pedunculate oak forests, it is justified to expand this species in forest cultures in order to obtain new forests with high productivity and ecological stability, capable of fulfilling their multiple ecological functions in a significant way, but also to meet the timber needs of the national economy (Negulescu and Săvulescu 1965, Cuza 2018).

Oak trees are of particular ecological importance, hosting species of flora and fauna (they also provide food for various species of forest fauna), some of which are rare, endangered, or of high ecological value. They play a particularly important role in soil stabilization, soil erosion protection, hydrological protection, carbon storage and climate regulation (MMAP 2022b).

The pedunculate oak is found in pure oak forest formations (*Querceta roboris*), hill and plain pedunculate oak forests (*Querco robori-Carpineta*) or floodplain forests (*Querco robori-Carpineta fraxinetosa*) (MMAP 2022b).

In general, in order to achieve stable, optimally structured stands capable of exploiting the full production capacity of the sites, it is necessary to introduce, alongside pedunculate oak, the main species of the mixture (ash, maple, cherry, linden, elm, black walnut, temporarily Euro-American poplar hybrids, etc.), auxiliary species (hornbeam, field maple, tatar maple, wild pear, etc.) and shrubs (hazel, dogwood, hawthorn, viburnum, soft willow, etc.) (MMAP 2022b).

Regeneration of pedunculate oak

Natural regeneration

The systematic and rational use of forest resources to ensure their sustainability requires the implementation of a wide variety of methods and approaches. The most important are those based on the natural regeneration process, which can significantly help promote valuable native species and contribute to maintaining soil cover. Ensuring this process guarantees the continued fulfillment of the multiple ecological, economic and social functions that forests as a whole perform (MMAP 2022a). Great importance must be attached to the conservation and enhancement of biodiversity in forest ecosystems, regardless of the treatments used, as this is an indispensable aspect of sustainable forest management (MMAP 2022a).

In general, ecological forestry encourages the normal use of valuable local species that are part of the fundamental natural ecosystem of the forest, as these are usually better adapted to local conditions and coexistence with other organisms (MMAP 2022b).

Natural regeneration involves the development of plants from seeds, shoots, suckers, or a mixture of these, both under the influence of environmental conditions and with the help of human intervention (assisted regeneration). Currently and in the future, natural forest regeneration through seeds is an important objective, both from an ecological point of view, for the conservation of valuable species and from an economic point of view, for reducing production costs (Nicolescu 2009, Constantinescu 1973).

Pedunculate oak: defining characteristics, in relation to applicable treatments for its regeneration: temperament, asocial character, fruiting periodicity

The temperament of the species. All sources of literature, including those from Romania (Drăcea 1920-1921, Negulescu and Săvulescu 1965, Haralamb 1967, Constantinescu 1973, Stănescu 1979, Stănescu et al. 1997, Șofletea and Curtu 2007, all in Nicolescu et al. 2021) and from several European countries relevant to their cultivation (Europe in general: Eaton et al. 2016; France: CRPF Aquitaine 1992, Bastien 1997, Lemaire 2011, CRPF Rhône-Alpes 2013; Germany: Anighöfer et al. 2015; Hungary: Ortmann-Ajkai et al. 2017; Belgium: Boudru 1989; Great Britain: Savill 2013; Spain: Diaz-Maroto and Vila-Lameiro 2014; Czech Republic: Dobrovolný 2014, all in Nicolescu et al. 2021), argue that the pedunculate oak is a species with high light requirements (strictly heliophilous species - Lemaire 2011, in Nicolescu et al. 2021). The pronounced light temperament manifests itself both during the tree's youth and as it develops and reaches maturity. This situation creates a number of major difficulties in the natural regeneration process of the pedunculate oak, as young specimens can only survive for 2-3 years in the dense shade of the old forest, after which they frequently self-thinning until they dry out completely (Petcuț 1942, Negulescu and Săvulescu 1965, Constantinescu 1973, Stănescu 1979, Stănescu et al. 1997, Dobrovolný 2014, all in Nicolescu et al. 2021). This necessitates the complete release of pedunculate oak seedlings from the upper or lateral canopy of the old forest within a maximum of 4-5 years (Vlad 1954, in Vlad 2007, Haralamb 1967, Boudru 1989, all in Nicolescu et al. 2021).

The problems related to the natural regeneration of pedunculate oak are due to the fact that this species is associated in large proportions (maximum 50% - Pașcovschi and Leandru 1958; 50-60% - Anonymous 1986, 1988 and 2000, in Nicolescu et al. 2021) with other deciduous species such as hornbeam, linden, common ash, field maple, norway maple and sometimes with mountain ash, wild pear and wild apple (Vlad 1946-1947, Pașcovschi and Leandru 1958, Doniță et al. 1981, all in Nicolescu et al. 2021). These species are better adapted to shading in their youth by the old tree stand due to their moderate tolerance, semi-shade temperament (hornbeam, field maple, norway maple, linden) or even preference for light (common ash). However, the above-mentioned species manage to tolerate overhead shading quite well during the first 5-10 years of their life (Negulescu and Săvulescu 1965, Haralamb 1967, Stănescu 1979, Stănescu et al. 1997, Șofletea and Curtu 2007, all in Nicolescu et al. 2021).

The asocial nature of the pedunculate oak. This species is considered to be asocial because it has difficulty competing with other tree species such as hornbeam, elm, linden, ash, field maple and norway maple. The aforementioned species have earlier and more abundant fruiting and grow faster in height when young (Negulescu and Săvulescu 1965, CRPF Aquitaine 1992, Bastien 1997, CRPF Rhône-Alpes 2013, Anighöfer et al. 2015, all in Nicolescu et al. 2021). If these mixtures are not properly managed during the natural regeneration process and measures to care for young natural regenerations are not applied or are applied improperly, undesirable successions may occur, by reducing the proportion of pedunculate oak or even eliminating it, as well as the appearance of degraded areas or derived stands such as lime or hornbeam forests (Haralamb 1967, Giurgiu 2005, both in Nicolescu et al. 2021).

The periodicity of pedunculate oak fruiting. In Romania, this species usually fruits at long intervals of approximately 6-10 years (Negulescu and Săvulescu 1965, Stănescu 1979, Stănescu et al. 1997, Şofletea and Curtu 2007, in Nicolescu et al. 2021), but in recent decades these have been even longer, reaching 12-15 years. In contrast, associated deciduous species have much shorter fruiting periods, even annual in some cases (Şofletea and Curtu 2007, in Nicolescu et al. 2021) (Table 1).

Table 1. Periodicity of fructification of pedunculate oak and main associated species in Romanian forests (Negulescu and Săvulescu 1965, Haralamb 1967, Stănescu 1979, Stănescu et al. 1997, Şofletea and Curtu 2007, in Nicolescu et al. 2021).

Species	Periodicity of fructification (years), according to…				
	Negulescu and Săvulescu 1965	Haralamb 1967	Stănescu 1979	Stănescu et al. 1997	Şofletea and Curtu 2007
pedunculate oak	6-10	4-8	6-10	6-10	6-10
hornbeam	2-3	2-3	1-2	1-2	1-2
small-leaved linden	~ annual	~ annual	~ annual	~ annual	annual (abundant every 2–3 years)
common ash	~ annual	~ annual	~ annual	~ annual	~ annual
norway maple	annual	annual	-	~ annual	2-3
field elm	~ annual	2-3	~ annual	~ annual	2-3
field maple	-	annual (abundant every 2-4 years)	-	-	annual (sometimes every 2-4 years)

Between two successive abundant fruiting periods, so-called "spillovers" may occur when the species is in favorable growing conditions (Negulescu and Săvulescu 1965).

The periodicity of pedunculate oak fruiting, which has a significant impact on the choice and use of silvicultural treatments, is as follows in several European countries relevant to the cultivation of this species:

- in France, where it is the main forest species in terms of area (1.85 million ha, of which 75% is in private forests - IGN 2021), the periodicity varies from 2-3 to 5 years (western and central parts of the country, with an Atlantic climate) to 6-10 years in the east (with a continental climate) (Bastien 1997, Lemaire 2010, both in Nicolescu et al. 2021).
- in Croatia, where the species occupied over 201,000 ha in 1996, the fruiting period is (2) 3-5 years (Klimo et al. 2008, in Nicolescu et al. 2021), with values ranging from 5 years (warmer climates) to 8-10 years in colder climates (Vidaković et al. 1996, in Nicolescu et al. 2021).
- in the United Kingdom, where pedunculate oak, together with sessile oak, occupies 219,000 ha (Forest Research 2021, in Nicolescu et al. 2021), the fruiting period of the species is 3-4, even 6 years (Matthews 1989, Kerr and Evans 1993, Hemery and Simblet 2014, all in Nicolescu et al. 2021).

The oak forests in our country are usually two-storey forests. The first (upper) storey consists of forest species such as pedunculate oak, ash, linden, elm, maple, etc., while the second (lower) storey consists of forest species such as hornbeam and field maple, along with wild pear, wild apple, field sorb (Vlad 1955, in Nicolescu et al. 2021).

Silvicultural treatments applied for the regeneration of pedunculate oak forests

In Romania, where pedunculate oak now covers only about 141,000 ha (Marin 2015, from Nicolescu et al. 2021), pure and mixed oak forests (lowland and floodplain forests) were managed in the early days of silviculture using "successive cuts on the surface" (Vlad et al. 1997, in Nicolescu et al. 2021), which was the most widespread treatment in Romania until the nationalization of forests in 1948 (Anonymous 1949, in Nicolescu et al. 2021). This treatment was still applied to 47% of the area of our forest stands in the mid-1950s (Filipovici and Lăzărescu 1956, in Nicolescu et al. 2021), compared to only 3% in 2019 (INS 2021, in Nicolescu et al. 2021). Its use has yielded good results in several situations, such as the Balta Neagră forest in the Snagov Massif, represented by a coppice, with seed cutting after the installation of pedunculate oak seedlings under the massif, followed by two development cuttings in years 2 and 3 and final cutting in year 4, resulting in vigorous oak regeneration (Ceacăreanu 1939, Vlad 1948, both in Vlad et al. 1997, from Nicolescu et al. 2021).

Subsequent research carried out in Romania (from Stegaru 1958, to Dămăceanu et al. 1980, Vlad et al. 1997, all in Nicolescu et al. 2021) shows that "through successive cuttings, oak and hornbeam regeneration can be achieved, provided that the cuttings are carried out at a rapid pace, repeated annually for oak and ending after 4-5 years for oak" (Vlad et al. 1997, from Nicolescu et al. 2021). This requirement for the application of the treatment is based on the fact that oak seedlings are not resistant under the canopy, but also on the fact that the species rarely fruits. If the above instructions were not strictly followed (such as uniform cutting at stable intervals, without taking into account fruiting, seedling establishment and development), the pedunculate oak was removed and replaced with other mixed species, such as hornbeam, linden and maple, which are shade-resistant and have abundant and frequent fruiting (Rădulescu 1929, in Negulescu 1959, Vlad et al. 1997, both in Nicolescu et al. 2021).

Towards the end of the 19th century, more precisely in 1878, the regeneration of pedunculate oak in Romania shifted from successive cutting to progressive cutting (in patches). This new concept was implemented at the time by German professor Karl Gayer (Troup and Jones 1952, in Nicolescu et al. 2021).

In Romania, patch cutting was proposed for use (as "regeneration cutting in groups") by Professor N.R. Danilescu at the end of the 19th century (1895), but its practical application was only officially considered by the Technical Forestry Council in 1938 (Negulescu 1957, in Nicolescu et al. 2021). However, the differentiation of its application to forest formations, as well as its ecological basis, were made much later (Vlad 1942, 1947, Constantinescu 1973, both in Ciobanu 1981, from Nicolescu et al. 2021).

In Romania, the regeneration of pedunculate oak forests is carried out through progressive (in patches) cutting (MMAP 2022a).

This treatment varies significantly in terms of how it is applied and is suitable for different types of stands, including species with varying temperamental characteristics. In Romania, it is recommended that these measures be applied in group II forests, which have production and protection functions. These measures should also be implemented in group I forests, which have special protection functions (MMAP 2022a). This treatment is applied for the regeneration of pedunculate oak, downy oak, fluffy oak, hungarian oak, turkey oak, sessile oak, as well as lowland, meadow and hill forests, mixed sessile oak and beech forests, beech forests, mixed fir and spruce forests, pine forests and larch forests (MMAP 2022a).

Progressive cutting treatment includes three types of cutting: opening cuts; thinning and widening cuts; connecting cuts (MMAP 2022a). The stages of applying progressive cutting (in patches) in pure or mixed pedunculate oak stands in our country are as follows (from Nicolescu et al. 2021):

1. The first regeneration cut begins by going through the stands to be regenerated and researching areas with pre-existing usable seedlings, which are then completely exposed to light through a single cut, without leaving any specimens behind. If these gaps are missing or too few, new gaps are opened, but in the year of abundant fruiting of the pedunculate oak or at most 1-2 years after the period of abundant fruiting (from Nicolescu et al. 2021). Given that in hot and dry regions (such as the plains), natural seedlings usually appear in the southern part of the gap, where they have the necessary shade and humidity, it is recommended to open elliptical gaps, oriented with the major axis in an east-west direction (Chiriță and Popescu 1933, Anonymous 1949, Rădulescu and Vlad 1955, Negulescu 1959, all in Nicolescu et al. 2021). It is recommended that the major axis of the gap be 1.5-2.0 times the average height of the stand (H) (Badea 1968, Constantinescu 1973, Purcelean 1981, Anonymous 1986, 1988, Vlad et al. 1997, Anonymous 2000, all in Nicolescu et al. 2021), the consistency should be reduced to 0.4 (Florescu 1991, in Nicolescu et al. 2021). Before acorn dispersal, the understory should be completely removed, the tree layer, as well as any pre-existing unusable seedlings that are over 1.2 m tall, to let light get to the ground (Brețcanu et al. 1953, Rădulescu and Vlad 1955, Purcelean and Ciumac 1965, all in Nicolescu et al. 2021). If short intervals are required, as is the case with light species such as pedunculate oak, the distance between the gaps should be limited to an average tree height (Achimescu et al. 1980, in Nicolescu et al. 2021). Cutting intensity: maximum 1/3 of the volume per tree (Vlad 1946-1947, in Nicolescu et al. 2021).

2. The second cutting corresponds to the thinning of the already established seedling stand (30-50 cm in height) and consists of the complete removal of the trees remaining inside the gap, within 2-4 years (at most) after the initial cutting to open the gap, and in floodplain forests at 2-3 years (from Nicolescu et al. 2021).

3. Cuts to widen the gaps are usually made in a year when the pedunculate oak has abundant fruiting, or they can be made when a pre-existing usable seedling has been established in the immediate vicinity of the gap. The widening of the gaps is carried out at their edges, using eccentric strips (in the plain region in the south and southwest direction, where the gaps were initially located in an east-west orientation). The width of the gap widening strips is no greater than the average height (H) of the stand (20-30 m). In the case of light species (such as pedunculate oak) or

under favorable regeneration conditions, the width of the strip can reach up to two average heights (2H) of the forest stand, and in this case, in some situations, the gaps can even be connected (Negulescu 1959, 1966, 1973, Purcelean 1981, Anonymous 1949, 1966, 2000, Vlad 1954, all in Nicolescu et al. 2021). It is preferable to widen the gaps with a single cut, as is the case with opening them. This process should not be delayed, as any delay may lead to the degradation of the remaining trees (MMAP 2022a).

4. The gap connection is achieved by a single cut of the last remaining trees from the old stand. This final cut is made when the seedling has fully developed and become biologically independent. In our country, connecting cuts are recommended when the seedling stand occupies more than 70% of the area and has heights between 15-40 cm for oak seedlings (Negulescu 1959, Anonymous 2000, both in Nicolescu et al. 2021, MMAP 2022a). However, if regeneration is difficult, incomplete, or the established seedling stand is severely damaged, connection cutting can be performed, but it must be followed immediately by replanting in the unregenerated areas (Nicolescu et al. 2021, MMAP 2022a).

In oak forests, lowland forests and floodplain forests, the regeneration period has changed substantially over time: 20-30 years (Giurgiu 1982), in the technical standards of 1986 and 1988 the regeneration period was 15-25 years (Anonymous 1986, 1988, in Nicolescu et al. 2021), and in the technical standards of 2000 it was reduced to 10-15 years (Anonymous 2000, in Nicolescu et al. 2021). According to the current standards published in 2022, the general regeneration period for progressive cutting varies between 15 and 30 years (MMAP 2022a).

In order to achieve natural regeneration of pedunculate oak, gap widening and gap connection cuts must be applied at times when the species has rare but abundant fruiting (from Nicolescu et al. 2021). The essential consequence of this is that when the gaps are connected, the regenerated specimens reach heights (several meters) that correspond to the stages of development of saplings and young trees, which leads to inevitable damage during harvesting and wood collection activities (from Nicolescu et al. 2021).

The successful implementation of cutting in patches in pedunculate oak stands depends heavily on the correct creation of the collection network from the outset, which can be used until the work is completed. The proportion of damage can reach 35-62% (if it is high), and this can be reduced to 8-20% if the work has been carried out correctly and the seedbed has been protected (Ciubotaru 1998, Florescu 1991, Vlad et al. 1997, all in Nicolescu et al. 2021).

An essential rule in the natural regeneration process of pedunculate oak is that, once started, regeneration work must be completed as quickly as possible (MMAP 2022a).

To allow for optimal seedling development, current technical standards recommend creating openings that are not too large, with a diameter of approximately two tree heights. In such situations, it is advisable to open the gaps with a single cut immediately after sowing, to allow the seedlings to benefit from the entire amount of water from atmospheric precipitation (MMAP 2022a). If the annual volume of wood available does not allow the entire stand on the open patch area to be harvested, it is possible to harvest gradually through several repeated, successive cuts, so as to create favorable conditions for the optimal development of the seedlings over as large an area as possible. In this situation, it is necessary to

An optimal solution, in a situation where it is not possible to remove the old trees from the regeneration area with a single cut after the first vegetation period of the seedlings, is to remove them with two cuts, performed one year apart. Regeneration areas can also be created through three cuttings, starting with the first cutting carried out in the autumn of the year with abundant fruiting, after the seeds from the extracted trees have been disseminated (MMAP 2022a).

To avoid problems related to frost and freezing of pedunculate oak seedlings during cold winters, as they are not sufficiently lignified, one of the following two solutions can be chosen (MMAP 2022a):

- cutting should be done when the cold period is over, more precisely in February-March;
- focus on removing large pedunculate oak specimens in the fall-winter period; then return in February-March and work on the understory.

Progressive cutting (in patches) is the most suitable regeneration method for pedunculate oak stands in marshy areas where there is a risk of waterlogging. To reduce the risk of this undesirable phenomenon, it is recommended to carry out a larger number of cuts on the gap surface (MMAP 2022a). During the first cut, pedunculate oak specimens that have acted as a source of seeds (seed trees) are removed. Then, through subsequent cuttings, the undergrowth species, such as hornbeam, elm, maple and others, are removed (MMAP 2022a).

carry out cuttings at short intervals so that the mother stand is completely removed within a maximum of 3 years and the pedunculate oak seedlings can develop under normal conditions (MMAP 2022a).

For terrace oak trees, where humidity conditions are limiting, the gap opening is done in a single step. Once installed, the seedling must be exposed to light by means of a single cut, preferably performed immediately after its first vegetation period. Widening the gap by cutting on the southern side, i.e., on the shaded side of the gap, where moisture is well preserved, is particularly necessary (MMAP 2022a).

In the case of the regeneration of highroad oaks and meadow oaks, the initial shape of the gap may be circular. Given the variation in ecological conditions at very short distances in meadows, especially in the forest-steppe and steppe in the south of the country, it is necessary to choose the direction of widening the patches after careful observation of the behavior of seedlings at different points on the surface of the patches. The widening cut should be made in the part of the patch where seedling growth is best (MMAP 2022a).

The appropriate method for regenerating oak trees in the forest-steppe, which live in the most arid areas, is progressive cutting (in patches). Initially, smaller diameter gaps are created to ensure the development of seedlings in the shade of the old stand during the first years of life (MMAP 2022a). Gap widening can be achieved by cutting on the shaded side of the stand. These cuts allow seedlings to establish themselves and develop initially in a protected environment, under the protection of the parent forest. The forests benefit from stronger light and the understory is better represented. It is important to implement measures to facilitate the natural regeneration process of ecosystems, these measures being represented by works to aid natural regeneration (MMAP 2022a).

Artificial regeneration

When environmental conditions do not allow for complete or partial natural regeneration, artificial regeneration can be chosen by introducing species that are suitable for the fundamental natural forest type. When regeneration is desired through plantations or direct sowing, thinning and widening of the gap is necessary, in accordance with the ecological requirements of the introduced species and the site conditions of the regeneration area (MMAP 2022a). In such cases, the spacing should be widened in a south and south-west direction to promote shade-tolerant vegetation species, while for light-preferring species, the spacing should be widened towards the north and north-east. The impact of the relief and the ecological characteristics of the respective stands must also be taken into account (MMAP 2022a).

If it is necessary to artificially introduce valuable species into the old forest stand that are underrepresented or completely absent, then thinning and widening of the gaps will be carried out to allow for planting or direct seeding (MMAP 2022a). This action will be carried out in the same way as natural regeneration, taking into account the ecological requirements of the introduced species and the regeneration conditions at each specific point. Progressive cutting (in patches) is used for both artificial and mixed regeneration (MMAP 2022a).

In the case of mixed regeneration, it is recommended to use the progressive cutting treatment technique. The main basic species and some of the main mixed species are planted artificially, while the auxiliary species, shrubs, and some of the main mixed species are planted naturally. The aim of seedling care is to ensure that the planted species are preserved in their entirety in the proportions required for the purpose of the respective tree stands (MMAP 2022a).

For low-yielding oak trees, natural regeneration is very difficult, and for this reason, natural regeneration is sometimes abandoned in favor of artificial regeneration (MMAP 2022a).

If natural regeneration is no longer possible due to excessive thinning, artificial regeneration will be used in the respective areas, using secondary forest elements and undergrowth as shelter (MMAP 2022b).

Afforestation compositions, afforestation schemes, planting season

In the case of afforestation with hornbeam, following the restoration-replacement felling of low-yielding and derivative stands, under specific site conditions where auxiliary species and shrubs regenerate easily by natural means (from seed or even from shoots), plantations shall be carried out in rows, at 4.0 × 0.5 m or 4.0 × 0.6 m spacing, in the case of using normal-sized seedlings, in rows, at 3.0 × 1.5 m, 4.0 × 1.5 m or 3.0 × 2.0 m spacing, in the case of medium-sized grafted seedlings, or in beds, at 4.0 × 4.0 m (3 seedlings per bed), in the case of large grafted seedlings (MMAP 2022b).

Within the rows, plantations shall be carried out on land prepared in strips 0.75-1.0 m wide or in 60 × 80 cm pits, and in the case of beds, the soil shall be prepared on an area of 2.25-4.0 m^2 (1.5 × 1.5 m, 2.0 × 2.0 m) (MMAP 2022b). The use of these schemes has the advantage of preparing and maintaining the soil on only 25% of the area at most, promoting the new arboretum with specimens of the main basic and auxiliary species, natural regeneration in the area between rows or between plots, and easier monitoring of artificially installed crops (MMAP 2022b).

In order to use the above-mentioned techniques, it is recommended to open the necessary access lines before planting so that silvicultural interventions can be carried out easily and without problems (MMAP 2022b).

Table 2. Number of seedlings per hectare and planting distances between them, for hornbeams and elms (MMAP 2022b)

Forest crops with the basic species	The situation of land for afforestation	No. of seedlings/ha	Distance between seedlings	Observations
oak stands and oak-dominated mixed deciduous stands	a. On empty and unregenerated land and to supplement natural regeneration - hills - plains	5,000	2.0 × 1.0 m	Mixtures shall be created in large biogroups as far as possible
		5,000 6,700*	2.0 × 1.0 m 2.0 × 0.75 m	
	b. In reforestation with medium-sized seedlings, the method developed by engineer Octav Rusu-Dorohoi	1,875	4.0 × 4.0 m (3 seedlings / bed)	The main species and mixtures are planted at a rate of 3 seedlings per plot (625 plots/ha) or one seedling per strip or plot, using large or medium-sized seedlings
		2,222	3.0 × 1.5 m	
		1,666	3.0 × 2.0 m	
		1,666	4.0 × 1.5 m	

* Determined based on local conditions - the site quality (a lower number of seedlings per hectare is recommended on high and medium quality sites).

In situations where there are mixed plantations with oak species, given that these have slower growth and are more susceptible to losses in the early years, it is recommended that planting be carried out in two stages. In the first year, hornbeam trees are planted in the specified proportion or even in their entirety, and in years 2-3, additions are made to compensate for losses and mixed or auxiliary species are added (MMAP 2022b).

Sometimes it is recommended to plant hornbeam with medium-sized seedlings obtained specifically by grafting (the Octav Rusu-Dorohoi method). The success of this method, recommended in medium-to-high quality sites, where at least 600 mm of annual precipitation has fallen in the last 10-15 years, is ensured by the use of well-formed 4-5-year-old seedlings, spring planting, the permanent maintenance of the forest environment through the use of natural regeneration aids (MMAP 2022b).

In the "Guide to good practices on compositions, schemes and technologies for forest regeneration and afforestation of degraded land – 2022" (MMAP 2022b), target compositions and regeneration compositions were established for each ecological group (G.E.) (Table 3) and afforestation compositions and afforestation schemes were established for each site group (G.S.) (Table 4).

Table 3. Target compositions and regeneration compositions according to ecological group (MMAP 2022b).

Ecological group	Composition of the goal	Regeneration composition
G.E-56	a_1-6-7 St, Go, Gâ, Ce + 3-4 Te, Ci, Ca, Pă, Sb, Ju a_2-5-6 St, Go, Gâ, Ce + 4-5 Te, St.r, Ci, Ca, Pă, Sb, Ju	b_1-6 St, Go, Gâ, Ce + 4 Te, Ci, Ca, Ar, Ju, Pă, Sb, Arb b_2-5 St, Go, Gâ, Ce + 5 Te, St.r, Ci, Ca, Ar, Ju, Pă, Sb, Arb
G.E-60	a_1-5-6 St, Go + 3-4 Fr, Pa, Te, Fa, Ci, Ca, Sb a_2-5-6 St, Go + 4-5 Fr, Pa, Te, Fa, Ci, Ca, Sb	b_1-6-7 St, Go + 3-4 Fr, Pa, Te, Fa, Ci, Ca, Sb b_2-6 St, Go + 4 Fr, Pa, Te, Fa, Ci, Ca, Sb
G.E-61	a_1-6-7 St, Go + 3-4 St.r, Fr, Ci, Pa, Fa, Te, Sb, Ca a_2-6-7 St, Go + 3-4 St.r, Fr, Ci, Pa, Fa, Te, Sb, Ca	b_1-5-6 St, Go + 3-4 St.r, Fr, Ci, Pa, Fa, Te, Ca b_2-5 St, Go + 5 St.r, Fr, Ci, Pa, Fa, Te, Sb, Ca
G.E-62	a_1-5-6 St + 1-2 St.r (Ce) + 2-3 Ca, Pă, Sb a_2-4-5 St + 3-4 St.r (Ce) + 2 Ca, Pă, Sb	b_1-5 St + 2 St.r (Ce) + 3 Ca, Pă, Sb b_2- 4-5 St + 3 St.r (Ce) + 2-3 Ca, Pă, Sb, Arb
G.E-63	a_1-6-7 St + 3-4 Fr, Pa, Ci, Te, Ca ± Ul.c, An.n, Pl, Pl.n a_2-6-7 St + 3-4 Fr, Pa, Ci, Te, Ca ± Ul.c, An.n, Pl, Pl.n a_3-3-4 St + 3-4 Nu.n + 2-3 Fr, Ci, Pa, Te, Ca	b_1-6-7 St + 3-4 Fr, Pa, Ci, Te, Ca ± An.n, Ul.c, Pl, Pl.n b_2-6-7 St + 3-4 Fr, Pa, Ci, Te, Ca ± An.n, Ul.c, Pl, Pl.n b_3-3-4 St + 3-4 Nu.n + 2-3 Fr, Ci, Pa, Te, Ca
G.E-64	a_1-6-7 St + 3-4 Fr, An.n a_2-6-7 St + 3-4 Fr, An.n a_3-6-7 St + 3-4 Fr, An.n	b_1-6-7 St + 3-4 Fr, Ju, An.n b_2-6-7 St + 3-4 Fr, Ju, An.n, Arb b_3-6-7 St + 2-3 Fr, Ju, An.n + 1-2 Arb
G.E-65	a_1-5-6 St, St.r + 2-3 Fr, Te, Nu.n + 2 Div (Pl, Pl.c, An, Ju, Pă)	b_1-4-5 St, St.r + 2-4 Fr, Te, Nu.n, Ul.c, Ci+2-3Div(Pl,Pl.c,An,Ju,Pă)
G.E-70	a_1-5-6 St (St.b) + 1-2 Fr + 3-4 Te.a, Pa, Mă, Pă, Ju a_2-4-5 St (St.b) + 2-3 Fr + 2-3 Te.a, Pa, Mă, Pă, Ju	b_1-4-5 St (St.b) + 1-2 Fr + 3-4 Te.a, Pa, Ul.c, Mă, Pă, Ju b_2-4-5 St (St.b) + 3-4 Fr + 2-3 Te.a, Pa, Ul.c, Mă, Pă, Ju
G.E-71	a_1-5-6 St, St.b (Ce) + 2-3 Fr, Ul.t + 1-2 Aj, Arb a_2-5-7 St, St.b (Ce) + 2-3 Ul.t, Fr +1-3 Aj, Arb 5-6 Ul.t + 2-3 Fr.p (Fr) + 1-2 Aj	b_1-5-7 St, St.b (Ce) + 2-4 Fr, Ul.t + 1-3 Aj, Arb b_2-3-4 St, St.b (Ce) + 3-4 Ul.t, Fr + 2-3 Aj, Arb 4-5 Ul.t + 2-3 Fr.p (Fr) + 2-3 Aj, Arb
G.E-72	a_1-6-7 St + 2-3 Fr, Pa, Ci + 1-2 Te, Ca, Ul.c 6-7 St + 3-4 Pa, Te, Fr, Ci, Ul, Ca a_2-5-6 St + 3 Pa, Fr, Ci + 1-2 Te, Ca, Ul.c	b_1-5-6 St + 4-5 Fr, Pa, Ci, Te, Ca, Ul.c b_2-5 St + 5 Fr, Pa, Ci, Te, Ca, Ul.c, Ar, Ju, Pă, Sb
G.E-73	a_1-6-7 St + 3-4 Fr,Te, Pa, Ci, Ca, Sb a_2-6-7 St (St.r) + 3-4 Fr, Pă, Te, Ci, Ca, Sb	b_1-5-7 St + 2-3 Fr, Te, Pa, Ci + 1-2 Ca, Ju, Sb, Pă b_2-5-7 St (St.r) + 1-3 Fr, Te, Pa, Ci + 1-3 Ca, Ju, Sb, Pă
G.E-74	a_1-5-7 St + 2-3 Fr, Ca + 1-2 St.r a_2-5-7 St + 2-3 Fr, Ca + 1-2 St.r	b_1-5-6 St + 2-4 Fr (An.n), Ca, Ml + 1-2 St.r b_2-4 St + 2-3 Fr (An.n) + 2-3 Ca, Ml + 1-2 Aj, Arb
G.E-75	a_1-6-7 Ce, Gâ (St) + 3-4 Te.a, Fr, Ca, Ju, Sb, Pă a_2-5-6 Ce, Gâ (St, St.r) + 2-3 Te.a, Fr, Pa + 2 Ju, Pă, Sb, Ar a_3-4-5 Ce, Gâ (St, St.r) + 2-3 Te.a, Fr, Pa + 2-3 Ju, Pă, Sb, Ar	b_1-5-6 Ce, Gâ (St) + 4-5 Te.a, Fr, Ca, Ju, Sb, Pă b_2-5-6 Ce, Gâ (St, St.r) + 2-3 Te.a, Fr, Pa + 1-2 Ju, Pă, Sb, Ar, Arb b_3-4-5 Ce, Gâ (St, S.tr) + 3-4 Te.a, Fr, Pa + 2 Ju, Pă, Sb, Ar, Arb
G.E-75A	a_1-6-7 St (Ce, St.p) + 3-4 Te, Ul.c, Ju, Pă a_2-6-7 St (Ce, St.p) + 3-4 Te, Ul.c, Ju, Pă a_3-6-7St(Ce,St.p)+3-4Te,Ul.c,Mj,Ju,Ar,Pă 7-8Ce+2-3Mj,Ju,Pă	b_1-5-6 St (Ce, St.p) + 4-5 Te, Ul.c, Ju, Ar, Pă b_2-5-6 St (Ce, St.p) + 4-5 Te, Ul.c, Ju, Ar, Pă b_3-4-6 St (Ce, St.p) + 4-6 Te, Ul.c, Mj, Ju, Ar, Pă, Arb
G.E-76B	a_1-6-7 St (St.b, St.p) + 3-4 Pă, Cr, Mj a_2-6-7 St (St.b, St.p) + 3-4 Pă, Cr, Mj	b_1-5-6 St (St.b, St.p) + 4-5 Pă, Cr, Mj, Vi.t, Pi.n b_2-5-6 St (St.b, St.p) + 4-5 Pă, Cr, Mj, Vi.t, Pi.n
G.E-78	a_1-6-7 St (St.b) + 3-4 Fr, Te.a, Ci, Ju, Ca, Ul.c a_2-6-7 St + 3-4 Fr, Te.a, Ci, Ju, Ca, Ul.c a_3-3-4 St + 2-3 Nu.n + 3-4 Te.a, Fr, Ju, Ca	b_1-6-7 St + 3-4 Fr, Te.a, Ci, Ca, Ju, Ul.c b_2-6-7 St (St.b) + 2-3 Fr, Te.a, Ci, Ca, Ju, Ul.c b_3-3-4 St + 2-3 Nu.n + 3-4 Ju, Te, Fr, Ca, Ul.c
G.E-79	a_1-4-6 St + 2-3 Te, Fr, Pa + 2-3 Ju, Pă, Pl	b_1-4-5 St + 2-4 Te, Fr, Ul.c, Pa + 2-3 Ju, Pă, Pl, Arb
G.E-88	a_1-5-6 St (St.r) + 4-5 Fr (Fr.p + Fr.î), Te.a, Ul.c a_2-5-6 St, Ce (St.r) + 4-5 Fr (Fr.p + Fr.î), Te.a, Ul.c a_3- 5-6 St, Ce (St.r) + 4-5 Fr (Fr.p + Fr.î), Te.a, Ul.c	b_1-St (St.r) + 2 Fr, Te.a, Ci, Ul.c + 2 Ju, Ar, Mă, Pă b_2-6 St, Ce (St.r) + 2 Fr, Te.a, Ci, Ul.c + 2 Ju, Ar, Mă, Pă b_3-5-6 St, Ce (St.r) + 2 Fr, Te.a, Ci, Ul.c + 2-3 Ju, Ar, Mă
G.E-89	a_1-7-8 St + 2-3 Fr, Ve, Te.a a_2-7-8 St, St.b + 2-3 Fr, Ve, Pl, Te.a a_3-7-8 St, St.b + 2-3 Fr, Ci, Ve, Te.a	b_1-6-7 St +3-4 Fr, Ci, Ve, Te.a, Ju b_2-6-7 St, St.b + 3-4 Fr, Te.a, Ci, Ve, Pl, Ju, Ar b_3-5-6 St, St.b + 2 Fr, Ve, Te.a + 2-3 Aj, Arb
G.E-92	a_1-5-7 St, Go (St.b, Ce) + 3-5 Te.a, Ci, Pă, Ju a_2-5-6 St, Go (St.b, Ce) + 4-5 Te.a, Ci, Pă, Ju	b_1-5-7 St, Go (St.b, Ce) +3-5 Te.a, Pă, Ju, Ci, Ar, Sc b_2-5-7 St, Go (St.b, Ce) +3-5 Te.a, Pă, Ju, Ci, Ar
G.E-93	a_1-6-7 St (St.r) + 3-4 Pl, Pl.c a_2-7-8 St (St.b) + 2-3 Te.a, Fr, Ml	b_1-5-6 St + 4-5 Pl, Pl.c, Aj, Arb b_2-6-7 St (St.b) + 3-4 Te.a, Fr, Ar, Pă, Arb (Al)
G.E-95	a_1-2-5 St, St.b + 4-5 Pl + 1-3 Fr, Fr.p, An.n, Fr.î, Pă, Mă a_2-2-5 Pl + 3-5 St, St.b + 1-3 Fr, Fr.p, An.n, Fr.î, Pă, Mă	b_1-2-5 St, St.b + 4-5 Pl + 1-3 Fr, Fr.p, An.n, Fr.î, Pă, Mă b_2-3-5 St, St.b + 2-5 Pl + 1-3 Fr, Fr.p, An.n, Fr.î, Pă, Mă
G.E-96	a_1-5-7 St, St.b + 3-5 Fr, Pl.c, Pl, Ve 5-7 Fr + 3-5 Pl.c, Ve, Mă, Pă a_2-5-7 St, St.b + 3-5 Fr, Pl.c, Pl 5-7 Fr + 3-5 Pl.c, Pl, Ve	b_1-5-7 St, St.b + 3-5 Fr, Pl.c, Pl, Ve 5-7 Fr + 3-5 Pl.c, Pl, Ve, Mă, Pă b_2-5-7 St, St.b + 3-5 Fr, Pl.c, Pl, Arb 5-7 Fr + 3-5 Pl.c, Pl, Ve, Arb
G.E-100	a_1-5-6 St, St.b, Ce + 2-3 Fr (Fr.p, Fr.î) + 1-2 Ul.t, Ju, Pă, Arb	b_1-4-5 St, St.b, Ce + 3 Fr + 2-3 Ul.c, Ju, Pă, Arb
G.E-102	a_1-5-7 St, St.b + 3-5 Fr (Fr.p, Fr.î), Pl, Pl.n	b_1-5-6 St, St.b + 4-5 Fr (Fr.p, Fr.î), Ve, Pl, Pl.n

Table 4. Forest composition and afforestation schemes according to site group (MMAP 2022b).

Ecological group	Afforestation composition	Afforestation scheme
G.S–8	50 St (Go, Str) 25 Fr (Te.a, Ci , Pa) 25 Sa (Lc, Co, Mc)	R1 = basic species; R2 = mixed species + shrub
G.S–9	25 St (Go) 50 Fr (Ci, Pa) 25 Lc (Co, Sâ, Pd), on fertile soils, over 75 cm thick, with a skeleton below 25%	R1 = St (St.r; Go) + shrub; R2 = mixed species
G.S–14	40 St.b (St, Ce, Gâ, Str) 30 Fr (Mj, Vi.t ,Pr ,Te.a , Ju, Dd, I.v) 30 Pd (Lc, Co, Mc, Sp, Ll), on fertile soils, on slopes less than 20 degrees	R1 = basic species; R2 = mixed species + shrub
G.S–17	25 St.p(Ce, Gâ, St), 50 Fr (Mj, Pr, Dd, Cd) 25 Pd (Lc, Co, Sâ, Pd), on fertile loamy-clay soils, over 75 cm thick	R1 = St.p (Ce, Gâ, St) + shrub; R2 = mixed species
G.S–54	25 St (Go, St.r) 50 Pa (Ci; Te.a; Vi.t) 25 Sâ (Pd, Co), on stabilized land with fertile, virtually undisturbed soil	alternating rows of oak or sessile oak + mixed species shrubs
G.S–54	25 St (Ce) 50 Mj (Ul.t; Ju, Vi. t) 25 Sâ (Co, Al, Po), on soils with a loamy-clay to clay texture	alternating rows of oak or turkey oak + mixed species shrubs
G.S–72	50 St.b (St) 25 Te.a (Ju, Ar) 25 Sâ (Lc), in forest sites with the most fertile soils.	alternating rows of St.b (St) with rows of Te.a (Ju, Ar) +Sâ (Lc),
G.S–76	50 St (St.r) 50 Ar (Te.a, Ju), on the richest soils	alternating rows of St (St.r) with rows of Ar (Te.a, Ju)
G.S–82a	25 St (Gl, Sc) 50 Fr (Fr p, Ar, Ul, Sf) 25 Arb (Ct, Pd,Ct.r)	R1 = St (Gl, Sc) ; R2,3 = Fr (Fr.p, Ar, Ul, Sf); R4 = Arb (Ct, Pd, Ct.r)
G.S–98	a. 50-60Go (St, Ce, Gâ) 15-30Dr 10Aj 10-15Arb* b. 50-60Go (St, Ce, Gâ) 15-30Df 10Aj 10-15Arb*	5,000/ha (2.0 × 1.0 m)
G.S–99	50Go (St, Ce, Gâ) 30Dr/Df 10Aj 10Arb*	5,000/ha (2.0 × 1.0 m)
G.S–101	60Go (St, Ce, Gâ) 15Dr, Df 10Aj 15Arb*	5,000/ha (2.0 × 1.0 m)
G.S–102	50Go (St, Ce, Gâ) 30Dr,Df 10Aj 10Arb*	5,000/ha (2.0 × 1.0 m)
G.S–103	50Go (St, Ce, Gâ) 30Dr 10Aj 10Arb*	5,000/ha (2.0 × 1.0 m)
G.S–106	70St 10Df 10Aj 10Arb*	6,000/ha (2.0 × 0.83 m)
G.S–107	50 St (Go, Ce, Gâ) 30Dr/Df 10Aj 10Arb*	6,000/ha (2.0 × 0.83 m)
G.S–109	a. 70St (Ce, Gâ) 10Df 10Aj 10Arb* b. 60St (Ce, Gâ) 15Dr 10Aj 15Arb*	6,000/ha (2.0 × 0.83 m)
G.S–110	50 St (Go, Ce, Gâ) 30Dr,Df 10Aj 10Arb*	6,000/ha (2.0 × 0.83 m)
G.S–111	50St (Go, Ce, Gâ) 30Df 10Aj 10Arb*	6,000/ha (2.0 × 0.83 m)

* Df (Ci,Fr,Fr.î,Fr.p,Me,Te,Ve,St.r); Aj (Ca,Ju,Mj,Ml,Ma,Pa,Ar); Arb (Al,Lc,Pd,Că,Sâ,S.m,Pt); Dr (La,Pi,Pi.s,Pi.n).

The table above shows that pedunculate oak is the main species, accounting for a significant proportion and having the greatest economic importance, while the secondary species serve to stimulate the growth of the main species and improve the soil. In general, broadleaves - and especially pedunculate oak - require large growing space for development due to their crowns (wide and rich) and root system. This results in afforestation schemes of 2.0 × 0.83 m (6,000 seedlings/ha), 2.0 × 1.0 m (5,000 seedlings/ha), 2.0 × 0.75 m (6,700 seedlings/ha), 2.25 × 1.0 m (4,500 seedlings/ha).

CONCLUSIONS

As shown above, the regeneration of pedunculate oak is achieved naturally, from seed, artificially, through seedlings, or through a combination of both.

Unfortunately, as Diaci et al. (2008) pointed out, "The natural regeneration of pedunculate oak is one of the most difficult objectives of modern forestry in Central Europe." Why? Due to rare abundant fruiting, severe damage (predation) to acorns by insects such as longhorn beetles, powdery mildew, pressure from wild and domestic fauna, competition with accompanying vegetation (from Nicolescu et al. 2021). Furthermore, as Savill (2013) rightly pointed out, "... people should not expect pedunculate oak regeneration to be achieved at no cost and with little effort. This is virtually impossible" (from Nicolescu et al. 2021).

REFERENCES

Constantinescu, N., 1973. Regeneration of forests. Second edition. Ceres Publishing House, Bucharest, 667 p.

Constantinescu, N., 1976. Forest management. Vol. I. Ceres Publishing House, Bucharest, 250 p.

Constantinescu, N., 1976. Forest management. Vol. II. Ceres Publishing House, Bucharest, 402 p.

Cuza P., 2018. AŞM Bulletin. Life Sciences. No. 2(335).

Florescu, I. I., 1991. Silvicultural treatments. Ceres Publishing House, Bucharest, 270 p.

Florescu, I.I., Nicolescu, V.-N., 1996. Silviculture. Vol. I. Forest study. Lux Libris Publishing House, Brașov, 210 p.

Haralamb At., 1967. Cultivation of forest species. 3rd edition. Agro-Silvică Publishing House, Bucharest, 755 p.

MMAP 2022a. Guide to good practices in the selection and application of treatments. Ministry of Environment, Water and Forests, Bucharest, 72p.

MMAP 2022b. Guide to good practices regarding compositions, schemes, and technologies for forest regeneration and afforestation of degraded lands. Ministry of Environment, Water, and Forests, Bucharest, 384 p.

Negulescu E.G., Săvulescu Al., 1965. Dendrology. State Agro-Forestry Publishing House, Bucharest, 511p.

Nicolescu, V.-N., 2009. Silviculture I. Forest biology. Aldus Publishing House, Brașov, 193 p.

Nicolescu, V.-N., 2014. Silviculture II. Silvetehnica. Second revised edition. Aldus Publishing House, Brașov, 289 p.

Nicolescu, V.-N., Ghinescu, M. N., Mihăilescu, G. 2021. The surprising simplicity of appropriate treatments for pure oak forests and oak mixtures. Bucovina Forestieră, 21(2), 183-197. https://doi.org/10.4316/bf.2021.018.

Stănescu, V., 1979. Dendrology. Didactic and Pedagogical Publishing House, Bucharest, 470 p.

Stănescu V., Şofletea N., Popescu O., 1997. The woody forest flora of Romania. Ceres Publishing House, Bucharest, 451 p.

Electronic sources

https://ibn.idsi.md/sites/default/files/imag_file/149-157.pdf (accessed on 10.11.2025)