Programme co-funded by European Union funds (ERDF, IPA)

Output O5.1

Planting material use and conservation guidelines

Prepared by:
Gregor Božič, SFI
Marjana Westergren, SFI
Peter Železnik, SFI
Heino Konrad, BFW
László Nagy, NAIK ERTI
Miran Lanšćak, CFRI
Zoran Novčić, ILFE
Sonja Rukavina, Hrvatske šume
Silvio Schueler, BFW
Srdjan Stojnić, ILFE

Data contributors:
Mitja Černela, Gozdarstvo Turnišče, Murska Sobota, Slovenia
Franc Kreft, Trgovina z lesom Franc Kreft s.p., Murska Sobota, Slovenia
Janez Kolenko, Arboris Janez Kolenko s.p. & BLS Gozd d.o.o., Lendava, Slovenia
Marija Planinšek & Vlado Planinšek, Drevesnica Omorika, Muta, Slovenia
Josef Schwanzer, Baumschule Schwanzer Ges.m.b.H., Langenschönbichl, Austria
Zoran Novčić, Institute of Lowland Forestry and Environment, Novi Sad, Serbia

Contents

1 Background

Riparian forests are among the most dynamic and the most threatened forests in Europe. The forests in the Mura Drava Danube biosphere reserve (MDD BR) are managed in different ways, from no management, through conservative management for nature protection, sustainable management for all ecosystem services to intensive short-rotation management, monoculture forestry managed for producing quality timber or energy-related biomass. The current composition and structure of riparian forests reflect a variety of historic and novel anthropogenic disturbances. Land use change led to notable reduction and fragmentation of the forest cover. Modified flood frequency, duration and/or intensity, depressed floodplain water tables and changes in alluvium deposition regime and pattern, introduction of novel pests, diseases and invasive plant species have contributed to the change of size, tree species composition and health of riparian forests.

Natural regeneration of riparian forests is often compromised or cannot be obtained because of the large-scale presence of very dense ground cover vegetation (often consisting of highly competitive invasive alien species). Dense ground cover vegetation may prevent regeneration from seed. Alternatively, the process may take too long in occasionally flooded terrain. Therefore, natural regeneration of riparian forests is often complemented by:

- artificial regeneration of old riparian stands
- restoration of destroyed riparian stands (disturbances: diseases, pests, windfalls, clear-cutting)
- establishment of new planted riparian forests on bare lands (plantation conversions, lack of forest vegetation)

In addition to supporting natural regeneration, identifying and utilizing the appropriate material of native tree species to be planted in riparian forests is the best pro-active method for maintaining or building up resilience in these forests. Although the native riparian tree species are under serious environmental pressure and declining, introduction of alien species is not recommended due to the missing scientific background. Instead, utilization of the existing intraspecific genetic diversity of the native riparian species may serve as a feasible and legal alternative. The use of site adapted (or pre-adapted) seed or planting material of high genetic diversity, high quality and increased tolerance/resistance properties is considered as primary option for artificial regeneration, afforestation or habitat reconstruction activities.

The chances of successful artificial regeneration depend on:

- ensuring high-quality forest reproductive material (FRM) with appropriate seed source selection, seed collection and processing
- good nursery practice and high-quality seedlings
- the combination of seedling quality and the level of environmental stress factors, such as drought, groundwater level, flooding frequency and duration, biotic agents
- the size of the planting area (the larger the better) is limited to a few ha, and areas less than 1 ha are suitable for colonization of invasive vegetation
- site conditions for regeneration

- best practices used for preparation of the planting site
- a good knowledge for understanding of population genetics, ecophysiology and biology
- proper planning of planting
- appropriate planting techniques
- weather conditions (also climate conditions)
- fencing of regeneration areas (to prevent browsing of seedlings by game)
- vegetation control (removal of weeds and competing vegetation, mowing,...)
- measures for assisting the growth and development of seedlings (soil preparation, removal of vegetation adjacent to the seedlings)
- measures for assisting natural regeneration of admixed species in the way not to damage the planted seedlings
- post planting protection (recognizing early symptoms of pests and diseases, individual stem protection)
- monitoring of the reforestation success and learning from failures.

Alien tree species should only be planted if not invasive and in situations where this is an economic necessity or as an insurance when all native tree species are not successful. Planting of these tree species is possible only if this is allowed by relevant forestry and nature protection legislation. Every decision on planting alien tree species should be taken carefully, must be well planned and the actions monitored.

Both natural and artificial forest regeneration are important in the riparian forests of the MDD BR. According to an expert estimation within the project REFOCuS, natural regeneration is predominant in Serbia (64%) and Croatia (80%) while in Hungary, Slovenia and Austria, artificial regeneration predominates with 80%, 75% and 60% of all forest regeneration in the Biosphere Reserve. These numbers are strongly driven by the predominant forest types and matching regeneration techniques. Natural regeneration works best for oak and willows but yields lower success for other riparian species.

2 Objective

Planting material use and conservation guidelines aim to provide guidance on seed source selection, seed collection and processing, fostering genetic diversity and good nursery conditions for production of forest reproductive material (FRM: seeds, parts of plants, plants) in riparian forests to ensure sustainable artificial regeneration, as close to nature as possible. They are formed on the crossroad of scientific knowledge and long-term experience from forest nurseries producing FRM of riparian tree species.

The guidelines also provide a unique insight into the forest nursery sector in the area of the MDD BR: the development, costs, daily work and problems.

3 Work process

To get an overview of nurseries that produce FRM in the area of MDD BR or provide FRM to the area and identify persons with expertise in handling FRM of riparian forest tree species, SFI with the help of REFOCuS project partners prepared a list of experts (with contact information) managing stool beds, seed and clonal orchards of target tree species, living archives and DNA banks.

The next step involved drafting of a questionnaire by SFI with the aim to collect narratives on nursery operations and best practices used by the experts and nurseries identified in the first step. The questionnaire was prepared in Slovenian language and tested in nursery Omorika in Slovenia. Later it was amended to include information identified as important during the test round. The questionnaire was then translated into English and distributed to project partner representatives in each of MDD BR countries for translation in national language (if necessary). It was agreed that all PPs would assist SFI with conducting the interviews to overcome potential language and specific country knowledge barriers. Interviews in Slovenia and Austria were conducted in person with digital voice recording. Later, transcript from speech to text was done and analysed. After the onset of COVID19 restriction measures, it was agreed that the experts may answer the questionnaire in writing or via video connection via Zoom, to all questions or only a subset selected by themselves. This was valid for Croatia, Serbia, and Hungary. However, the nursery experts preferred in person interviews and the process was therefore delayed.

The aim of the interview was to obtain information on forest nurseries that supply FRM to the MDD BR forest area. The emphasis was on the production of healthy and quality seedlings of forest tree and shrub species in nurseries and transportation of seedlings to the end users for planting in riparian forests. The second aim of this interview was to obtain information on regulations, national and European development incentives, subsidies, schemes, and possible obstacles for the restoration of riparian forests through planting.

Each conducted interview lasted 5 to 6 hours. Transcription from speech to text, considering the language barriers (translation) was demanding and long lasting. Only after the transcription into Slovenian or English, SFI could analyse the interviews for commonalities and differences among countries and nurseries.

Figure 1: An interview in Slovenian nursery Arboris (photo: A. Kolenko)

4 State of the art for the small sized forest nurseries

4.1 Supply and demand of forest reproductive material for riparian tree species on the market

The demand on the market in and around the MDD BR is mostly for native tree species of good quality and specific size. The best sold seedlings are from 50 to 80 and from 80 to 120 cm tall. The demand for seedlings of riparian tree species has grown in the last years and is still rising, mainly because of the dieback of Norway spruce (*Picea abies*), black alder (*Alnus glutinosa*) as well as common (*Fraxinus excelsior*) and narrow-leaved ash (*F. angustifolia*).

Forest nurseries also observed that increased harvesting in the forest (clear cuts) leads to higher demand for seedlings.

Because the demand for native tree species is highest, nurseries in and around the MDD BR and those supplying plants to the MDD BR promote regional plant collections. However, a notable increase in interest for seedlings of black walnut (*Juglans nigra*) has been observed by the nurseries.

4.2 Market for regional (small size) forest nurseries

The nurseries report that the main market for small size nurseries as the ones in and around the MDD BR is the home country. Mostly, large forest owners and state forest service's buy the produced seedlings.

Most of the seed for producing plants is collected locally. Only when there is a lack of local seed, the nurseries import it.

Depending on the species, the nurseries can produce seedlings of genera *Salix, Populus, Alnus* and *Fraxinus* in one to two years. The higher the seedlings are, the higher the price. Seedlings of pedunculate oak can be bought in the following height classes (in cm): 15/30, 30/50, 50-80, 80-120, 120-150, 150-200 while seedlings of black poplar are found in height classes 80/120, 120/200, 150/200 and 200/+ and for willow in height classes: 120/200, 150/200, 200/250, 250/300, 300/+. The classes may differ in different countries of the MDD BR.

Small size nurseries are extremely adaptable and diversify their production to keep functioning. Sometimes, they also plant the seedlings for the customers for extra income.

Despite the small size, nurseries often produce more seedlings that they can sell as demand for different species varies from year to year.

Figure 2: Plant production area in the forest nursery Schwanzer, Austria (Photo: dr. G. Božič)

Figure 3: Plant production area in the forest nursery Gozdarstvo Turnišče, Slovenia (Photo: M. Černela)

4.3 Investment in new technologies and machinery

The highest cost of producing seedlings is the cost of manual labour, which is also physically demanding. Therefore, it is more economic to invest into machinery and new technologies and reduce labour cost. Still, the nurseries must regularly maintain the machinery and keep informed on the newest technologies to keep improving the seedlings production.

Based on the experience of the nurseries, container seedlings work well for high altitudes forests. But in the lowlands, the container seedlings perform poorly, because the roots are often misshapen (grow in circles) and the substrate dries out too quickly if not planted properly.

4.4 Nursery establishment costs

The cost for establishing a nursery strongly depends on the desired size and respective equipment. Table 1 lists equipment needed for an average small size nursery and approximate costs of this equipment/infrastructure. In addition to equipment and infrastructure, the most important cost is the labour.

Table 1: Equipment and infrastructure needed for an average small size nursery and approximate costs of the different items.

Item	**Cost (EUR)**
Tractor	50000
Different ploughs	20000
Various machines (seed processing, transplanting, and lifting machines)	150000 - 200000
Greenhouse facilities, buildings for storage and cold storage halls	500000

Modern machinery and equipment can increase efficiency and productivity in all phases of nursery operations without sacrificing quality or safety. As costs are high, national and EU subsidies are very important for establishment of local, small size nurseries.

4.5 Perspectives and obstacles

Compared to large nurseries, small family led nurseries are more adaptable in terms of tree species and can sell all seedlings on local or national markets while larger nurseries rely on export to survive. Another advantage is that the seed is collected locally, and therefore produced seedlings are adapted to local conditions. However, they are also more vulnerable to large market fluctuations. Small nurseries are primarily interested in cooperation with forestry enterprises and public forest services.

The open market with FRM (within the EU) brings an opportunity for small nurseries as there are new buyers for their seedlings. On the other hand, large international nurseries, especially from countries with low labour costs, provide inexpensive seedlings and may put local, small nurseries out of job.

In the case of larger nurseries with appropriate international connections, the share of targeted production for export is increasing. The seeds are imported from abroad and the seedlings produced from these seed lots are sold back to the country of origin.

Another difficulty is the uncertainty; production of seedlings takes a few years while there are no guarantees whether the seedlings will be purchased at the time when they are ready for transplanting. If this does not happen, the seedlings must be destroyed, and the work was in vain.

Nurseries also find the regulations controlling FRM overly complicated and time consuming to enact.

5 General guidelines for producing planting material

The guidelines are based on scientific recommendations, considering the current policy landscape, and are enriched by forest nurseries' best practices.

5.1 Basic material selection

Trees from which FRM may be obtained are called basic material. There are several types of basic material, which relate to different categories of FRM (Table 2).

Table 2: Categories of FRM in which the various types of basic material may be certified when fulfilling the respective requirements

Type of basic material	**Description of the type**	**FRM category**			
		Source Identified	Selected	Qualified	Tested
Seed source	Trees within an area from which seeds are collected	X	-	-	-
Seed stand	A delineated population of trees possessing sufficient uniformity	X	X	-	X
Seed orchard	A plantation of selected individuals in which each individual is identified by clone, family or provenance, is isolated or managed to avoid alien pollen and is managed to produce frequent, abundant, and easily harvested seed crops	-	-	X	X
Parents of family (-ies)	Trees used to obtain progeny by controlled or open pollination of one identified parent used as female, with the pollen of one parent (full-sibling) or a number of identified or unidentified male parents (half-sibling)	-	-	X	X
Clone	Individuals (ramets) derived from a single individual (ortet) by using vegetative propagation (i.e., cuttings, micropropagation, grafts, layers, etc.)	-	-	X	X
Clonal Mixture	A mixture of initially identified clones in defined proportion	-	-	X	X

The type of basic material and FRM category will depend upon the intended use. No or very little phenotypic selection took place in the FRM category Source identified FRM. Selected FRM was phenotypically selected at the population level while qualified FRM was selected at the individual level. Tested FRM was proven genetically superior in comparative field tests. The higher the category, the more information on the quality and the growth potential of the FRM is available. However, this does not mean that the best we know is the best we have.

5.2 Collection of FRM

The way the seeds are collected is crucial for FRM categories Source identified and Selected. To safeguard genetic diversity, it is best to collect seed during full mast years, when most trees in a given stand have contributed to the production of seed. Consequently, seed lots collected at that time, represent the genetic variation of the whole stands. We advise to collect seed from at least 25 unrelated trees, distributed over the entire seed stand. Equal quantities of seed should be collected from each tree. The higher the number of trees for seed collection, the better.

Mixing of seed lots can increase genetic diversity. It is usually allowed when basic materials are located in the same region of provenance and the procedure of mixing is documented.

If properly designed and containing enough genotypes (trees with different genetic makeup), seed orchards represent genetically diverse artificial populations of superior individuals (plus trees) which mate with each other, producing high quality seed. They are established for the reproduction of phenotypically superior parents to produce offspring with fast growth, good form, and higher resistance (breeding orchards). They are also used for the reproduction of scattered or endangered tree species that do not produce enough offspring in forests (*ex-situ* gene conservation orchards). We advise to collect seed in seed orchards in years, when most genotypes have flowered. Minimum of 20 clones must be harvested which is usually equal to about half of the clone present. Approximately equal quantities of seed from each genotype should be collected.

Harvesting seeds from the ground is the simplest way to gather them. Heavy seeds / fruits from tree species like oaks, maples, chestnut, walnut, apple and pear can be gathered manually, by raking, sweeping or with special vacuum cleaners. It is also possible to track and use seed stocks prepared by various animals. The right timing of seed harvesting is crucial. The first seeds that fall are usually dead or infected with insects or fungi and should therefore not be collected.

Acorns can be gathered easily but germinate very quickly in suitable weather conditions. If the sprouts of the germinated acorns are not longer than 1 cm, they can still be collected. As acorns can sometimes be heavily infected with insect larvae (especially *Balaninus* species) it is best to test them by soaking them in water which exposes the defected acorns as they float. Since the long-term storage of acorns is difficult, it is best to sow them immediately after bringing them to the nursery. Floating acorns of oak species in 40 degrees hot water for 3 hours and consecutive drying off and storage at around -3°C is also practised to allow sowing in spring, thus avoiding damage from rodents over the winter.

Seeds can also be **harvested directly from trees**. This can be done by shaking the tree, climbing, shaking and cutting off branches, or the trees can be cut down to harvest. Seed gathering by climbing is one of the most dangerous tasks in forestry. Different climbing techniques and specialized equipment is available to aid tree climbing.

Samaras (winged seeds - achenes) of species like maples and elms can be harvested by shaking the tree, climbing, pounding and cutting branches with fruit or from felled trees.

Seed collection from felled trees carries the risk that the number of parents will fall below the desired level, as large numbers of trees are usually not cut down solely because of seed collection. It is best to harvest samaras from standing trees. Seed collectors spread tarpaulins under the tree, one person climbs a tree and beats the branches with a stick. On the ground, they manually separate the leaves from the fruits. Such fruits are already ready for sowing. For storage, they are further dried and stored in plastic or jute bags. This is hardly feasible in high standing trees; therefore, smaller trees are often harvested or material from seed orchards is used.

Beating of the branches is also used to harvest wild cherry fruits.

Alder seeds can be **harvested from the water surface** with the help of nets and sieves.

Table 3: Properties of seed for riparian forest tree species, time of collection and storage conditions

Tree species	Time for seed/fruit collection	Colour of seed/fruit at collection	Seed quantity [kg] per 100 kg fruit	Number of seeds per kg of seed	Typical germination (average) [%]	Seed type[1]	Dormancy[2]	Conditions for storage		Storage duration under optimal conditions [years]	Frequency of full mast [years]
								Moisture content [%]	Temperature [°C]		
Acer campestre	October			12.000 - 25.000	40 - 70 (55)	O	D			1,5 - 2,5	2 - 3
Alnus glutinosa	September - November		10,5	636.000 – $1{,}4\times10^6$	20 - 65 (40)	O	S	5 - 7	3	4+	2 - 3
Alnus incana	September - October		12,5	1×10^6 - 2×10^6	20 - 80 (30)	O	S	5 - 7	3	4	1 - 4
Carpinus betulus	September - December	green-brown, brown	50	14.000 - 19.000 (with wings)	50 - 70	O	D	8 - 10	-10 do -3	1,5 - 2,5	3 - 5
Fraxinus excelsior	August - October	green-brown, brown		9.000 - 26.000	50 - 70	O	D	8 - 10	-5 do -3	6	1 - 2
Fraxinus angustifolia	August - October	yellow, brown		10.000 - 21.000	50 - 70			less than 8	-3	6	1 - 2
Malus sylvestris	autumn	yellow to red	0,8 - 0,9		60 - 70	O	D	6 - 7	3		
Populus nigra					67 - 100	R		less than 6	3	1	almost every year
Prunus avium	summer	red, black	8	4.800 - 6.500	75 - 90	O	D	9 - 11	0 do 5	4+	1-2
Quercus robur	August - October			130 - 290	81	R		no long-term storage possible		1	2 - 4
Quercus rubra	August - October		90 - 175	165 - 560	58	R				0,5	3 - 5
Salix × spp.		yellowish		1×10^6 - 22×10^6	30 - 100	R		6	room	4 - 6 weeks	every year
Tilia cordata	after first frost	yellow brown		24.000 - 48.000	40 - 50	O	D	dry	3	2 - 3	almost every year
Ulmus glabra		yellow brown		36.000	61 - 80	O	D	approximately 10	-4 do 4		2 - 3
Ulmus laevis			60	82.000	62 - 80						2 - 3
Ulmus minor				80.000 - 160.000	60 - 80						

[1] O = orthodox, R = recalcitrant

[2] S = shallow dormancy, D = deep dormancy, M = soft dormancy (hard seed coat)

5.3 Seed handling and processing

After FRM collection, seeds should be extracted from pods, conelets or fleshy fruits (e.g., apples). This is necessary to facilitate further processing and storage of seeds in a way that retains their germination ability and allows proper manipulation before sowing.

The most common seed extraction method is **extraction with drying**. Fruits can be dried outside in open air or in a seed dryer. In general, seeds of broadleaves should not be dried at temperatures above 20°C. After drying, seeds are cleaned, if necessary, of wings, husks, or other impurities.

Seeds from certain fruits like common hornbeam or walnut are **extracted with threshing**. As manual threshing can be very time consuming and labour intensive, power driven machinery is used. A wide range of equipment is available for threshing agricultural grain crops; some can be adapted for the extraction of tree seeds. The tolerance of seeds to threshing depends on the species, thus machinery must be carefully tested for harmful effects on each seedlot before the bulk of the seed is subjected to the treatment.

Pulpy fruit like cherry should be macerated before storage or sowed immediately since the pulp starts to ferment very quickly, which can seriously decrease their germination ability. Fruits are squashed or gently mashed and mixed with water. As a result, pulp and skins can usually be separated from the seed by washing through a sieve to remove heavy material and later by flotation in water to remove unwanted lighter impurities. This deboning should take place on the same day as the collection. However, in Austria, the fruits are soaked for 2-3 days and then the pulp is removed by high pressure water application. Because cherry seeds (pits) contain a lot of moisture, they should be dried in a shady, airy place for at least 3 weeks before storage. Otherwise, the seeds go to nurseries for sowing immediately after soaking them in water.

5.4 Seed storage

Seed storage is determined by two seed attributes: seed type (orthodox or recalcitrant) and subsequent decrease of seed viability during storage and seed dormancy.

Orthodox seeds survive drying and/or freezing during ex-situ conservation for extended periods of time. This is because physiological processes of seeds and of growth of pathogenic fungi stop entirely. On the other hand, recalcitrant seeds are seeds that do not survive drying to moisture lower than 40% and freezing during ex-situ conservation. These seeds cannot be stored for long periods like orthodox seeds because they lose their viability. When stored for shorter periods, they are kept at temperature slightly above 0 °C, where physiological processes of pathogenic fungi and biochemical activity in seed are merely slowed.

Seed dormancy is an evolutionary adaptation that prevents seeds to germinate during unsuitable conditions for seedling growth. Non-dormant seeds germinate when suitable temperature and moisture conditions are met. On the other hand, dormant seeds germinate in favourable conditions only after the cause of dormancy has been eliminated. These causes include hard seed coat, germination inhibitors, immaturity of the seed embryo, impermeability of seed coat to water or oxygen, mechanically resistant seed coat, etc. More than half of forest tree species have dormant seeds, which is naturally eliminated under proper conditions. The duration of dormancy varies also within the species, depending on the

provenance of seed, i.e. its origin. In a controlled environment, we can eliminate dormancy in the process called stratification. Depending on the tree species, stratification can be simple or complex but always takes place in a moist environment with different temperatures. It enables better germination compared to natural germination. Due to usually expensive equipment, needed for the process, stratification is suitable for large seed quantities. Different nurseries have different stratification protocols for seeds of the same tree species.

5.5 Growing seedlings

For the purpose of forest regeneration, three types of seedlings are used - **bareroot seedlings, container seedlings and wildlings**.

The cultivation of **bareroot seedlings** is a complex multi-year process (usually four to five years) in which individual phases of work follow each other in the following order:

- soil preparation,
- seed sowing,
- transplanting seedlings and care for perennial seedlings,
- excavation and preparation of seedlings for planting in the field.

Soil preparation includes:

- sowing plants for green fertilization,
- autumn ploughing,
- fertilization,
- harrowing or milling the soil,
- design of seedbeds,
- spraying with pesticides.

Seed sowing includes:

- analysis of seed purity and germination potential
- soaking in water
- disinfection and protection against rodents and birds
- sowing, covering, and rolling seeds,
- watering and spraying with fungicides
- de-weeding
- additional fertilization
- overwintering.

A year after seed germination, young plants can be transplanted to a new nursery bed. The process includes:

- spring artificial fertilization (optional)
- weeding. However, weeding of seedlings is carried out less frequently, as the seedlings are dense enough and cover the surface
- watering the seedlings (only during longer dry periods)
- regular protection with fungicides.

Seeds are transplanted in the spring. When transplanting seeds, we need to know what the target stock type of the seedlings being transplanted is. The number of seedlings per unit area depends on the stock type. Stock types are: 1 + 1, 1 + 2, 2 + 2, 2 + 3. “1/2” or “1 + 2” are the symbols that tell us the age of the seedling, namely: 1 year before transplanting and 2 years after transplanting. The total age of the seedling in this case is 3 years. The aim of transplanting is to strengthen the root system and increase the height of the seedlings. Deciduous trees are transplanted after the first year. For most riparian tree species (*Acer, Fraxinus, Malus, Quercus*…) the best stock type is 1 + 2. Only for *Prunus* and *Alnus*, type 1 + 1 is more suitable.

Wildlings are used in case planting material of certain tree species and provenance is needed, but appropriate seeds were not gathered in adequate quantities to raise seedlings in a nursery. This happens most often with species who have sporadic mast years. Wildlings are collected in a forest at the sites with known provenance or origin. Seedlings must be dug out of the ground with much care, transported to a nursery and planted. They must remain in a nursery for at least one year to recuperate after the transplantation shock.

Before transplanting seedlings into the forest, the bareroot seedlings and wildlings need to be excavated. This usually happens after the end of the vegetation period, after the seedlings have shed all leaves. If the customer requires seedlings beforehand (during the vegetation period), these need to be transported and transplanted immediately (within a day).

Container seedlings offer an alternative to bareroot stock, especially when short production times are required (for example shortage of bareroot seedlings), the planting is performed outside usual months, or adverse sites are to be planted. Production of the container seedlings is in general shorter than the production of the bareroot seedlings and lasts from one to two and a half years. Seedlings are grown in a controlled environment to achieve desirable maturity and quality. The content of nutrients in the growth substrate is very important. All this makes container tree seedlings production much more intensive in comparison with bareroot seedlings production. Important to mention, the quality of the seedlings depends strongly on the quality of the seeds sown. Since container seedlings are planted together with the growth substrate, they can be planted from spring to autumn, which is one of the biggest advantages of container seedlings.

5.6 Transporting seedlings

Before planting the seedlings in the forest, they need to be transported from the nursery to the planting location. Quick transport and proper seedlings handling (ensuring roots remain moist) during and after transport are essential for the success of the artificial regeneration. Therefore, the date of delivery of the seedlings should also be the date the seedlings are loaded to trucks for transport.

The ability of coupling seedlings to available soil water via the roots depends on the water balance of the seedlings. Improper handling of seedlings causes dehydration and drought stress in seedlings, root rot, pest attack, mould and disease and thus reduced seedling vitality. Therefore, during and after transport, forest seedling must not be exposed to dry air, strong wind or direct sunlight before planting. Special transport bags for FRM are available.

All types of seedlings are more resistant to stress during transport when they are inactive (Grossnickle and El-Kassaby 2015).

Drying can occur:

- during excavation in the nursery, seedlings should be transported as soon as possible to the storage facilities
- while waiting for the buyer to collect the seedlings in the nursery; seedlings should be stored in cold and dark storage or refrigerator (at +2 °C). If the seedlings are stored for more than a few days, it is necessary to moist the roots of the seedlings.
- during transport to the forest, transport of seedlings is possible only under tarpaulin protection or with refrigerator truck
- after transport due to late and poorly heeled in seedlings; before heeling seedlings in, it is necessary to untie the bunches of seedlings and spread moist soil (not humus) over the roots so that all the roots are in contact with the soil. In the case of many seedlings, the trenches must be dug by machine. Another method of storage at the site is storage under metallized, reflective foil. To maintain a constant humidity of the soil, watering is necessary, but seedlings should not be soaked in water or watered directly over roots. Container seedlings cannot be heeled in. Therefore, transport must be organised to the designated storage for container seedlings on or near the planting site. The storage location can be outside but should not be in direct sunlight.
- at the time of planting due to careless transfer or storage of seedlings to the planting site; seedlings must be well protected from drying and mechanical damage during transport to the site and should be carried in canvas bags.

Good transport logistic and organization of work in the listed stages can ensure that the seedling will remain in good condition until the actual planting.

Transportation of bare-root seedlings and container seedlings does not differ much more than in the fact that the transportation of container plants requires much more space. This is because containers cannot be stacked on top of each other and seedlings are not bundled together. Sometimes special vans are used where containers are loaded on several levels, leaving enough vertical space between them for the aboveground parts of seedlings. As container trays are cumbersome and heavy to carry, special backpacks or hand carriers for multiple trays are available. For container seedlings good road access is beneficial due to the high tray weight.

5.7 Planting of seedlings

Lately, winters are becoming drier which diminishes the success of planting carried out in the autumn. If dry winter is expected, it is advisable to soak the roots in water for one to two days. If planting is planned for the spring, it must be carried out as close as possible to a predicted rainfall, but not more than 15 days beforehand. Before planting, it is advisable to dip the seedlings' roots shortly into a mud slurry. In general, it is still better to do the planting in the autumn if possible, as dry springs in most countries are both more harmful and common.

In case seedlings are not planted immediately as delivered, special precautions must be taken to avoid drying out. For bare-root seedlings, the roots are covered with soil to temporarily store them in the ground before planting. Container seedlings can be stored above ground, out of direct sun light and watered if needed.

Bare root seedlings and wildlings of the majority of the riparian tree species (except poplars and willows) are planted manually in riparian forests. First, planting pits are excavated. Roots are then spread across the entire pit. Soil is added sequentially, pushing it down with the hand. At the end, the soil around the seedling is pushed down gently with the foot, not to destroy the seedlings' roots but hard enough so the seedling cannot be pulled out with a gentle hand pull. The seedling must be covered with soil up to the same height as it was in the nursery.

Container seedlings are planted using special planting tools - corers, usually provided by the seedling producers. Care needs to be taken when using those tools in clay soils or when the soil is too wet, otherwise soil pores might get closed by the torsion with the tool and the plants will have problems to root in. Before planting, the ground vegetation should be adequately suppressed. The spot where a hole for the container seedling is to be made must be totally cleared of the ground vegetation. This significantly increases the survival of the seedling in the first year after planting. The plots with container seedlings need significantly more ground vegetation

control in the first few years after planting due to their smaller size in comparison with other seedling stock types. Container seedlings should be planted deep enough otherwise they tend to succumb to drought stress. After the seedling is in the ground, the substrate with the seedling is gently pressed with hands. This enables the substrate to adhere to the soil in which we are planting.

After planting, seedlings must be protected from browsing individually as soon as possible or latest within a few days after planting, if the planting area has not been fenced beforehand. Mowing of competitive vegetation is also advised for the first two years.

6 Protocols for seedling production of target tree species

6.1 *Alnus glutinosa* (L.) Gaertn., black alder

Seed collection: Black alder trees, growing in a stand, start to fruit at about the age of 30 years, whereas solitary trees start fruiting at least 10 years earlier. Alder can produce seeds every year, but abundant seed crops come every two to three years. Conelets with seeds are harvested from standing trees or recently felled trees when ripe - their colour changes from black to brown. This usually happens in October and the conelets can be collected until the end of the year. For 1 kg of seeds around 15 to 20 kg of conelets are needed. Since the conelets have relatively high moisture content, they must be transported rapidly to the nursery after harvest. They open when the moisture content falls to 8 or 9%

Seed storage and handling: Dried black alder seeds can be stored in a fridge or frozen for up to five years. Sowing is carried out in wet weather conditions.

Seedling handling in a nursery: Seeds are sowed densely onto a seedbed in the spring, during wet weather conditions. In Slovenia, this happens most often in mid-May. Before the seeding, the seeds are soaked in water for two to three days. Stratification of seed is not needed. Seedlings are watered if needed, weeds are removed. Towards the end of June, a mineral fertiliser is used to fertilise the seedlings. After one year, in the spring, the seedlings are transplanted with help of a transplanting machine which also trims root systems to achieve slightly more bushy and denser root growth. The distance between individual seedlings is approximately 20 cm.

Figure 4: Black alder seedlings production in forest nursery, Ižakovci, Slovenia (Photo: M. Černela)

Seedling handling while waiting for transport: Black alder seedlings are very susceptible to drought. After they are dug out in the nursery, they should wait for transport in bundles, covered with moist soil.

6.1.1 Production of black alder seedlings using hydroponic technology

The production of black alder seedlings has a long tradition in the Croatian forest ltd. nursery "Limbuš". Since 2006, ecological hydroponic technology has been used to do this. In hydroponic cultivation, plants develop on the surface of the water, and their roots develop inside a dynamic solution of nutrients.

Black alder seeds are collected during autumn and winter (depending on whether the cones are collected, or seeds are scattered from the trees), and processed and stored at the Seed bank of Croatian Forest Research Institute in Jastrebarsko until the beginning of sowing, which is from 5 to 15 March.

Seed is sown into Styrofoam containers using special machines. There are 150 holes in each Styrofoam container. From mid-March to mid-May, the containers are left in hydroponics in a greenhouse during which time they grow 10 - 15 cm high. Afterwards, the seedlings are transplanted into soaked nursery beds, into five rows per bed. Planting is done by a semi-mechanized method, where five workers place each seedling individually in the planter. The planter then puts the seedlings into the ground. After planting, the seedlings must be watered regularly. Weed control is conducted by inter-row cultivation, and the remaining weeds are removed by hand weeding.

There are no pesticides used in hydroponic, therefore the cultivation produces no environmental pollution. Further advantages are reduced pathogen occurrence, a high degree of automation, high production intensity, less work on processing and disinfection, and lower consumption of water and nutrients (Jakobović, 2019).

Figure 5: Seedling production in specialised black alder forest nursery Limbuš, Croatia (Photo: S. Rukavina)

6.2 *Fraxinus angustifolia* Vahl. and *Fraxinus excelsior* L., narrow-leaved and common ash

Seed collection: Seed is collected either in August, September or October while still green. Depending on the time of seed collection, the seed handling differs.

Seed storage and handling: When seed is collected in (early) August, stratification in wet sand and storage at 2°C follows. Seed is sown in spring, after the late frosts. When seed is harvested in September (or when the seed stalks are just starting to turn brown), stratification of seed for two to three months at 12 to 15°C follows. After two to three months, the seed is kept at 0 C for the

rest of the time, until its sowing in April. When seed is collected in October, it is immediately sown densely by hand into seedbeds and covered with a thin layer of soil.

Seedling handling in a nursery: During the following vegetation season, the seedbed is weeded and watered regularly and the nutritional supplements for the foliage development are applied occasionally. Also plant protection is carried out during the vegetation season if necessary, to protect the seedlings from harmful insects and diseases. Insecticides such as Actara or Mospilan and the fungicides Sphere SC, Signum or Copper oxychloride are used, the latter not in the EU. Against the infection by *Hymenoscyphus albidus* (ash dieback), the seedlings should be sprayed every three weeks with Sphere SC or Signum, alternating the two.

After the first year, the plants are removed from the seedbed and transplanted to the growing site into milled soil with distance 0.80 m x 0.25 m between individual plants. After transplanting, during the second vegetation period hoeing, sparring, weeding, and watering are applied. Supplements to increase foliar growth are also applied several times during the vegetation period. Also during the second vegetation period the same pesticides as in the first vegetation period are applied. At the end of the year the seedling type is 1 + 1. If older seedlings are produced, e.g., 1 + 2, the roots are pruned (undercut) with plows in the spring of the third year, and immediately after pruning, the plants are watered and the soil around them is trampled.

Seedling handling while waiting for transport: Standard measures should be taken to prevent seedlings from drying out.

6.3 *Populus nigra* (L.), European black poplar

Cuttings production:

1) Autochthonous black poplar in its natural habitats is determined by morphometric signs using the EUFORGEN identification key for black poplar. Trees are selected in local populations that are part of the black poplar metapopulation along the river system.

2) Among the trees selected in step 1, those that have at least one well-developed one-year upright shoot with dormant buds growing from the trunk at the appropriate height or at the bottom of the trunk are further selected. A suitable one-year-old shoot measures at least 1 cm in diameter at the base of the shoot.

3) Cuttings obtained from large old trees usually have the least possibility of rooting. Rooting of cuttings is also genetically determined. Cuttings obtained from i) one-year upright shoots growing out of the main branches of young adult black poplars, which still have a large height increment (i.e., younger than approximately 12 years), ii) one or two-year old upright shoots on the pollarded trees and iii) annual upright shoots from vital coppiced tree stumps have the highest

possibility of rooting. In the nursery, most vital shoots are then produced by cutting the shoots of one year old poplar seedlings. Therefore, these are most suitable to produce the FRM in registered rootstocks of poplar clones.

4) Garden shears or scissors on a telescopic handle are used to remove annual shoots (switches) from the trees to make cuttings. Switches/shoots are cut at the end of winter in dry weather when the vegetation is dormant. The lowest and thinnest upper part (non-woody tip) of the switch/shoot are not suitable for cuttings production and must be discarded. The rest of the shoot is cut into cuttings. Cuttings should be 18 to 40 cm long and 8 to 13 mm in diameter. The upper incision is made with sharp scissors horizontally just above the dormant bud, and the lower incision obliquely below the dormant bud. Thus, even after cutting, both ends of the cuttings are well differentiated. Sharp scissors are needed to prevent damage to the bark of the cutting. There must be at least 3 to 4 buds on each cutting, of which the upper one (the horizontal one just above the dormant bud) must be well developed and undamaged.

5) Cuttings obtained from the same parent tree are put in a bundle. The thicker parts of individual cuttings are always together. The bundle is labelled with an identification number that connects the bundle with the parent tree.

6) The production of poplar cuttings and seedlings is to be monitored by the authorized institutions. Disinfection of cuttings and seedlings is mandatory.

Cuttings storage and handling:

7) The cuttings are stored in a refrigerator at 4 °C to inhibit bud growth until planting. The bundles of cuttings should be wrapped in paper. The paper should be kept moist but not soaked to avoid growth of undesired fungi. Regular inspection of stored material is advisable.

8) Cuttings are planted into prepared beds in early spring (late March or early April). The soil must be such that it agrees with poplars; light stone-free soils with a pH of 5.5 to 7.5 are best. Dry, sandy soils and soils exposed to wind are not suitable for growing poplars from cuttings. The soil in the nursery should be prepared in the fall, by ploughing at least 40 cm deep. The surface must be cleared, the existing vegetation removed, the land finely treated and disinfected before planting of cuttings.

9) It is recommended to soak the lower end of the cuttings in water for 24 hours immediately before planting.

10) Cuttings are planted vertically into the soil so deep that only the upper most bud is seen a few cm above the soil surface. The soil around the planted cutting is pressed with feet well. During the planting, the upper bud and bark must remain undamaged. In addition, care must be

taken so that the cuttings do not dry out in the sun or the wind. The cuttings are then covered with a thin layer of light soil. Regular weeding, hoeing and watering should be carried out.

11) The planting area must be marked. Each genotype of poplar (clone) must be planted on a separate surface. Records on the number of planted cuttings, survival rate and growth performance of individual clones must be kept at the facility.

Young plants of rooted cuttings (i.e. seedlings) handling in a nursery:

12) Weeding and releasing seedlings from competition should be done regularly, seedlings should be hoed several times. Weeds greatly hinder the development of seedlings. The side branches of the seedlings should not be cut. If two tops appear, the worse one is cut off.

13) At the end of the winter, one- or two-year-old seedlings are cut 5 cm above the ground and new cuttings are produced for the propagation of the genotype. In the nursery, they are planted in rows, at a distance of about 30 to 40 cm within a row and 50 to 70 cm between rows. Higher planting density yields slender and weak seedlings, which tend to bend and defy wind poorly after transplantation into the field.

14) The herbaceous layer in the first and second year of growth should not exceed the size of the shoots or seedlings. It should be removed next to the seedling to prevent rodents damaging seedlings in the winter. Suitable herbicides can also be used to control the herbal layer. After leaf unfolding, protection against defoliators may be needed.

15) The facility must be fenced with a strong fence to protect the seedlings from the herbivores.

Seedling handling while waiting for transport:

16) When the poplar seedlings are dug up, the root part should be heavily covered with moist soil. The seedlings are also covered with a shading net to make them less prone to drying out.

17) 1 + 2 or 2 + 3 seedlings are used for planting.

6.4 *Populus* hybrids and other non-native poplar species

Cuttings production: Annual poplar shoots grown in the nursery are cut into cuttings, usually in March.

Cuttings storage and handling: Until planting, cuttings are stored in refrigerators (at +4 C) to inhibit bud growth. It is advisable to wrap them in moist paper to prevent drying out. Cuttings are planted into the ground in the spring when the outside temperature is high enough. It is even better if we wait for the possibility of spring frosts to pass. In the case of poplar cuttings, sufficient size and quality of the cutting should be ensured. Then the probability of successful cultivation and good seedling growth is high.

Seedling handling in a nursery: The procedures are the same as for the European black poplar.

Seedling handling while waiting for transport: When the poplar seedlings are dug up, the root part should be heavily covered with moist soil. The seedlings are also covered with a shading net to make them less prone to drying out.

Figure 6: Poplar seedling prepared for transport (Photo: Z. Novčić)

6.5 *Quercus robur* L., pedunculate oak

Seed collection: Acorns are harvested in the fall, usually in October, depending on the maturity of the seeds. Damaged acorns and acorns containing holes are sometimes discarded. This last step is often neglected due to the high demand on manual labour. This may have a positive effect too, as seedlings can emerge from damaged acorns if the embryo is intact.

Seed storage and handling: The seeds are stored for a relatively short time and sown as soon as possible, most often in October or November. The seeds are sown in straight rows by hand 2 to 5 cm deep into narrow seedbeds and covered with a thin layer of soil (Croatia). In Slovenia, acorns are treated with a substance that repels rodents while no additional treatment is used in Serbia. It is essential to move the acorns from the forest to the storage facility and then to the planting site and plant them as quickly as possible, best immediately after bringing them to the nursery.

Floating acorns of oak in 40 °C hot water for three hours and consecutive drying and storage at around -3 °C is practised in Austria to allow sowing in spring, thus avoiding damage from rodents over the winter.

Seedling handling in a nursery: Seeding is carried out in rows (manually in Slovenia) prepared by special machines. In Slovenia, the seeded acorns are covered with sawdust from conifers, but not thicker than twice the thickness of the acorns. This is because the seedlings grow easier through the sawdust than soil.

After the first year, the plants are removed from the seedbed and transplanted to the growing site into milled soil with distance 0.80 m x 0.25 m between individual plants. In Slovenia, the distance between the seedlings is smaller, only approximately 20 cm. After transplanting, during the second vegetation period hoeing, sparring, weeding and watering are applied, if needed. Mineral supplements to increase foliar growth are also applied several times during the vegetation period.

In the second year (and all subsequent years, if such material is being grown), the roots are pruned with plows in the spring period, in order to form a quality root system. Production of seedlings usually lasts 3 (1 + 2) years, whereby seedlings about 80 cm high (although they can grow up to over 1 m) with a well-developed root system are obtained.

Throughout the production process, protection is carried out against the oak powdery mildew (*Erysiphe alphitoides* (Griffon and Maubl.) U. Braun and S. Takam.), oak lace bug (*Corythucha arcuata* SAY) and the oak flea beetle (*Haltica quercetorum* Foudr.) in countries where these are present. It is best to rotate the pesticides and fungicides to avoid resistance. Pesticides based on Bifentrin (Bifenicus) and Thiamethoxam (Actara, Amos, Cruiser 70 WS) have shown excellent efficacy against the oak lace bug in Serbia. Mainly fungicides based on sulphur are used against the powdery mildew.

Seedling handling while waiting for transport: Oak seedlings are bundled, and put back into the ground, covered by soil immediately after excavation. Water is poured over the roots. Thus, the exposure of the roots to external drought influences is minimal.

6.6 *Ulmus laevis* Pall. *and Ulmus minor* Mill., European white elm and the field elm

Seed collection: Seed is collected in the first half of May.

Seed storage and handling: In the autumn, the fresh seeds are sown immediately after the harvest. They are sown densely by hand into seedbeds and covered with a thin layer of soil. Another option used in Austria is to saw the seeds after stratification in the spring.

Seedling handling in a nursery: During the following vegetation season, the seedbed is weeded and watered regularly and the nutritional supplements for the foliage development are applied occasionally. Also plant protection is carried out during the vegetation season if necessary, to protect the seedlings from harmful insects and diseases. Insecticides such as Actara or Mospilan and the fungicides Sphere SC, Signum or Copper oxychloride are used. However, copper may be used only under a total application of 28 kg of copper per hectare over a period of 7 years.

After the first year, the plants are removed from the seedbed and transplanted to the growing site into milled soil with distance 0.80 m x 0.25 m between individual plants. After transplanting, during the second vegetation period hoeing, sparring, weeding and watering are applied. Supplements to increase foliar growth are also applied several times during the vegetation period. Also, during the second vegetation period the same pesticides as in the first vegetation period are applied. At the end of the year the seedling type is 1 + 1. If older seedlings are produced, e.g. 1 + 2, the roots are pruned with plows in the spring of the third year, and immediately after pruning, the plants are watered and the soil around them is trampled.

Seedling handling while waiting for transport:

The same protocol is used as for the oak.

Figure 7: *Ulmus* seedlings in the Schwanzer forest nursery storage facility (Photo: dr. S. Schueler)

7 Literature

1. Eleršek at al. 1985. Morfološke in fiziološke lastnosti sadik.

2. Eleršek L. 1984. Shranjevanje sadik pod folijo namesto v zasipu. Gozdarski vestnik, p.92

3. FAO. A guide for collecting, extracting, cleaning, and storing the seed and for treatment to promote germination of dry-zone acacias. FAO, http://www.fao.org/3/q2190e/Q2190E00.htm#TOC

4. Forest tree seedlings. Forestry Commision.

5. Herman - Planinšek, M., 2020: Protokol za vzgojo sadik hrasta doba in črne jelše. Drevesnica Omorika d.o.o. 1p.

6. Jakobović H. 2019: Umjetnost uzgoja biljaka iz vode poput Babilonskih vrtova, Hrvatske šume, 271–272, p.38-39.

7. Kraigher H. 2020. Semenarski praktikum (2. prenovljena izdaja). GIS, Ljubljana

8. Mary L. Duryea and Phillip M.Dougherty (ed.) (1990). Forest regeneration manual. Kluwer Academic Publishers, https://rngr.net/publications/forest-regeneration-manual (6.1.2021)

9. Medved et al. 2011. Gospodarjenje z gozdom za lastnike gozdov. Ljubljana: Kmečki glas, 2013. 311 pp.

10. OECD Forest Seed and Plant Scheme. 2018. http://www.oecd.org/agriculture/forest

11. Slovenia Forest Service. 2019. Protocol on the management of forest tree seedlings from excavation in the nursery to their planting in the forest in cases where the seedlings are provided by the Slovenian Forest Service from the budget of the Republic of Slovenia.

12. Steven C. Grossnickle, Yousry A. El-Kassaby (2015). Bareroot versus container stock types: a performance comparison. New forests. DOI 10.1007/s11056-015-9476-6

13. Suszka, Muller, Bonnet-Masimbert (1984). Seeds of forest broadleaves, from harvest to sowing. INRA editions

14. Kraigher H., Brus R., Batič F. (2011). Technical Guidelines for Genetic Conservation and Use: *Alnus glutinosa*, *Alnus incana*, *Alnus.* Gozdarski vestnik, 69: 475-484

15. EUFORGEN. *Populus nigra* identification sheet. http://www.euforgen.org/fileadmin/templates/euforgen.org/upload/Publications/Other_PDFs/Pop_nigra_IdSheets/English.pdf

16. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1981&rid=3

Annex 1: List of forest nurseries producing forest reproductive material for riparian forests of the Mura Drava Danube Biosphere reserve

Country	Name and address	Contact information	Lat., Long.	Altitude [m]	Area [ha]	*Alnus glutinosa*	*Fraxinus angustifolia*	*Fraxinus excelsior*	*Populus nigra*	*Ulmus leavis*	*Ulmus minor*	*Quercus robur*	Other species planted in riparian forests	Remarks
Slovenia	Gozdarstvo Turnišče d.o.o.; Ulica Štefana Kovača 6; SI-9224 Turnišče	mitja.cernela(at)gmail.com +386 (0) 40 33 41 42	46.5876, 16.2038	179	2.8	X			X			X	*Salix alba*	
	Trgovina z lesom, Franc Kreft s.p.; Kutinci 5; SI-9244 Sveti Jurij ob Ščavnici	kreft.franci(at)gmail.com +386 (0) 40 33 41 42	46.5508, 15.9753	271	0.42							X	/	
	Forest nursery Omorika, Koroška street 44, SI-2366 Muta	https://www.omorika.si/ drevesnica(at)omorika.si +386 (0)31 621 643 +386 (0)41 621 643 +386 (0)2 87 69 000 +386 (0)2 87 61 319	46.6000, 15.1527	380	15	X		X	X			X	*Acer pseudoplatanus, Acer campestre, Carpinus betulus, Prunus avium, Prunus padus, Salix alba, Pyrus pyraster, Malus sylvestris*	
	BLS GOZD D.O.O and ARBORIS Janez Kolenko s.p., Polanska ulica 40, Kapca, SI-9220 Lendava	kolenko.j(at)gmail.com +386 (0)41 657 843	46.5910, 16.3638	165	0.6	X			X			X	*Acer pseudoplatanus, Salix alba*	Established in 2018
Croatia	Nursery Limbuš Pridvorje bb 48 362 Kloštar Podravski	www.hrsume.hr sonja.rukavina(at)hrsume.hr www.hrsume.hr +385 (098) 451 521	45.9894, 17.1709	115	15.3	X	X					X	/	
	Nursery Drnje Kolodvorska bb 48 322 Torčec	www.hrsume.hr sonja.rukavina(at)hrsume.hr www.hrsume.hr +385 (098) 451 521	46.2137, 16.8918	128	12.19		X		X			X	*Populus alba, Juglans nigra*	
	Nursery Močile Močile 12 48 000 Koprivnica	www.hrsume.hr sonja.rukavina(at)hrsume.hr www.hrsume.hr +385 (098) 451 521	46.1787, 16.7839	149	11.22							X	/	

	Nursery Zelendvor Ulica grofa Bombellesa 4/d 42 206 Petrijanec	www.hrsume.hr sonja.rukavina(at)hrsume.hr www.hrsume.hr +385 (098) 451 521	46.3346, 16.2014	166	21.65								/	
	Nursery Višnjevac Lugarski put I 31 220 Višnjevac	www.hrsume.hr Helena.Prevoznik(at)hrsume.hr +385 (098) 447 066	45.5727, 18.6134	90	26.16		X		X			X	*Populus alba, Salix alba, Robinia pseudoaccacia*	
Serbia	University of Novi Sad, Institute of Lowland Forestry and Environment, Antona Čehova 13, Novi Sad	www.ilfe.org ilfe(at)uns.ac.rs +381 21 540 383	45.2946, 19.8904	84	0.5		X					X	*Acer pseudoplatanus, Populus alba, Prunus avium,*	Production of FRM for commercial & experimental purposes
	Public Enterprise "Vojvodinašume", Forest Estate "Banat", Maksima Gorkog 24, 26000 Pančevo	www.vojvodinasume.rs/en sdabic(at)vojvodinasume.rs +381 21 431 144	44.7305, 20.9891	68	18							X	hybrid poplars, hybrid willows	State owned
	Public Enterprise "Vojvodinašume", Forest Estate "Sombor", Apatinski put 11, 25000 Sombor	www.vojvodinasume.rs/en sdabic(at)vojvodinasume.rs +381 21 431 145	45.7807, 18.9196	101	21.5		X					X	hybrid poplars, hybrid willows	
	Public Enterprise "Vojvodinašume", Forest Estate "Sremska Mitrovica", Parobrodska 2, 22000 Sremska Mitrovica	www.vojvodinasume.rs/en sdabic(at)vojvodinasume.rs +381 21 431 146	45.0224, 19.2234	77	1.2		X						/	
	Forest nursery "Vikumak"; Vuka Karadžića 9, 23323 Iđoš	http://vikumak.co.rs rasadnikvikumak(at)gmail.com +381 23 065 265	45.8237, 20.3321	76	8			X				X	*Acer pseudoplatanus*	Private, established in 2003
Hungary	Forestry nursery 'Beck Antal' Deák F. u. 8/a., 7756 Borjád,	+36 69 372010 antal.beck(at)gmail.com, info(at)beckcsk.hu http://www.beckcsk.hu	45.9354, 18.4664	110		X	X	X	X	X	X	X	*Acer pseudoplatanus, Acer campestre, Carpinus betulus, Prunus avium, Prunus padus, Salix alba, Pyrus pyraster, Malus s*	
	Ásványráró Nursery	+36 96716844 beliferenc(at)hotmail.com	47.8341, 17.5087	108	17				X				Populus x euramericana, Salix alba	

	Rákóczi u. 6., 9177 Ásványráró													
	Tolna Nursery, Gemenc Forestry Plt. Szent Imre tér 2. 6500 Baja	+36 79324-144 gemenc(at)gemenczrt.hu http://gemenczrt.hu	46.4216, 18.7977	95	28				X				Populus x euramericana, Salix alba	
	Bajti Nursery, Forest Research Institute Várkerület 30/a, 9600 Sárvár	+36 95320070 erti@erti.hu	47.2698, 16.9770	160	65				X				Populus hybrids	
Austria	Forest nursery "Baumschulen Schwanzer Ges.m.b.H";Hauptstrasse 15, 3442 Langenschoenbichl	https://www.baumschule-schwanzer.at office(at)baumschule-schwanzer.at +43 2272 66 1670			17	X		X	X	X		X	*Acer pseudoplatanus, Acer campestre, Carpinus betulus, Malus sylvestris, Prunus avium, Pyrus pyraster, Populus alba, Populus tremula, Populus canadensis* clones, *Salix alba, Salix viminalis, Salix fragilis, Salix purpurea, Salix caprea, Salix cinerea, Tilia cordata, Tilia platyphillos, Robinia pseudoacacia, Robinia pseudoacacia hybride* clones, *Quercus rubra, Juglans nigra*	Established in 1948. Seed of oak were collected in approved Forest Seed Stand Murska šuma, Slovenia
	BFW, Seckendorff-Gudent-Weg 8, 1131 Wien	www.bfw.gv.at T +43 1 878 38						X						State owned

Names and contact details of experts managing stoolbeds, seed and clonal orchards, living archives and gene banks for riparian forests of the MDD BR can be obtained by enquiring at the nursery.

Annex 2: Questionnaire for expert interviews

Place and Date:
Hour start:
Hour end:

The aim of the interview is to obtain information on forest nurseries that supply forest reproductive material (FRM) to the Mura Drava Danube Biosphere reserve in your country. The emphasis is on the production of healthy and high-quality seedlings of forest tree and shrub species and transportation of seedlings to the end user for planting in riparian forests. The interview also aims to obtain information on regulations, national and European development incentives, subsidies, schemes and possible obstacles for the restoration of riparian forests through planting.

Technology of production of forest tree seedlings suitable for use in riparian and floodplain forests in the Mura Drava Danube biosphere reserve in the nursery

Protocol to produce *Alnus glutionosa* seedlings: yes / no
Protocol to produce *Quercus robur* seedlings: yes / no
Protocol to produce *Fraxinus excelsior* seedlings: yes / no
Protocol to produce *Fraxinus angustifolia* seedlings: yes / no
Protocol to produce *Populus nigra* seedlings (cuttings): yes / no
Protocol to produce *Ulmus leavis* seedlings: yes / no
Protocol to produce *Ulmus minor* seedlings: yes / no

INTERVIEW DATA

a. Title, name and surname of the Experts
b. General occupation and the field of expertise of the Expert

GENERAL NURSERY DATA

G1. Short nursery description (max ½ page)

G2. Basic data and general photo of the nursery

a. General data
   1. Company Name
   2. Location (settlement, country)
   3. Year of nursery construction
   4. Year of the start of operations
   5. Ownership structure
   6. Total investment cost (€)
   7. Annual operation cost (maintenance, electricity, people, €)

b. Operations
   a. Harvesting: yes / no
   b. Purchase of seeds of forest trees: yes / no and/or bushes: yes / no
   c. Sale of Seeds of forest species: yes / no and bushy species: yes / no
   d. Own production of forest tree species: yes / no and forest bushes: yes / no
   e. Nursery production: yes / no and sales of horticultural plants: yes / no

c. Capacity
   a. Annual seedling production capacities:
   b. Profit:
   c. Number of full-time employees:
   d. Number of part-time/contract/seasonal workers:
   e. Do you plan to employ new staff (yes, no)? If yes, how many:

G3. Forest nursery description (max. 1 page and up to 5 pictures)

a. What are positive factors in forest nursery production (like quality, healthy seedlings, high success rate, planting success….):
b. What are negative factors in forest nursery production (like bed choice of provenance selection, breeding seedlings in nursery, date of planting, planting technique, staff qualification, seedling transport, manipulation)?
c. Other comments

G4. Brief description of the technology used in your forest nursery production

(for example: facilities, cooling room, seed room, machinery and technical equipment, water pool, pumps, glasshouse, capacities...) & max. 5 photos / pictures

a. Technology used
b. What makes your forest nursery so different from others?
c. What is advantage of your nursery?
d. What is your specialisation in the process?
e. Why is it a Best practice in your case?

G5. Further information

a. Website:
b. Contact person:
c. E-mail*:*
d. Phone*:*
e. Telefax*:*

QUESTIONS

0. What do you think is the importance and role of forest seed and nursery production nowadays?
1. Who represents the forest nursery industry in your country?
2. How many forest nursery producers are there in your country?
3. Are you cooperating with them and how?
4. What are market conditions in your country?
5. What is the trend in forest nursery market in your country vs. international markets in general and more specifically for riparian forest seedlings?
6. What is the state of nursery in your country compared to abroad?
7. What do you produce?
8. Does your nursery produce seedlings from seeds, uses preproduced seedlings or just trades FRM (seed and seedlings)? What is optimal production for you?
9. What forms of planting material do you produce? Bare root production, container (cell) production?
10. What is your domain market? Domestic use and domestic trade or international trade?
11. What are the specifics of the production of riparian forest tree species FRM and the location of the nursery?
12. Can every nursery produce (or grow) everything?
13. What forest tree species do you already grow in your nursery?
14. How many tree species for use in forestry can be grown in your nursery? Is the location of the nursery important? Explain the answer.
15. What are the key elements of nursery management in your case? Explain the answer regarding to the place (is the location of the nursery important), the forest species grown in nursery and the human resources.
16. What is your annual production of seedlings for your main species and for riparian species?
17. What is your seedlings production profile?

18. What about container (cell) grown nursery products?
19. Do container seedlings already exist in your country (or in your nursery) and to what extent?
20. What is your opinion on these seedlings and about the future of such production?
21. What is the proportion of forest tree species for transplanting (use) in riparian lowland forests vs. all other forest tree species grown in your nursery?
22. Please indicate the quantity of seedlings (or proportion) in annual production for each riparian forest tree species produced in your nursery.
23a. Where do you get the appropriate forest reproductive material (seeds, uprooted plants, parts of plants, cuttings) to grow high quality and healthy forest seedlings?
23b. What is your seed and seedlings supply of forest tree species for the restoration of lowland riparian forests for continuously distributed species (like oak (*Quercus robur, Quercus petraea*) and for scattered species (elm (*Ulmus leavis*), ash (*Fraxinus excelsior , Fraxinus angustifolia*), sycamore (*Acer pseudoplatanus*), wild cherry (*Prunus avium*), European black poplar (*Populus nigra*), white willow (*Salix alba*)) in comparison to forest restoration supplies through planting and sowing in the wider area?
24. Does the authority check the collection of seeds in situ?
25. Are these checks free or do you have to pay them?
26. What is the fallout after uprooting forest plants out of the forest soil?
27. What is the success of planting by individual tree species, grown in your nursery?
28. By when are deciduous forest seedlings very sensitive in nursery production – in your opinion? Are there any unknowns how to grow these seedlings in changing climate conditions (according to needs and unpredictable seed years, frosts)? Is their production risky? If YES – how to secure the production?
29. Is it necessary to use herbicides and fungicides in your nursery to ensure forest tree seedlings production for use in restoration of riparian forests?
30. What systemic fungicide is used to distribute it throughout the plant?
31. Is soil pollution high?
32. How do you grow deciduous forest tree seedlings? How to provide a suitable microclimate for growing seedlings in nursery? Do you apply shading?
33. Do you have your own guide for production of forest seedlings in your nursery?
34. How do you provide favourable growth conditions for high quality yields? Soil mixture, disinfection of the substrate, quality of the substrate, sowing seeds, microbial inoculation, maintenance, weed control, irrigation and water management, date of planting, planting technique...
35. Do you fertilize seedlings?
36. How do you measure the success rate in forest nursery and when?
37. How old are trees from the forest nursery production for planting in riparian forest?
38. Do you have problems with assuring enough workers? There is a lot of manual labour: weeding, planting seedlings.
39. How do you secure human resources?
40. Where do you get workers? Do you have problems providing human resources?
41. Who grows seedlings? Young or older people? More female or male workers?
42. What education is needed?

43. Who are mainly manual / labour workers? Country origin, mainly retired people or young unemployed?
44. How costly are human resources for nursery production?
45. What is the cost of machinery vs. human resource?
46. Is it better to invest in machinery or employ more people? What do you recommend?
47. Machine treatment - optical recognition of relevance?
48. What is the cost of machine treatment? High?
49. Excavation machines: to what depth can it be dug?
50. What happens to species that have strong roots?
51. What are developments in technology?
52. In terms of technology, what is the market currently offering?
53. Where are you now in terms of technological development?
54. How much money (financial input) is needed to establish a nursery and to start production for large, medium-sized (transnational and national markets) and small nurseries (for local area)?
55. How much money is required for equipment and human resources?
56. How do you get healthy and quality deciduous seedlings for planting in riparian forests in your nursery related to plant cultivation and maintenance? …including plant seeds: Sorting and drying the seeds? Seed treatment. Stratification. Germination of seeds. Are there any unknowns in production?
57. Where do you plant seedlings (directly in seed beds, in pots)?
58. In what way (or how) are the seedlings extracted from the soil, sorted and prepared for sale?
59. How should the seedlings be dispatched and how (in what way) should they be transported to the customer?
60. How is this taking place in your nursery?
61. What are the needs of seedlings like oak (*Quercus robur, Quercus petraea*) and for scattered distributed species (elm (*Ulmus leavis, Ulmus minor*), ash (*Fraxinus excelsior , Fraxinus angustifolia*), sycamore (*Acer pseudoplatanus*), wild cherry (*Prunus avium*), European black poplar (*Populus nigra*), white willow (*Salix alba*) from end users (large, medium, small; growing / declining) for planting?
62. What is the demand for these tree species on the national market and specifically in the Mura Drava Danube biosphere reserve?
63. What is the demand for your seedlings in the EU market and in the non-EU markets?
64. Has the demand for seed and seedlings of forest tree species in your country increased in recent years?
65. Do you notice a similar trend in demand for seed and seedlings for the restoration of riparian forests?
66. Who are the main stakeholders for purchase of forest seedlings in your country?
Individual forest owners, wood processing industry, Forest Service, Institute for Nature Conservation, …
67. What are forest owner's needs?
68. How many seedlings do the main customers need for planting in forests annually?
1 -10.000, 10.000-50.000, 50.000-100.000, > 100.000?
69. Who are your most important customers?
70. Do you export seedlings? To which countries?

71. Can nurseries in your country quickly adapt to the new unplanned increased need for seedlings and seed on the market and in what way?
72. Does the same apply also to forest reproductive material intended for the restoration of riparian forests?
73. Can seed and seedling stock be increased? For example, by establishing smaller local nurseries to cover regional needs, by increasing the activity of medium and large nurseries, by payment for the risk for growing seedlings in the nursery (unpredictable seed years, frosts…)
74. Is intensive nursery production permitted in protected areas such as Natura 2000?
75. Which way is the trend of nurseries in your country now compared to other countries in the Mura Drava Danube biosphere reserve (Austria - Slovenia – Croatia – Hungary – Serbia)? Producers, traders, users? Climate change issues, investment in new technologies, machinery, financial issues, management production risk.
76. What is the size (area) of nurseries that grow forest reproductive material compared to previous years? Has it increased or decreased?
77. What does a forest nursery need to do in order to be competitive in the current national context and at the same time competitive enough to assert itself and to survive in the wider international market over the long term?
78. What could be forest nursery in the future to serve the end users' needs in general?
79. Where do you see opportunities for developing your nursery in the transnational environment of the project region?
80. What are your advantages?
81. What is your cooperation with research institutions in the field of forest seed and nursery production and what is your cooperation with forestry sector?
82. Are you included in forest management planning? Do you consult with experts when planning production, what are the needs in forestry, what tree species are suitable and why, what are the provenances and what are the wishes of forest owners?
83. How do you ensure that seedlings are not infected and that harmful organisms are not transmitted to the forest (implementation of health care measures and controls)?
84. What is the marketing of forest reproductive material for black alder? How do you prevent the transmission of any contamination of seedlings of this tree species?
85. How is forestry seed and nursery production in your country positioned in the political framework (EU subsidies, state support schemes and incentives for planting material)?
86. What are the effects of the support mechanisms in your opinion?
87. In your opinion, where are the key obstacles to the faster development of forest seed and nursery production in your country?
88. What to improve for smoother nursery production: legislation, market conditions, development grants, financial help (machinery & infrastructure), quality demand?
89. In Slovenia we see the problem of critical mass – the size of the country is small. What is your opinion on this question regarding your own country?
90. What are the benefits of / constraints for cooperation between two countries?

91. Do you agree with the assertion that it is necessary to set up conditions that are directed into own resources and that it is necessary to maximize the effects at home (your own country)?
92. Are current risk prevention measures, incentives and support schemes supporting the development of small size nurseries?
93. What do you think about EU Funds grants?
94. Is there a need for transnational, national and territorial solution to this problem?
95. What needs to be changed? Note: Is there anything that needs to be changed?
96. How should these changes be implemented in practice?
97. Is the state also a problem? Legislation?
98. What kind of waste is generated in nursery production (for example biological waste such as cones and , and non-biological waste such as old plastic and plastic covers of peat, soil and fertilizer packages) and how much of that waste do you produce annually in your nursery?
99. Are unsold forest seedlings a waste for you?
100. Do you consider orientating yourself to new products, such as: intensifying the cultivation of shrub forest species for use in forestry, new business models and integration among nurseries in waste reprocessing?
101. Where and how does the importance of sharing knowledge, education, and research in your work manifest in your work?
102. Do you think that a new agreement is needed to strengthen cooperation and education in the forestry sector in the light of the challenges of the 21st century?
103. What is the perspective of forest nurseries, especially in relation to the challenges posed by climate change?
104. What can you highlight as potential challenges for the future? Perhaps human resource problems (both in ownership and labour work), investment in machineries (this might become a great issue due to HR costs), adaptation of new technologies due to financial and climate change issues, prolonging the planting season,…)
106. What is the interest of young people in the nursery professions? Is education appropriate in this area?
105. Where would you rank your nursery by development technologies (smart or traditional, machinery development, new producing methods (bare roots, containers…) compared to European nurseries?
106. What are the opportunities for restoration of riparian forests by planting in the Mura - Drava - Danube Biosphere Reserve?
107. Do afforestation grants influence prices in the nursery market in your country in your opinion? If so, on what scale?
108. Growing forest shrub species in nurseries. Today and tomorrow?
109. Anything else?
110. Did I (interviewer) forget anything?