Science for resilient livelihoods in dry areas

R4D INITIATIVE

© Mounir Louhaichi (ICARDA)

SUMMARY

This research-for-development guide serves as a practical and comprehensive resource on seeds and seedlings management techniques essential for the success of rehabilitation projects in dryland ecosystems. It delves into critical practices such as seed collection, storage, and processing, emphasizing the need to preserve genetic diversity and viability. Key topics includeseed collection, storage, and processing, emphasizing methods to preserve seed viability and optimizing germination potential.

The document also covers detailed guidelines for nursery establishment, including site selection, infrastructure setup, and management practices designed to produce healthy seedlings.

Special attention is given to the critical role of seed quality testing and techniques for breaking seed dormancy, which are essential for improving germination rates and promoting robust seedling development.

Additionally, the authors discuss various types of nursery stock, highlighting the importance of selecting the right stock type based on project objectives and environmental conditions. They stress the need to maintain a balance between root and shoot growth to enhance seedling survival and adaptability in arid and semi-arid regions. The content is designed to support practitioners in implementing effective and science-based strategies for ecological restoration in drylands.

PASTORAL SEED & SEEDLING MANAGEMENT

Azaiez Ouled Belgacem
Mounir Louhaichi
(ICARDA - TUNISIA)

2024

CONTENTS

CGIAR

A CGIAR Research Center

cgiar.org

1. INTRODUCTION

The native plants of dry areas are experiencing renewed interest because of their potential for environmental and economic purposes and their capacity for adaptation to climate change. However, the continued diminution of the density of these plants and the unavailability of seeds, due to the lack of knowledge for their handling and conditions of germination make any possibility of their valorization for rangeland rehabilitation, aromatic and medicinal, honey, ornamental, water and soil conservation, dunes fixation.

Rangeland rehabilitation projects and programs require adequate shrub and tree seeds and seedlings and call for capacity for seed collection, processing, storage, transportation, and production lof healthy seedings. This is important because quality seeds and seedlings are the foundation of rehabilitation programs, determining successful post-planting survival and development.

Seedling quality is a significant aspect to be considered for rehabilitation programs, as it will highly influence post-planting survival and plant development (Davis & Pinto, 2021)

BOTH SEEDLINGS AND SEEDS MIGHT BE USED IN COMBINATION WITH SOIL PREPARATION AND WATER HARVESTING MEASURES *(Ouled Belgacem, 2021a,b).*

Figure 1: Pastoratum for aromatic and medicinal plants

© Mounir Louhaichi (ICARDA)

2. SEED MANAGEMENT

Various plant seeds, cuttings, tubers, and spores are used to propagate seedlings. Seeds are the most used propagation material in native species nurseries in drylands. Furthermore, seeds can be used to rehabilitate some degraded areas. This chapter will focus on aspects required for proper seed management, which is crucial to provide quality seeds suitable to support successful nursery and seed-based rehabilitation programs.

2.1. SEED COLLECTION

Local seeds sourced from the wild are preferred for seedling development, as they have adapted to environmental conditions and have the genetic makeup required to adapt to harsh environmental conditions. While collecting seeds, it is important to ensure they are collected from as many mother plants as possible to ensure a good representation of the genetic pool and conserve the diverse plant population.

SIMILAR AMOUNTS OF SEEDS SHOULD BE COLLECTED FROM 50 PLANTS OR MORE. COLLECTED SEEDS SHOULD NOT EXCEED 20% OF AVAILABLE SEEDS, AND SHOULD BE MUCH LESS IN CASE OF ENDANGERED SPECIES OR RESTRICTED POPULATIONS

(Penfield, 2017).

If local seed sources are limited, seeds can be collected from habitats like the one to be restored. Alternatively, seed orchards can be established to ensure sustainable production of good quality seeds of desired species. Nevertheless, care should be taken to use enough mother trees to ensure a good representation of the species' genetic makeup. Sourced mother trees should be healthy and vigorous.Seeds vary in shape and size and differ in dispersing mechanisms. Knowledge regarding species flowering and ripening seasons, seed type, and dispersal mechanism helps in developing a proper approach for seed collection and required management (Dumroese et al., 2009; Penfield, 2017). For example, cones and dehiscent (open-to-disperse seeds) fruits should be collected before they start seed dispersal. Seeds are collected by hand picking, cutting fruit, clipping branches, shaking branches over a canvas tarp or blanket, orenclosing developing fruit or cones in a bag or cage.

Various tools and equipment can be used to facilitate seed collection. Seeds found on the ground or in animal caches should not be collected.Dry fruits, cones, and seeds should be handled with care after collection and can be stored in paper and cotton bags for a short time in a shadowed dry place until they are processed to extract seeds. Fleshy fruits should be kept in a fridge until they are being processed (Penfield, 2017).

Seed health and maturity should be assessed to ensure they are not damaged or affected by pests. Seed maturity should be inspected by cutting seeds along their longest axis. Immature seeds are mostly identified by their soft seed coat and watery internal tissue. Mature seeds are characterized by a solid seed coat and firm milky internal tissue (Kildisheva et al., 2020).

Collected seed lots should be kept separate until they are inspected to avoid cross-contamination of lots with weed seeds or pathogens. Seed lots should be properly labeled with species, collection date, location, habitat, collector, and other details deemed relevant (OSU et al., 2020d).

2.2. SEED EXTRACTION AND CLEANING

This operation depends on the fruit type (Dumroese et al., 2009; Penfield, 2017):

- **Fleshy fruits** should be soaked in warm water and squeezed to release the seeds. Seeds are then washed with running water and allowed to dry before undergoing further processing.
- **Cones and dehiscent seeds** can be placed in shadowed seed collection beds over a sieve and dispersed seeds are collected in a canvas blanket.
- **Collected seeds** can be placed in paper or cotton bags and crushed, then poured in front of a fan. Filled seeds fall closest to the fan. A mixture of filled seeds, empty seeds, and debris falls after. Empty seeds and debris fall farthest from the fan.

2.3. SEED QUALITY TESTING

Seeds are inspected to assess their quality and identify needs for certain treatments to enhance seed germination. This is important to (1) determine their sustainability for planting, (2) identify the problems and probable causes, (3) determine if seeds meet established quality standards or labeling specifications, (4) establish quality, (5) provide a basis for price and consumer discrimination among lots in the market, and (5) determine the need for drying or processing.

• **Purity**: This is the first aspect to be tested in a seed lot. This investigation seeks to determine the number of pure seeds in a seed lot, indicated as pure seed units (PSU). PSU is expressed as the weight percentage of a seed lot. A seed lot also contains debris, seeds of other species, and damaged seeds (Pedrini & Dixon, 2020).

• **Viability:** Refers to the number of seeds that have the potential to germinate and develop into seedlings and is indicated as viable seed units (VSU).
Common viability tests include:
Cut test: Seeds are cut along the longest seed access and seed tissue is visually examined. Watery and soft tissue indicates immature seeds. Damaged, infected, and abnormal seeds are not considered viable. Mature seeds are recognized by milky and firm seed tissue (Frischie et al., 2020; Penfield, 2017; Pedrini & Dixon, 2020). This is an indicative but not a conclusive viability test, so it should be combined with other viability tests.
X-ray test: Seeds are inspected using X-ray imagery. Seeds that appear healthy and intact are considered viable. This non-destructive procedure allows using seeds for other tests (Frischie et al., 2020; Pedrini & Dixon, 2020).
Tetrazolium test: This reliable and widely used test depends on the ability of living tissue to reduce a colorless chemical (2, 3, 5 triphenyl tetrazolium chloride or bromide) into a red-colored insoluble compound, triphenyl formaza. The test is a bit time-consuming and requires experience in seed morphology to assess staining topography to determine seed viability (Frischie et al., 2020; Pedrini & Dixon, 2020).

Germinability: Is used to assess the percentage of seeds able to develop into seedlings. This can be done by conducting a germination test. However, the seeds need to be able to absorb water to germinate. For that, an imbibition test is conducted to assess the seeds ability to absorb water and conduct a gravimetric assessment of seed weight (Penfield, 2017).
Imbibition test: the test determines the seeds' ability to absorb water, which is a prerequisite for seed germination. The test can be conducted by taking a 100-400 seed sample and dividing it into four similar subsamples. Weigh each sample, then place them in a mesh bag under running tap water. After 48 hours the seeds are taken, dried, and weighed again (Davis et al., 2014; Penfield, 2017). The change in seed weight will indicate if seeds were able to absorb water.
Germination test: This test is essential to determine the number of seeds to be sown in each container during the sowing season. A sample of 100–400 seeds is collected and divided into four equal portions. Each portion is placed over a 1 cm thick pad of moist tissue paper in a dry plastic container and covered by a transparent plastic lid. The seeds should be placed in a warm place around 21–23° C and kept moist. Direct sunlight should be avoided. Germinated seeds should be inspected for up to one month and observations documented every 1–5 days. Germinability is based on the number of germinating seeds compared to the total number of seeds (Penfield, 2017; Pedrini & Dixon, 2020).
The Germinable Seed Unit (GSU) indicates the number of seeds able to develop into seedlings. However, if dormancy-breaking procedures are not fully understood, the germination test might underestimate the number of viable seeds (Pedrini & Dixon, 2020). The Dormant Seed Unit (DSU) can be calculated based on the viability and germination test results. Viable seeds that fail to germinate (dormant seeds) within one month under good germination conditions will need to be pre-treated before sowing.

2. SEED MANAGEMENT

A schematic overview of seed quality testing is presented in Figure 2.

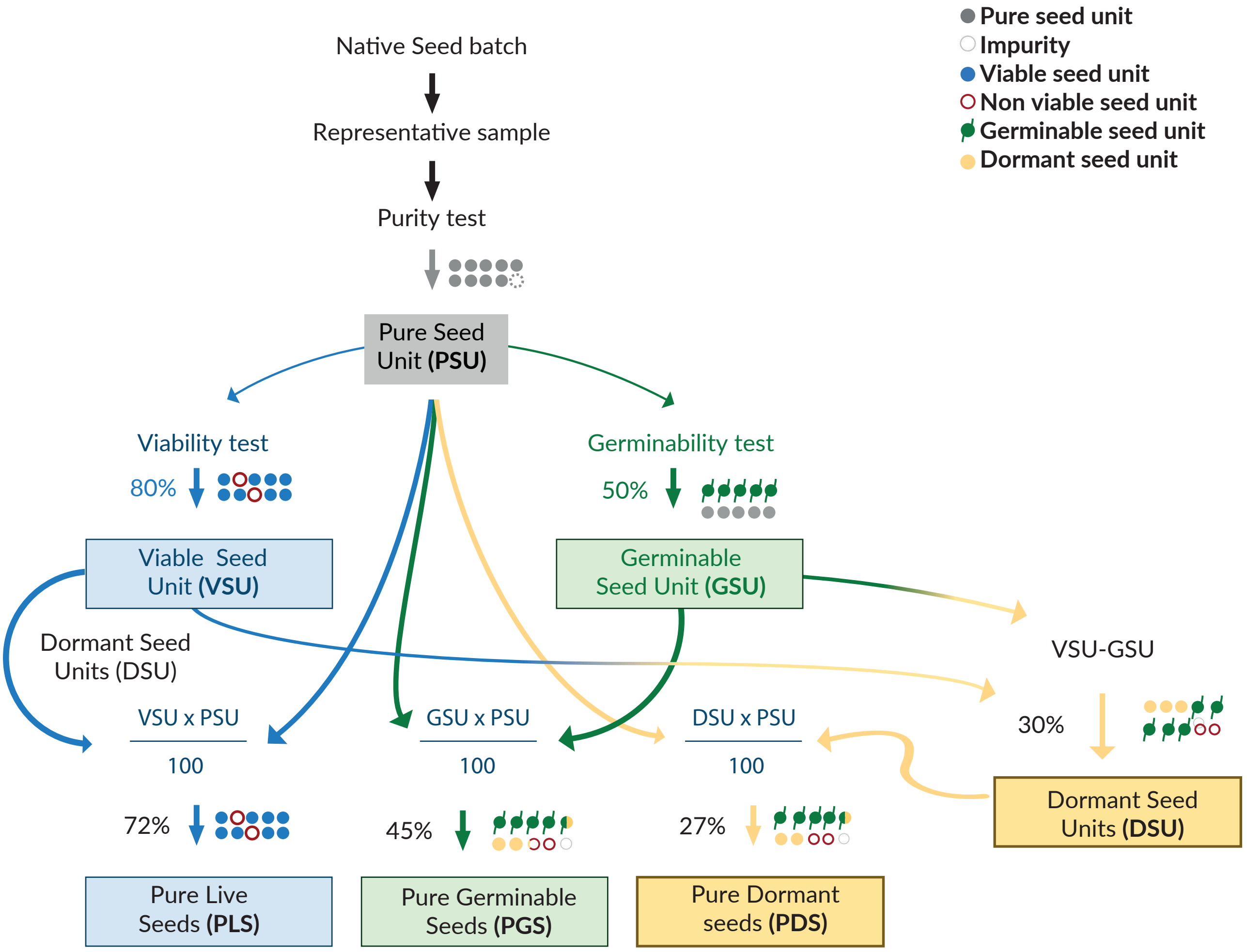

Figure 2: Seed quality testing *Source: Pedrini & Dixon, 2020.*

Notes: *A pure seed unit (PSU) indicates the number of pure seeds in a sample and is composed of Viable Seed Units (VSU) and Germinable Seed Units (GSU). The Dormant Seed Unit (DSU) describes the difference between viable and germinable seeds. Pure live seeds, Pure Germinable Seeds, and Pure Dormant Seeds (PDS) are calculated to represent fractions of viable, germinable, and dormant seeds of a certain lot*

2. 4. SEED DORMANCY

Seed dormancy is the state in which the seed will not germinate even in ideal conditions before protective barriers are broken down. Many seeds have developed these protective barriers to endure unfavorable conditions and prevent them from being killed off by weather. Seed dormancy can aid plant survival in the wild but can be a hindrance to those who want to propagate plants from seeds at home.

Dormancy is caused by physical impediments such as the seed coat being too hard or the waxy layer keeping water from penetrating. In nature, this can be remedied by animal digestion, microorganisms, or freezing and thawing.

Seed viability is important as it reflects the number of seeds that have the potential to germinate. Viable seeds of many native species undergo physical, physiological, or combinational dormancy (Kildisheva et al., 2020; Penfield, 2017). Dormancy is a mechanism developed by plants to prevent germination during unsuitable conditions. Dormant seeds are viable but not readily germinable and require treatment to enhance their germination. Common treatments are scarification and stratification. Stratification uses temperature to break dormancy, while scarification uses mechanical, chemical, or thermal means to break down a hard seed coat that is impervious to water.

Knowing the dormancy type helps develop a suitable mechanism to overcome it and improve germination (Kildisheva et al., 2020; Penfield, 2017).

In general,dormancy can be broken using:

- **Scarification:** the process in which a seed's hardcoat is broken down to allow water to penetrate and the seed to germinate. Breaking dormancy can be manual (such as removal of bracteoles of Chenopodiaceae) using chemical, mechanical, or thermal means. These treatments aim to improve water absorption by weakening the seed coat. This can be conducted by using filing, nicking, sanding, or soaking seeds in hot water or a solution of sulfuric acid.
- **Stratification:** the process in which a seed is exposed to moist, cold, or warm conditions. It can be conducted by placing seeds in a well-covered mesh bag surrounded by a moist growing medium in a plastic container. The container is tightly covered by a plastic cover. Allow air circulation by making several small holes in the plastic cover. The container is placed in a fridge at 1–5° C for cold stratification, or 20–30° C in a cabinet or incubator for warm stratification. Some species might require treatment with both types of stratification. The time required for seed stratification varies among species. Stratified seeds should be investigated every two weeks and rinsed with running water if needed. I If mold starts to form, anti-fungal agents can be used after washing seeds.

As species vary in the type of treatment required, and the required dormancy breaking might not be known, some trials can be conducted, Figure 3 illustrates dormancy-breaking treatments.

HOW TO BREAK DORMANCY

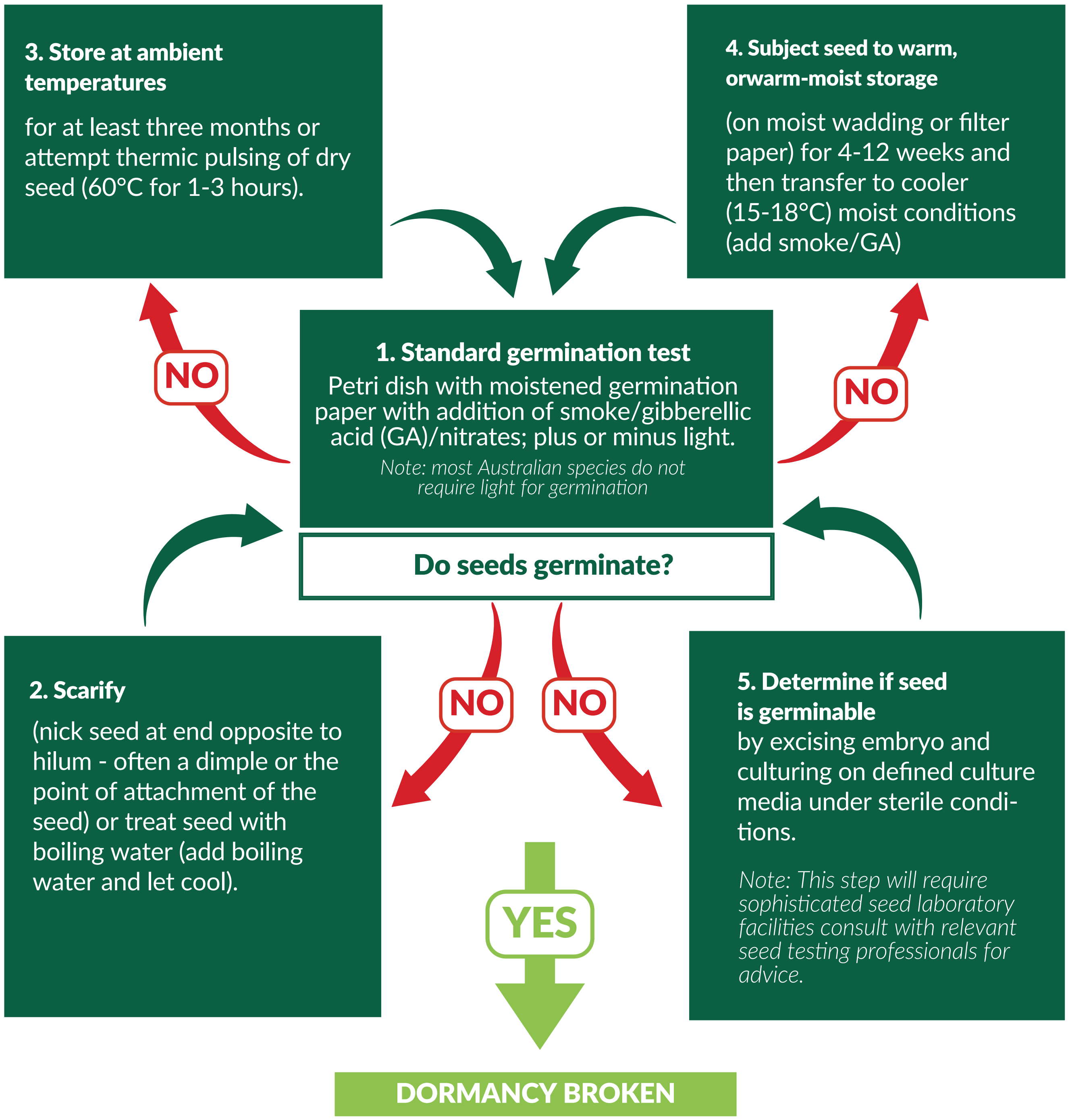

Figure 3: Breaking seed dormancy with a series of trials

Source: Pedrini & Dixon, 2020.

2. SEED MANAGEMENT

2.5. SEED STORAGE

Based on their physiological attributes, seeds can be classified as recalcitrant or orthodox. Knowing seed type will facilitate proper handling. Recalcitrant seeds cannot be dried to a moisture content below 20–30% without injury, but they can be kept for a short time under cool temperatures in moist and well-aerated environments. Orthodox seeds tolerate drying and if stored in dry and cool environments, seeds with low internal moisture content remain viable for years. Before storage, orthodox seeds should be dried under conditions of 15° C and 15% relative humidity for 2–4 weeks (Penfield, 2017; Wilkinson et al., 2014).

To prepare seeds for storage, they are usually placed in shallow trays or air-permeable bags and shacked frequently to allow for even drying. The exact time for drying a seed lot depends on seed size and lot volume (Penfield, 2017). Once ready, seeds are stored in labeled, air-tight, durable containers or bags. Seeds are periodically checked for signs of mold or discoloration Penfield, 2017). Desiccants can be used to facilitate seed drying. Some desiccants, such as silica gel, can be used as humidity indicators (Vitis et al., 2020).

2.6. SEED DISTRIBUTION

Seed distribution is based on the needs of projects to propagate seedlings or for direct use in rehabilitation programs. Ideally, gene banks will collect and store seeds to meet national seedling propagation and rehabilitation plans. Therefore, required quantities of seeds of desirable species suitable to the locations to be restored are collected, processed, and their quality tested before being stored for later use (Cross et al., 2020). These seeds are distributed as needed by various projects (Figure 4).

In certain cases, seeds need pre-treatment to alleviate dormancy in viable seeds (Kildisheva et al., 2020). Recently, seed enhancement protocols have been applied to the seeds of native species. These technologies are adapted from the industrial seed industry to overcome logistical and ecological barriers in restoration. Seed enhancement technologies are used to enhance and synchronize germination and improve seed vigor, seedling emergence, and establishment.

Figure 4: Native seed supply chain *Source: Cross et al., 2020.*

3. NURSERIES

3.1. GENERAL CONSIDERATIONS

Nurseries are facilities established to propagate seedlings of desirable plant species (Krishnan et al., 2014). The main objective is to rehabilitate degraded ecosystems. Other aspects are considered as well, such as propagating seedlings for forage production, landscaping, and beekeeping. Nurseries management practices will differ according to the objectives for their establishment (Carsan and Munjuga, 2020).

Nurseries can be classified into permanent nurseries (established for long-term seedling production) which have a well-established infrastructure, allocated staff, and annual production plans. Temporary nurseries are established for short-term seedling production or to store seedlings in other nurseries until they are planted. Temporary nurseries have basic infrastructure and minimal labor (Alnsour, 2016).

An important aspect to be considered is the nursery size, which is influenced by seedling production needs and demand from nearby communities and development projects. Nurseries located near major urban settlements, main roads, and development projects are usually larger than those in remote areas with limited accessibility and located near small communities.

Nurseries producing **more than 100,000** seedlings are considered **'large' nurseries,** while those producing **less than 100,000** seedlings are classified as **small nurseries**

(Alnsour, 2016).

Nurseries can also be classified according to their propagation approach, such as container seedlings, bare root seedlings, or nurseries dedicated to germinating seeds. Some nurseries propagate seedlings in the open air, while others propagate them under controlled environments such as greenhouses (Carsan and Munjuga, 2020).

3.2. NURSERY ESTABLISHMENT

3.2.1. NURSERY LOCATION

Some aspects to be considered for selecting a nursery location include (Alnsour, 2016; Dharmasena, 2016):

- Availability of adequate water supply in terms of quality and quantity. This might be a running water stream, an artesian well, or a suitable nonconventional water source (e.g., treated wastewater, harvested atmospheric water ...).
- Availability of nearby sources for growing media (natural or commercial).
- Protection from floods.
- Protection from storms and wind through topographic formations (hills, mountains) or windbreaks comprised of fast-growing tree species.
- Proximity to transport networks.
- Availability of local labor.

3.2.1.1. WATER SOURCE AND QUALITY

The availability of sufficient high-quality water is among the most important considerations for establishing a nursery (Penfield, 2017; Dharmasena, 2016). Salt concentration, pathogens, weed seeds, and other contaminants can affect water quality and its suitability for irrigation. These contaminants can cause challenging problems for nursery management and affect seedling quality. In some cases, filters can be used to remove contaminants according to their size. Various filter types, such as granular or surface filters, should be installed before the irrigation lines (Penfield, 2017).

3.2.2. NURSERY DESIGN

One section of the infrastructure to be considered when preparing for nursery establishment includes buildings, such as offices, warehouses, workers' rooms, and service facilities. The second part is a working area to prepare planting media and store soil, sand, organic fertilizer and building materials. This area should be relatively far from the buildings and seedling propagation sections. The third section is the seedling production site, where production beds or greenhouses are established. The nursery should also have good service roads (Alnsour, 2016; Krishnan et al., 2014) and contain all the required facilities to achieve its objectives. An example of a native species nursery design is presented in Figure 5.

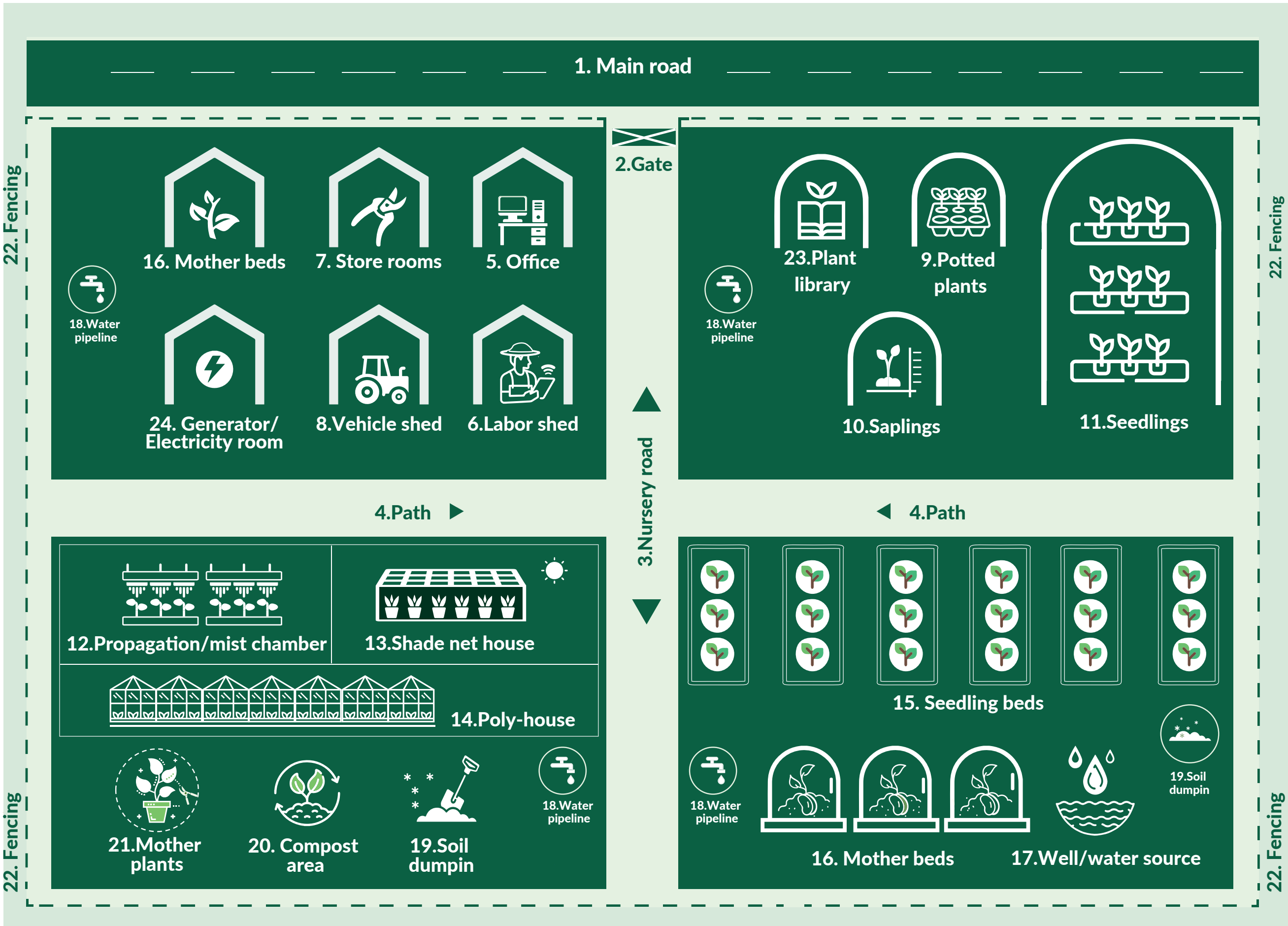

Figure 5: Example nursery design

Source: Alnsour, 2021.

Notes: 1: Main road, 2: Gate, 3: Nursery road, 4: Path, 5: Office, 6: Labor shed, 7: Store rooms, 8: Vehicle shed, 9: Potted plants, 10: Saplings, 11: Seedlings, 12: Propagation/mist chamber, 13: Shade net house, 14: Poly-house, 15: Seedling beds, 16: Mother beds, 17: Well/water source, 18: Water pipeline, 19: Soil dumping, 20: Compost area, 21: Mother plants, 22: Fencing, 23: Plant library, 24: Generator/Electricity room

3.2.2.1. SEEDLING PRODUCTION BEDS

Seedling production beds are used to organize propagated seedlings during the growing season and should be organized to facilitate effective handling.

They can be established directly over the nursery ground, where seedlings are staked over the soil directly, over a plastic sheet or concrete pad. Seedlings can be also organized within a defined boundary made of stacks connected by robes or wires.

Frequently used bed boundaries are constructed from concrete and cement blocks either on or below ground level (Figure 6). Some aspects that should be considered when designing concrete seedling production beds are (Alnsour, 2016):

- The width of the beds is usually around 1 m but can vary in length.
- The bed can be dug into the ground or surrounded by cement blocks 15–20 cm high. It might be better to establish the beds at ground level and delimit them with ropes and wires to allow good aeration and water drainage.
- The ground is covered in concrete, plastic, or gravel to reduce weed growth. Using permeable plastic sheets improves water infiltration and prevents weed growth.
- The beds are designed with a slight slope and good water drainage to avoid water accumulation in the beds, which helps reduce weed growth and pathogen infestation.

© Azaiez O. Belgacem (ICARDA)

Figure 6: Seedling production beds
Source: pastoral and forest nursery in Kairouan, Tunisia

3.2.2.2. GREENHOUSES:

Greenhouses provide a controlled propagation environment. Sometimes, plastic covers and shading nets are installed to provide a controlled environment during winter (Figure 7). Care should be taken not to overshade a seedling propagation space, as this will affect seedling development and quality. Changing one aspect of the growing environment might require changes in other aspects. Thus, if some aspects of the propagation methodology change, the whole process should be revised and combined with close monitoring of the growing season and seedling quality (Carsan and Munjuga, 2020).

© Azaiez O. Belgacem (ICARDA)

Figure 7:

Greenhouses can be covered by high-degree (70–80%) shade nets

Plastic sheets and shade nets installed

3.3. SEEDLINGS PRODUCTION

Seedling quality can be determined by their appearance in the nursery and by attributes related to plant survival and growth after being planted in nature (Davis & Pinto, 2021). Plant quality depends on two factors; genetic characteristics and propagation environment (Davis & Pinto, 2021; Dharmasena, 2016). Propagating quality seedlings depends on implementing key tasks during the growing season (Krishnan et al., 2014). Most of these tasks are ordered chronologically through the growing season (Alnsour, 2016) and some of them are conducted in parallel. The cycle for propagating quality seedlings is summarized in the next section.

3.3.1. PREPARATION PHASE

The preparation phase is key for a successful sowing season and starts 4–6 months before sowing. It includes these tasks:

- Develop the nursery production plan including total production, species, number of seedlings per species, and characteristics of propagated seedlings.
- Design the nursery and document staff and workers' responsibilities.
- Procure the required propagation material (e.g., seeds, cuttings) in abundance. Seed viability and germination tests can be conducted at this phase to assess needs.
- Identify growing media and other supplies. Allow enough time for the procurement process, especially for imported goods.
- Prepare the nursery structures, irrigation system, and nursery grounds.
- Conduct a technical refresher and planning session to discuss the new season's production plan with nursery staff and workers, including the plan for media mixing, container filling and sowing, and irrigation management.
- Identify and conduct the required seed pre-treatment procedures.

3.3.2. MEDIA MIX PREPARATION

The media mix is the growing medium for the propagated seedlings. In general, any media mix should provide four main functions for propagated seedlings:

- Seedling support.
- Supply water.
- Provide aeration.
- Supply nutrients.

The media should provide suitable conditions for optimal macro and micronutrient absorption a balanced organic material content to ensure good water-holding capacity, and good aeration to avoid anoxia. The media should have a pH value ranging between 5.5 to 6.5 (Davis et al., 2014; Dharmasena, 2016) .

Electrical conductivity (EC) is used as a measure of salinity and as an indicator for fertilizer release and nutrient availability and uptake from the growing medium. The optimal EC value varies according to species and plant growth phase. In general, EC values range between 1–2.5 mS/cm at early growing stages, while well-established seedlings grow well up to 4.6 mS/cm.

Traditionally, media is composed of locally available materials such as soil, sand, and fermented organic fertilizer. The common ratio in the Near East North Africa region is equal volumes of soil, sand, and organic fertilizer. In some cases, these ratios can be changed to obtain the required physical structure and desired chemical characteristics to support specific seedling propagation needs (Al-Ghamdi et al., 2020; Alnsour, 2016).

Media components, especially soil, are refined using a 0.5–2 cm grid sieve. This ensures consistent and suitable media particles, reduces air pocket formation, and improves root system development. Commercial media components can also be used to develop an improved consistent media that can be reliably replicated in different locations and over the years. Such media can be composed of equal amounts of peat moss and cocopeat (fermented coconut husks) and amended with controlled-release fertilizers and hydrogel. The media is topped with a mulching layer of perlite to protect sown seeds from animal predation and reduce water evaporation (Carsan and Munjuga, 2020).

3.3.2.1. NUTRIENTS AND FERTILIZATION

Plants require 13 nutrients for good growth. These elements are divided into six macronutrients required in greater amounts compared to the other seven. Macronutrients are Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). Micronutrients are boron (B), manganese (Mn), iron (Fe), zinc (Zn), molybdenum (Mo), copper (Cu), and chloride (Cl) (Dumroese et al., 2012). Various organic and synthetic fertilizers are available. Organic fertilizers are traditionally used, but their nutrient content varies according to their source and is largely inconsistent across seasons. Chemical fertilizers are available in various compositions and are used to provide the required nutrients. Unlike common readily soluble chemical fertilizers, controlled-release fertilizers provide nutrients throughout the growing season. For controlled-release fertilizers, their release is controlled by coat type, temperature, and water.

3.3.3. CONTAINERS AND CONTAINER FILLING

The most common type of containers are polyethylene bags. They are mass-produced in the market and can be found in various sizes. However, they do not support healthy root system formation (Haase et al., 2021). Once roots reach the bag bottom, they start swirling within the bag and eventually result in root plugging (Dharmasena, 2016; Khurram et al., 2016). Polybags also limit the development of root tips, are generally only once, and contribute to considerable environmental pollution (FAO, 2021).

Traditional polybags are filled manually using simple tools. It is preferable to leave around 2 cm at the top for collecting water. Other containers are also manually filled and some machines have been developed to automatically fill some container types (Krishnan et al., 2014). Other types of containers can improve seedling development (Khurram et al., 2016; Wilkinson et al., 2014). For example, Deepot containers produced by Steuwe and Sons are reusable for many seasons.

3.3.4. SOWING CONTAINERS

The number of sown seeds in a container depends on seed germination test results. The aim is to ensure that each container will have at least one germinating seed. Generally, 90–95% filled containers is a reasonable rate (Dumroese et al., 2009). If seeds are available, the number of sown seeds can be increased to enhance the percentage of containers with germinating seeds. However, sowing too many seeds should be avoided.

The timing of sowing is a crucial aspect to consider, as it greatly affects seed germination. It is best to sow seeds under ambient weather conditions in early winter (October–November) or in spring (February–March). Suitable time selection is based on the species and preferred seedling age at the time of planting. For example, fast-growing species should be propagated for around 8–9 months and sown in the spring. Slow-growing species developing slowly might be sown earlier in winter and can be propagated for 10–12 months (Wilkinson et al., 2014).

Only one seedling should be propagated in each container. If multiple seeds are germinating in the same container, seedlings at around 5 cm high are thinned out to improve quality (Dumroese et al., 2009). Thinned seedlings can be transplanted into other containers.

3.3.5. VEGETATIVE PROPAGATION

This is a useful technique for species for which collecting or handling seeds is difficult, with limited availability of viable seeds, nursery stock is needed in a short time, an individual, unique plant needs to be propagated, or specific genotypes are desired.

Stem and shoot cuttings are divided according to collection date; softwood cuttings are composed of soft tissue that can be bent and collected in late spring and early summer, semi-hardwood cuttings are collected in late summer and early fall after softwood maturation. Hardwood cuttings are collected after tissue further matures in the late fall and can be collected in winter (Wilkinson et al., 2014). Hardwoods are the easiest and cheapest type of cuttings (Dharmasena, 2016; FAO, 1992). Some considerations for collecting hardwood cuttings are:

- Should be less than one year old.
- 15–25 cm long and 10–20 mm diameter.
- A cutting should have at least 2 buds, but better to have 3-5.
- Cut the top of the cutting straight 2 cm above the upper bud and make an angle in the lower part. This helps in positioning the cutting.
- Remove leaves and side branches.
- Cuttings should be planted in well-drained soils and containers.

Cuttings are planted to propagate new plants. Some general guidance for using cuttings are (Dharmasena, 2016; Wilkinson et al., 2014):

- Keep tools and working space clean.
- Wear protective clothing and gloves if chemicals and hormones are used
- Some species might require cutting wounding to improve growth
- Dip the cutting in hormone powder or a solution to enhance the rooting
- Maintain polarity of all planted cuttings
- At least two buds are covered with the growing medium
- Cuttings are planted in well-drained soils and containers
- Pack growing media well around planted cuttings to remove air pockets

3.3.6. NURSERY STOCK TYPE

Nursery stock is a term used to describe seedling size and type, which is an important aspect to be considered. The stock type will determine the required resources, nursery management, and practices during the season (Davis & Pinto, 2021; Dumroese et al., 2016). Seedlings propagated to rehabilitate degraded dryland ecosystems should have balanced root and shoot growth. This will ensure the optimal use of water resources.

Seedling growth can be controlled by regulating growing conditions such as temperature, water, and fertilizer. Thus, management practices are modified according to plant development, while taking the size of the required seedlings as a reference. Most rangeland shrubs can be pruned to control their growth. However, some species such as gymnosperms, cannot be pruned (Davis et al., 2014). In these cases, their development should be regulated through adaptive management practices throughout the season. Proper management practices also focus on distributing resources for balanced seedling development.

Management practices help reallocate nutrients to lower leaves, stems, and root systems. Management practices will also prepare seedlings for the planting season. Some aspects, such as seedling height, stem diameter, root volume, and formation need to be considered to assess seedling development and quality (Landis, 2011).

3.3.7. IRRIGATION MANAGEMENT

Careful scheduling of irrigation might be one of the most important, yet challenging tasks for nursery managers. The process depends on replacing the amount of lost water, either consumed by plants or evaporated. Among the many irrigation systems used in nurseries are hand, drip, submerge, boom, overhead, and sprinkler irrigation systems (Dumroese et al., 2009). An effective system is characterized by uniform application, the ability for precise scheduling, and water conservation.

Irrigation scheduling varies with seedling development. For example, at the early sowing stage until germination, seedlings are irrigated with frequent showers to moisten the area surrounding the seeds 2–5 cm of the upper layer of the media mix). Thus, improves germination, and reduces water consumption and the probability of pest infestation and damping off. During the active growth stage, seedlings are irrigated according to weight. Based on species, seedlings are irrigated at 80–85% of the saturation weight. During the hardening stage, irrigation frequency not amount is decreased gradually and based on the species, irrigation can be reduced from 80–85% to 55–60% of saturation weight.

If automatic irrigation systems are used, zoning is helpful. Zoning means that seedlings with similar irrigation needs are grouped in the greenhouse. Zoning allows for the flexibility to irrigate seedlings differently and is based on species, development stage, and container size.

3.3.8. PEST MANAGEMENT

During their propagation, plants can suffer from abiotic and biotic stresses. Abiotic stress is caused by adverse environmental and propagation conditions. Biotic stress is caused by a wide array of bacteria, fungi, viruses, weeds, snails, and rodents (Dharmasena, 2016). Plant biotic diseases evolve because of the interaction of host suitability, a conducive environment, and pathogens. Abiotic stress results from the interaction between the host and the environment. Water management is crucial to developing healthy seedlings and avoiding a conducive environment for pathogen infestation (Dharmasena, 2016; Wilkinson et al., 2014).
Plant conditions should be monitored continuously for any symptoms of disease and plant protection specialists should be consulted as needed. Biopesticides can be used to treat initial or slight infections. In certain cases, specialized pesticides are used to avoid losses caused by pathogen infestation. Specialized pesticides and their application methodology should only be prescribed by plant protection experts.

3. 4. TRANSPORTING SEEDLINGS

Seedling transportation is important to avoid damage or stress and to ensure the best seedling quality to support rehabilitation or planting programs. Nursery considerations for seedling transportation include:

- Hardening seedlings to prepare them for planting in nature.
- Inventory of propagated seedlings, including number, species, and stock type.
- Inspecting propagated seedlings, including damaged, infected or under-developed seedlings.
- Documenting seedling inventory and inspection. This should be counter-signed by the nursery manager and the client (restoration practitioner) for transported seedlings.
- Loading trucks.
    - Loading trucks using boxes or trays.
    - Transport seedlings in the early morning or evening.
    - Seedlings are staked upright and not be piled over each other.
    - Use refrigerated or closed trucks.


Periploca angustifolia


Retama raetam


Ceratonia siliqua


Atriplex halimus


Hedysarum coronarium


Anthyllis henoniana


Thymbra capitata


Medicago arborea


Haloxylon aphyllum

4. REFERENCES

Al-Ghamdi, A.A., Tadesse, Y., Adgaba, N. 2020. Evaluation of major Acacia species in the nursery towards apicultural landscape restoration around Southwestern Saudi Arabia. Saudi Journal of Biological Sciences, 3389–3385 ,(12)27.

AOAD. 2020. Review Of Regional and Global Policies in Support Of SRM, Especially LDN and Opportunities for Leveraging Further Funds for SRM Initiatives in the Arab Region. AOAD-IUCN SRM Policy Review final.pdf

Carsan, S., Munjuga, M. 2020. Tree Nursery Management Guide for Land. Restoration Planners. ICRAF, Nairobi, Kenya. 38pp.

Cross, A.T., Pedrini, S., Dixon, K.W. 2020. Foreword: International Standards for Native Seeds in Ecological Restoration. Restoration Ecology. 218–216 ,(28)28.

Davis, A., Kildisheva, O., Aghai, M. 2014. A guide to container seedling production. Lebanon Reforestation Initiative: Beirut, Lebanon. https://api.lri-lb.org/Content/uploads/resource-publications/A-Guide-to-container-Seedling-Production.pdf

Davis, A., Pinto, J. 2021. The scientific basis of the target plant concept: An overview. Forests. 13–1 ,(9)12.

Dharmasena, P. 2016. Nursery Management: Handbook for Beginners. https://www.studocu.id/id/document/universitas-bengkulu/management-nursery/nursery-management-handbook-for-beginner/47824604

Dumroese, K., Luna, T., Landis, T. 2009. Nursery Manual for Native Plants: A Guide for Tribal Nurseries. Cover and Frontmatter.pdf

Frischie, S., Miller, A. L., Pedrini, S., Kildisheva, O.A. 2020. Ensuring seed quality in ecological restoration: native seed cleaning and testing. Restoration Ecology. 248–239 ,(28)28.

Haase, D.L., Bouzza, K., Emerton, L., Friday, J.B., Lieberg, B., Aldrete, A., Davis, A.S. 2021. The high cost of the low-cost polybag system: A review of nursery seedling production systems. Land, 19–1 ,(8)10.

Khurram, S., Burney, O., Jacobs, D., Van Eck, F. 2016. Use of Plastic Bottles as Nursery Containers for Growing Forest Tree Seedlings. https://doi.org/10.13140/RG.2.2.21814.50249

Kildisheva, O., Kildisheva, O.A., Dixon, K.W., Silveira, F.A.O., Chapman, T., Di Sacco, A., Mondoni, A., Turner, S.R., Cross, A.T. 2020. Dormancy and germination: making every seed count in restoration. Restoration Ecology. 28(S3), 265–256.

Landis, T.D., Riley, L.E., Haase, D.L. and Pinto, J.R., 2011. The target plant concept-a history and brief overview. Riley LE, Haase DL, Pinto JR (tech coords) National Proc: Forest and Conservation Nursery Assoc—2010. Proc RMRS-P-65. US Dept Agric Forest Serv Rocky Mtn Res Sta, Ft Collins, CO, pp.66-61.

Ouled Belgacem, A. 2021a. KSA Rangeland Sector Review. Food and Agriculture Organization of the United Nations, Riyadh KSA.

Ouled Belgacem, A. 2021b. Rangeland Rehabilitation Guideline. Food and Agriculture Organization of the United Nations, Riyadh KSA.

Pedrini, S., Dixon, K.W. 2020. International principles and standards for native seeds in ecological restoration. Restoration Ecology. ,28 303-236.

Penfield, S. 2017. Seed dormancy and germination. Current Biology. 909–853 ,27.
ullamcorper suscipit lobortis nisl ut aliquip ex ea commodo consequat.

For more information:

Azaiez Ouled Belgacemi, *A.belgacem@cgiar.org*

How to cite:

Ouled Belgacem, A., Louhaichi, M. 2024. Pastoral Seed and Seedling Management. Research for Development Initiative. Tunis, Tunisia: International Center for Agricultural Research in the Dry Areas (ICARDA).

CGIAR is a global research partnership for a food-secure future. CGIAR science is dedicated to transforming food, land, and water systems in a climate crisis. Its research is carried out by 13 CGIAR Centers/Alliances in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations and the private sector. *www.cgiar.org*

PRIMA (Partnership for Research and Innovation in the Mediterranean Area) supports research and innovation to improve food systems and water management in the Mediterranean, addressing sustainability and climate challenges. It fosters collaboration among researchers, policymakers, and stakeholders. *www.prima-med.org*

To learn more about this Initiative, please visit *https://www.cgiar.org/initiative/livestock-and-climate/*
To learn more about this and other Initiatives in the CGIAR Research Portfolio, please visit *www.cgiar.org/cgiar-portfolio*

To learn more about TransforMed Project, please visit *www.transformed-prima.eu*

ICARDA
Science for resilient livelihoods in dry areas

CGIAR
INITIATIVE ON
Livestock and Climate

TRANSFORMED

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION
IN THE MEDITERRANEAN AREA

PRIMA programme is supported by Horizon 2020, the European Union's Framework Programme for Research and innovation.