Target Plant Concept

Introduction

The Target Plant Concept is a framework designed to bring plant production and field establishment into a single holistic process. Since many plant attributes can be linked to outplanting success, seedlings in a nursery should be grown with full consideration of the intended outplanting site conditions. Nursery growers and field managers should work in partnership to identify plant attributes that are likely to lead to project success. Quantifiable plant attributes are the **"targets"** for seedling production. The targets can be refined each season based on regular monitoring of field performance. This approach allows for continuous improvement of nursery production, outplanting, and tending practices. The Target Plant Concept has five core components, each of which should be addressed before producing seedlings in a nursery. These core components can also be easily adapted for use with direct seeding, transplanting from other sources, or using cuttings. By discussing each of the five components of the concept (detailed in the following sections) nursery and field partners can work together to define the target plant for each reforestation or restoration project.

COMPONENT 1

Program Objectives and Constraints

Seedlings are produced for a number of reasons. Understanding the objective for a given project is critical for guiding the allocation of time, money, and personnel resources and for defining the target plant. For example, restoring large, degraded areas may require growing small quantities of many species, or large quantities of a few select species.

Each production goal requires different infrastructure needs such as containers, growing media, and irrigation systems, as well as knowledge of plant growth and development for the target species. The more clearly defined the objectives are, the more likely it is that the program will be properly resourced and managed. Similarly, it is important to identify potential constraints, such as access to funding, water, labor, or other resources. Once constraints are identified, partners can determine how they can be mitigated through effective planning.

PRODUCTION CYCLE

Step 1: Define the Target Plant

Nursery growers and field managers work in partnership to identify plant attributes that are likely to lead to project success.

Step 2: Source Plant Material for Propagation

Focus collection efforts to ensure the crop produced is diverse and well suited to the planting environment, while protecting wild populations from overharvesting.

Step 3: Sowing and Propagation

Seed of some species may require treatment to break dormancy prior to sowing. Careful application of nutrients and water is critical to maximize seedling quality while also avoiding waste.

Step 4: Site Preparation

Take measures to reduce animal damage and control competing vegetation.

Step 5: Planting

Seedlings can be planted once they have reached target specifications and the site has been prepared. It is important to protect seedlings and use proper planting tools and techniques.

Step 6: Monitoring

Monitor planted seedlings regularly to ensure they are getting enough water and are protected from animal browse and insect damage. All monitoring and post-planting activities should be documented for future propagation and nursery planning needs.

COMPONENT 2

Limiting Factors on the Outplanting Site

Every outplanting site is different and should be characterized before nursery production begins. Many factors can limit plant survival, growth, and reproduction on the planting site. Common issues are the depth and type of soil; the timing, amount, and form of precipitation; accessibility and current site uses; and the type and level of vegetative competition and animal browse likely to occur.

Those factors, and more, can limit project success, but some can be mitigated through nursery practices, site preparation, or tending after outplanting. For example, understanding the depth of soil in which seedlings will be planted should determine the choice of container, while knowledge of animal grazing in the area may require a conversation and management plan with local shepherds or community groups, and result in the need to budget for fencing or plant cages.

COMPONENT 3

Managing Genetic Resources

Selecting a particular species or multiple species for a project will depend on the availability of propagation material, project goals, site conditions, and limiting factors. A diverse mix of native species is usually best for projects that aim to restore the natural structure and support ecological function of habitats. Once the species of interest have been identified, sources of seeds or cuttings for propagation in the nursery must be identified. Usually, these sources should be selected from nearby populations occupying environments similar to the planting site, and should be collected from many different individuals to allow for adequate genetic diversity.

Some species are highly sensitive to differences in elevation, moisture gradients, or temperature, and may not grow well if planted away from the conditions with which they have evolved; others are more general in their habitat needs. Thus, if appropriate seeds or cuttings are not available, a different species may be better for meeting the long-term project objectives. Finally, when collecting seeds and cuttings, care must be taken to avoid overharvesting a given population.

COMPONENT 4

Seedling Size and Quality

There are hundreds of ways that seedlings can be grown in a nursery, using different container sizes, fertilizers, irrigation schedules, and countless other tools. Each **"stocktype"** reflects the specific nursery cultural methods used to influence plant growth and development to achieve targets.

Containers are available in an assortment of shapes and sizes, allowing a grower to customize the way a seedling is grown for the intended outplanting site, while also considering the growth rate of the species. For example, deep containers produce seedlings with longer root systems, which may have better survival and growth on droughty sites whereas short containers will produce seedlings for planting on sites with shallow soils.

Continued on next page.

SEEDLING QUALITY MATTERS

Morphology

Morphology involves the physical attributes of a seedling.

- Height
- Stem Diameter
- Bud Length
- Root Mass
- Color
- Shoot Mass
- Shoot:Root
- Form

Physiology

Physiology involves the functioning of a seedling.

- Cold Hardiness
- Bud Dormancy
- Nutrient Content
- Root Growth Potential
- Plant Moisture Stress
- Chlorophyll Fluorescence

COMPONENT 4

Seedling Size and Quality Continued

Plant quality is defined by physical and physiological attributes that allow a plant to survive and grow once outplanted. Irrigation and fertilizer regimes are used to maintain plant moisture and nutrient levels to support growth and survival after planting. Irrigation can be modified to reflect the crop's growth phase, with frequent, light mists during the germination phase, regular irrigation during the phase of active growth, and less frequent irrigation to harden the crop and condition it for outplanting. Under-irrigating seedlings in the nursery can lead to internal plant stresses, while over-irrigating can result in problems with insects and disease. Therefore, careful application of nutrients and water is critical to maximize plant quality while also avoiding waste. By manipulating the culturing regime in the nursery, specific target characteristics can be achieved. For example, a high root-to-shoot ratio may be desirable for sites where water is limited, or a tall shoot may be desirable for sites with heavy competition.

COMPONENT 5

Post-Nursery Practices

Once seedlings are removed from the nursery, they immediately become susceptible to stresses associated with handling, transportation, planting, and environmental conditions. Therefore, the timing and method of outplanting should be considered before the crop is even sown in the nursery. The outplanting window should coincide with favorable environmental conditions for plant growth and survival, typically at the onset of the annual rainy season. Working backward from this window of time will help growers schedule the entire production cycle, from seed collection, through sowing and growing, to hardening. Ensuring that the site has been prepared and that seedlings are transported in a careful and timely manner can maintain the quality of plants for a longer period. Use of tools that make the right size planting hole for the seedling root system, mitigation to reduce animal damage, control of competing vegetation, and watering seedlings before and after planting (either manually or through rainfall) all contribute to higher survival and better growth.

The true test of target plant success is field performance. Plants should be regularly monitored once outplanted to assess survival and growth. This information helps to set and refine targets for future crops and connects the nursery production and field performance phases of projects in a quantifiable manner.

Seed Sourcing and Collection

Introduction

Sourcing seeds from the wild requires careful planning, anticipating seed needs well in advance of sowing. It is important to target specific populations for collection so that the crop produced is diverse and well suited to the planting environment. At the same time, wild populations must be protected from overharvesting. It is recommended that no more than 20% of any given population's seeds be collected throughout the duration of one collection season. If the particular population is very small, the percentage harvested should be even lower.

Seeds come in a variety of shapes and sizes, with various means of dispersal. Seeds develop in cones or fruits. Cones and dry fruits can be dehiscent, meaning they open when ripe to release their seeds, or they may be indehiscent, meaning they retain their seeds after ripening. When collecting seeds from dry, dehiscent fruits, care must be taken to ensure the seeds have not already dispersed. This can be accomplished by collecting seeds as soon as the fruits begin to split or by enclosing the developing fruit or cone in a cage or fine-mesh bag to capture seeds upon dispersal.

Genetic Considerations

Locally collected seed lots are considered best because they are likely well suited to the local environmental conditions. This principle that populations adapt to specific conditions over many generations is the basis for guidelines or limits often called zones, within which seeds can be moved with little risk of being poorly suited to the environment. Based on evidence from a diversity of species, it is essential to carefully consider the environmental conditions of where seeds are collected and where the seedlings will be out-planted.

Depending on the objectives of the project and the quality and quantity of local seed sources, it may be necessary to collect seeds from non-local sources to ensure access to high quality (viable) and genetically diverse seed lots. When using non-local seed sources, it is essential to collect from environments that match as closely as possible the environmental conditions at the out-planting site.

Determine whether permission or a permit is required for seed collection. It is important that the project planners and the grower determine clear objectives and identify regulations that surround seed collection prior to the beginning of the collection season.

Collecting Seed

There are many factors that affect the timing and effort needed for seed collection of any given species, such as the abundance of the species, the ease with which it can be identified and accessed in the field, and the timing of seed maturation and dispersal. Flowers and fruits of many species develop and mature over an extended period of time. For these species, seeds should be collected throughout the entire season. Some species may require special equipment for seed collection or may be thorny or poisonous, necessitating careful attention on the part of the collector. Scout populations in advance of seed ripening to determine whether an adequate crop will be available for collection. If possible, collect seed from 50 randomly selected plants, acquiring a similar number of seeds from each individual. If collecting seed from multiple populations, keep each population separate initially. The decision to combine seeds from different populations can be made just prior to sowing.

Seeds can be collected by hand picking, cutting fruit, clipping branches, shaking branches over a canvas tarp or blanket, or by enclosing developing fruit or cones in a bag or cage. Seeds and cones should not be collected from animal caches or from the ground.

When transporting fruits, cones, and seeds to the nursery for processing, handle with care, avoiding mechanical damage and exposure to direct sunlight or high temperatures. Dry fruits, seeds, and cones can be kept in cotton or paper bags for short durations until processed in the nursery but fleshy fruits should be kept in a cooler and processed soon after collection. **See Seed Storage and Handling Worksheet for additional information.**

USEFUL TOOLS

When collecting seeds from wild populations, it is useful to have the following tools:

Collection Bags
Cotton or paper bags for dry fruits and cones, plastic bags for fleshy fruits

Labeling Supplies
Labels and permanent markers or pencils

Fine-mesh bags and rubber bands or cages
If collecting from species with rapidly dispersing seeds

Gloves

Scissors or hand pruners

Pruning poles
If collecting from trees

Hand lens and a sharp tool
For the cut test (see next page)

Box or cooler
For transporting seed

GPS unit
Also available as a app on most smart phones

Assessing Seed Maturity and Health - Cut Test

To assess seed maturity and health, use a sharp tool such as a safety razor, knife, or scalpel to cut the seed along the longest axis. Examine the internal tissue. If the seed coat is soft and the internal tissue is soft and watery, the seed is likely immature. If the seed coat is hard and the internal tissue is firm and light tan or white in color, the seed is mature. Be sure to examine seeds from several different individuals in a population, noting any signs of insect damage or disease.

Record Keeping

It is extremely important to properly label each seed lot. These labels should include information about the species, the population(s) from which seed was collected, the collection location and date, the collector(s), and how the seed was stored and cleaned. Documenting the timing and location of each seed lot will help with planning collection efforts in subsequent years.

EXAMPLE OF SEED LOT LABEL

Species __________

Lot Number __________

Collector __________

Collection Date __________

Location __________

Habitat __________

Population Extent *frequency and cover* __________

____

Number of Plants Sampled __________

Collection Method __________

Storage Conditions *prior to cleaning* __________

____

Cleaning Method __________

Cleaning Date __________

Storage Conditions *after cleaning* __________

Additional Notes __________

Seed Cleaning and Storage

Seed Cleaning

Seeds often need to be cleaned prior to storage and sowing. Seeds of fleshy fruits should be kept in plastic bags or buckets and stored in a cool place, out of direct sunlight, until they can be cleaned. Do not allow seeds to dry out, and clean seeds as soon as possible, ideally within a few hours of collection.

To clean, soak fruits in water to soften the fleshy tissue. Change the water every few hours during soaking. Floating seeds are often damaged or empty and can be discarded, but for some species even viable seeds will float when attached to fleshy tissue. Remove the fleshy tissue by squeezing by hand, mashing the fruits with a wooden tool, gently rubbing against a screen under running water, or using a kitchen blender or food processor. If using a blender or food processor, be sure to cover the blades with rubber or with a thick layer of duct tape to avoid damaging the seeds. Blend a small handful of seeds with enough water to cover and give the mixture a few short pulses. This may have to be done several times. Slowly add water to the mixture. The pulp and empty seeds will float and viable seeds will sink, allowing for seed separation. Viable seeds should be rinsed and dried before being stored.

Seeds borne in cones or dry fruits can be kept in paper, burlap, cotton, or nylon bags until cleaned. Be sure to use an appropriate bag for the given seed type. Certain seeds (for example, grasses and certain species of forbs) may stick in burlap bags and can easily be lost or cross contaminate collections. For these seeds, cotton bags or paper bags or envelopes are preferable. Only fill halfway and keep out of direct sunlight in a dry, well-ventilated area protected from rodent predation. Bags can be suspended from hooks or kept on open shelves. Maintain a temperature between 18 and 27°C and rearrange frequently to improve air circulation.

Seeds of dry fruits and cones may be cleaned using screens to separate large debris and seeds from fine debris. Alternatively, place seeds in a bag with an object such as a large metal washer, tie it shut, and gently shake, rub, or knead to detach the seeds. This material can then be slowly poured in front of a small electric fan to separate filled seeds (which will settle near the fan) from empty seeds and small debris (which will settle out away from the fan).

Depending on species, it may be necessary to perform an immediate sorting of seed at the time of collection to remove those with obvious signs of disease or insect predation. The seeds can then be cleaned as stated above. All cleaning techniques should be documented and kept for future reference, noting the species name, collection location, date collected, date cleaned, cleaner's initials, technique(s) used, and total weight of cleaned seed.

CLEANING PROCESS

Fleshy Fruits

Cleaning fleshy fruits involves the following process:

1. Soak to soften tissue
2. Remove fleshy tissue
    - Squeeze by hand
    - Mash with wooden tool
    - Rub against screen under running water or
    - Use kitchen blender/food processor
3. Add water to mixture
4. Collect viable seeds

Dry Fruits/Cones

You can clean and separate the seeds of dry fruits and cones by using one of the two following methods:

1. Use screens to separate seeds and fine debris
2. Use bags
    - Place seeds into bags with heavier object
    - Tie bags shut
    - Shake, rub or knead to detach seeds
    - Pour mixture in front of fan to separate seeds

Storage and Monitoring

Always clean and label seeds prior to storage and maintain stable temperatures and moisture levels in the storage area.

See Seed Sourcing and Collection Worksheet for examples of a seed label.

Seeds may be described as orthodox or recalcitrant, and knowing which type of seed you are working with will help determine the best means of storage. **Recalcitrant seeds** are short-lived and difficult to store. They cannot be dried to moisture contents below 20 – 30% without injury and are intolerant of freezing. Recalcitrant seeds can be stored for short periods of time under conditions of high relative humidity, good air circulation, and cool temperatures.

Orthodox seeds are long-lived and can tolerate drying down and freezing and are easy to store. They may remain viable for years when stored in conditions of low relative humidity, low seed moisture content, and cool temperatures.

Prior to long-term storage, dry seeds for 2 – 4 weeks in conditions of 15˚C and 15% relative humidity. Seeds can be dried in a shallow tray, stirring weekly to prevent uneven drying, or in hanging paper bags that are filled less than halfway and shaken every few days to prevent uneven drying. The time required for seeds to dry fully depends on the size of the seed and the size of the collection.

Once dry, store dry seeds in labeled, durable, airtight containers that are rodent proof and water resistant. Some species can be stored in a freezer, but a self-defrosting refrigerator can be used for species sensitive to freezing. If ample seed is available, divide collections among multiple storage units to prevent the loss of an entire collection if a particular unit fails (for example, in the event of power loss).

Periodically inspect stored seeds for signs of mold or discoloration, which indicate seeds will need to be cleaned again or discarded. Performing an annual or semi-annual seed inventory is also recommended, which also allows the grower to effectively monitor seed lots on a regular basis.

Seed Dormancy and Germination

Dormancy

Many seeds exhibit some form of dormancy, which acts to prevent germination during unsuitable conditions. Knowing which kind of dormancy a seed possesses is important, and if this information is not known prior to propagation, the process will require some trials and careful documentation to determine what is necessary for production. **Physical dormancy** describes seeds with seed coats that are impermeable to water at maturity. Because germination requires the seed to absorb water and swell, seeds with physical dormancy will require scarification. **Scarification** is the weakening or breaking of the seed coat through mechanical, thermal, or chemical means to allow water to penetrate the seed. This can be achieved by filing, nicking, or sanding the seeds by hand or by soaking the seeds in boiling water or in concentrated sulfuric acid for a short period of time. An imbibition test (see below) can be used to determine whether a seed has physical dormancy.

Cold stratification involves exposing hydrated seeds to temperatures of 1 – 5°C while warm stratification involves exposing hydrated seeds to temperatures of 22 – 30°C. Some species require both warm and cold stratification.

To stratify, place seeds in a labeled fine-mesh bag and tie it closed. Mix and moisten growing media to the extent that only a small amount of water drips off when squeezed. Fill a plastic bucket with the media and place the mesh bag with the seeds in the center of the bucket. Cover the bag completely with the media. Place a plastic bag tightly around the top of the bucket. Be sure to poke several small holes (~ 5 mm diameter) in the plastic bag to allow for air circulation. Label the bucket with the species name and the date. Place the bucket in a refrigerator set to 1 – 5°C or 22 – 30°C (depending on the required stratification).

The length of time required for stratification will depend on the particular species. Again, if this is not known, conduct trials and carefully document the results to determine what is necessary. Rinse the seeds every 2 weeks under running water to reduce pathogen growth. Record the species, date, and status of the seeds each time you check on them. If seeds begin to germinate, they need to be sown as soon as possible!

DORMANCY TYPES

Physical dormancy describes an impermeable seed that must be scarified.

Physiological dormancy describes a permeable seed with some mechanism that prevents the growth of the embryonic root known as the radicle. It requires a moist, chilling period called cold stratification.

Morphological dormancy describes a permeable seed that has an underdeveloped embryo at the time of maturation and dispersal and requires warm stratification.

Seeds may also exhibit **combinational dormancy** in which the seed is impermeable and the embryo is dormant. These seeds must be scarified and stratified.

STRATIFICATION

SCARIFICATION

Imbibition Test

Seeds must absorb water to germinate via a process known as **imbibition**. An imbibition test helps determine if seeds can absorb water. To conduct an imbibition test, separate 100 to 400 seeds into four equal samples. If a seed lot does not have 100 seeds, a representative number of seeds should be chosen to perform this test. Record the weight of each seed sample. Place each sample into a mesh bag and then into a bucket to soak for 48 hours under a small stream of running water, allowing for aeration. After 48 hours, remove the bags from the water.

For each sample, spread the seeds out on a paper towel and pat dry so there is no water on the seed surface. Re-weigh each sample and subtract the original weight from the new weight to determine if the seeds increased weight, indicating that they absorbed water. For example, if a sample of seeds initially weighed 10 grams and after soaking in water and being allowed to dry it weighed 12 grams, the seeds absorbed water. Be sure to blot seeds dry before re-weighing, as free water (or water that has adhered to the surface of the seeds) may add significant mass to the sample, but is not representative of internal water uptake.

Germination Test

Another important test to perform is a germination test. This is used to determine the viability of seeds and can help estimate the number of seeds and containers needed to produce the desired number of seedlings. If seeds are viable but do not germinate to a high extent (› 75%) within a month across a range of temperatures that would typically facilitate germination (e.g. spring temperatures for species that typically germinate in spring) then they are dormant and may need a scarification or stratification treatment. Germination testing requires you sacrifice some of your seed, so if you have limited seed, forgo the germination test and carefully plant what seed you have. To perform a germination test, separate 100 to 400 seeds into four equal samples. Fold several paper towels (~1 cm thick) and soak them in water. Allow the extra water to drip off and then place the paper towels in 4 plastic containers. Spread seeds evenly over the surface of the paper towels. Close the lids or place plastic wrap or a clear plastic bag over the containers. Keep the containers at room temperature (21 – 23°C) and do not put them in direct sunlight. Make sure the paper towels do not dry out; a spray bottle with a fine mist is a good tool for this task. Check on the seeds every 1 to 5 days for 30 days. Write down the number of seeds that germinate every time you check. Remove germinated seeds. To calculate germination percentage, divide the total number of germinants by the number of seeds in the test and multiply by 100. For example, if you started with 100 seeds and had 80 germinants, your germination rate is 80%.

Water Quality

Introduction

One of the biggest considerations before operating a nursery is whether there is access to a reliable, consistent source of high quality irrigation water. Growing even small seedlings for restoration projects can use several liters of water per day during the hottest, driest, and windiest parts of the season. The concentration of dissolved salts and the presence of pests, pathogens, weed seeds, sediments, and residual pesticides all affect water quality. Often undetected, these can impact seedling health and quality. Remediation practices can be expensive, emphasizing the need for proper nursery location in relation to water supply. Recognizing that water quality can vary among sources and change over time, it should not only be tested before a nursery is established but also at regular intervals to ensure the quality has not changed.

Suspended solids such as sand and silt can be removed from irrigation water by filtration. Filters should be installed before the water passes through the irrigation line to remove particulates that can cause excessive wear or clog valves. Granular filters consist of beds of granular particles that trap fine sand and organic matter in the pores between the particles and can be back-flushed for cleaning. Surface filters use a porous screen or mesh to strain the suspended material from the irrigation water. Screens must be physically removed, cleaned and reused whereas cartridge filters must be replaced regularly.

CHLORINATION WITH HOUSEHOLD BLEACH

A simple chlorination using diluted household bleach can often effectively control pathogens, mosses, and liverworts. Mix household bleach (5.25% sodium hypochlorite) at a rate of 18mL per 1,000L of water.

Testing Water Quality

A water quality test should include an assessment of **salinity** (soluble salts) and pH. **Electrical conductivity (EC)** is a common method used to monitor salinity and can be measured at the nursery using a simple handheld EC meter. pH can also be measured at the nursery using test strips or a handheld meter. Irrigation water may also be tested for pathogens and residual pesticides if particular problems are suspected but these assessments will require sending water samples out to a laboratory for testing.

To test irrigation water, collect a water sample in a labeled, clean, plastic bottle with a firm, watertight lid. First, run the water for several minutes then rinse the sample bottle a few times before collecting the water sample. If testing water from a tank or well, rinse the sample bottle several times with the tank- or well-water before taking the final sample. If mailing the water sample off for analysis, it is important to keep it refrigerated and send it as soon as possible.

SALINITY

Salts are chemical compounds that release charged particles when dissolved in water. Some salts, like fertilizers, are beneficial for plant growth, but an excess of salts or the presence of certain types of salts can damage or even kill plants. EC of irrigation water should not exceed 1,500 uS/cm (microsiemens per centimeter).

ACIDITY

pH is a measure of acidity and can affect the availability of other compounds in the water such as fertilizer. Irrigation water pH should range from 5.4 to 6.8. Acidic irrigation water can be corrected by injecting $CaCO_3$ (calcium carbonate, calcite, limestone) or $KHCO_3$ (potassium bicarbonate) into the irrigation line to raise the pH. To acidify irrigation water, H_3PO_4 (phosphoric acid) or H_2SO_4 (sulfuric acid) can be injected into the irrigation line to lower the pH.

Crop Irrigation

Overhead Irrigation

There are several ways to irrigate nursery crops and the most suitable method will depend on the size of the nursery and the crop diversity. **Hand watering** is the simplest form of irrigation. It can be done using a watering can or a hose fitted with a spray nozzle. However, with hand watering it is difficult to apply water uniformly to the seedling crop and hard to manage over large areas. When hand watering, foliage can intercept a lot of the water, which keeps the water from reaching the roots. Thus, it is important to ensure that water is directed to the roots. Adjust the flow, volume, and pace of watering to the needs of the crop in an even and efficient manner. Take care to avoid exposing the hose to the sun, which will heat the water within the hose. Watering seedlings with hot water can damage or even kill them.

An alternative to hand watering is the use of an **overhead irrigation system**. Overhead irrigation systems are either fixed or mobile. Fixed overhead sprinkler systems consist of parallel irrigation lines with evenly spaced sprinklers to form a grid. Mobile or moveable boom irrigation systems are efficient but relatively expensive and require constant maintenance. They apply water in a linear fashion as the boom passes over the crop. Whether fixed or mobile, it is important to consider nozzle design, the size of the nozzle opening, water pressure, application rate, nozzle spacing, and the effects of wind.

Testing for Evenness of Irrigation

The cup test can be used to assess how evenly water is distributed during irrigation. To conduct the cup test, set out a series of identical plastic cups in a regular grid pattern throughout the nursery and irrigate as usual. Make sure that the cups have narrow rims and are deep enough to prevent water from splashing out. Following irrigation, assess the water level in each cup. If the water level differs among cups, water distribution is uneven. The nozzles on an overhead boom or hand-watering techniques may need to be adjusted.

Subirrigation

Many of the headaches associated with overhead irrigation can be avoided with **subirrigation**. In subirrigation systems, containers sit in water for a period of time (as determined by the species, growth phase, climate, growing medium, and container type) and seedlings are irrigated as this water rises through the growing medium via capillary action before it drains away.

This method of irrigation is more even and efficient than overhead irrigation systems because water is not intercepted by foliage and can be recycled for future irrigations. However, subirrigation comes with its own set of challenges. One major drawback of this irrigation approach is the potential for salt accumulation in the water and in the growing medium, which can be harmful to seedlings. Measuring salinity using a handheld electrical conductivity meter can be used to monitor for this problem. While salt accumulation can be harmful, a single overhead irrigation event can flush salts from the growing media. Additionally, subirrigation can spread root diseases.

See Water Quality Worksheet for more information on measuring EC and controlling pathogens.

There are also other forms of irrigation worth considering. Among these is **microirrigation**, which involves the use of poly pipes attached to individual microsprayers or drippers. This is an efficient method for nurseries that grow plants in large containers.

Irrigation Scheduling

The amount of water needed to grow a crop depends on the species, growth phase, climate, growing medium, and container type.

During the **establishment phase**, when seeds are germinating, water is lost primarily as a result of evaporation from the top of the container and should be replaced by frequent misting or light irrigation. Care must be taken to prevent the seeds from drying out while not creating excessively wet conditions that may lead to disease. After seeds have germinated and root systems have become established, water loss is primarily due to transpiration, as water taken up by roots moves through the plant and evaporates through leaf pores. During this **rapid growth phase**, irrigation events must be longer and more frequent, although this varies among species. It may be helpful to group species by their relative water needs. Also, be aware of the potential for uneven watering if hand watering or using an overhead irrigation system as the canopy of the crop grows larger and broad leaves intercept irrigation water, leaving some containers saturated and others dry. Finally, at the end of the growing season, irrigation practices can help with **hardening** seedlings because growth is tied to moisture stress levels. By withholding irrigation to induce moderate water stress, seedlings will slow or stop shoot growth, begin to set bud, build resistance, and become cold hardy. However, dormancy and hardiness are controlled by more than just moisture stress and little is known about the physiology of many native species so care must be taken not to overstress plants. Documenting the differences between species and the results when outplanting can assist in making irrigation decisions for subsequent growing seasons.

Knowing When to Irrigate

Knowing when and how much to irrigate a crop can be the most challenging aspect of nursery crop production. Ensuring proper irrigation timing requires daily monitoring. Assessing irrigation needs by monitoring the crop to ensure that shoots are healthy and not wilted and that the growing medium is moist throughout requires experience and careful handling. A simpler method to monitor irrigation needs is to track container weight. Container weight decreases as water is lost to evaporation and transpiration. Knowing what a tray of seedlings weighs at saturation (when fully watered), and tracking the tray weight to a predetermined level can help nursery staff determine when and how much to irrigate. For example, if a tray of containers weighs 1 kg at saturation and the predetermined satisfactory irrigation level is 75% saturation weight, then the tray of seedlings should be watered when the tray declines to a weight of 0.75 kg or below. Using this method allows the guesswork to be removed from irrigation practices. The predetermined level at which irrigation should be applied will vary among species and according to the growth phase of the crop. This information should also be documented from year to year to assist with production planning and managing water needs.

Handling and Planting Seedlings

Introduction

Seedlings should be grown for only a single growing season to reduce risks associated with pests, overwinter storage, and growing too large for the container. Irrigation can be adjusted throughout the growing season to prepare the seedlings for outplanting. Once seedlings have reached a pre-determined target size and have been properly hardened off, they are ready to be planted. Seedlings that do not meet these targets should not be planted.

Seedling Transportation

All seedlings should be handled with care during transportation from the nursery to the planting site as dropping, crushing, excessive vibration, and extreme temperature fluctuations can reduce seedling health and survival. Seedlings should be kept in their original growing containers if possible. When transporting seedlings from the nursery, make sure they are protected from direct sun, wind, vehicle exhaust, and sources of heat. Pack seedlings upright for transport to prevent them from falling over and breaking and keep roots moist (but not soaking wet). An enclosed trailer is best for transporting seedlings, but pickups with canopies can provide ample protection from sun and wind. Covering seedlings with a tarp, especially a dark-colored one, can collect heat and damage seedlings. If you must transport seedlings a long distance, do so at night or in the early morning to avoid the hottest part of the day.

Site Preparation and Planting Windows

At the planting site, seedlings will have to compete with the existing vegetation for sunlight, water, and nutrients. To reduce competition, remove vegetation and expose the mineral soil from a 0.5-m radius surrounding each planting spot. Seedlings can be planted at a density appropriate for the species in cleared areas surrounded by basins of soil or into trenches dug into the soil to protect them from wind and to collect and hold water that will drain directly to the root system. Rocks and logs can also work to control erosion and prevent water loss and can be used to protect seedlings. It is best if rocks and logs are located south of the seedling to protect them from direct sunlight and heat during the hottest parts of the day. It is best to plant seedlings during the rainy season in the autumn, when the soil is moist. You should wait to plant seedlings until there have been enough rain events to ensure adequate soil saturation. If possible, plant on a day that is not hot or windy. If the seedlings are planted before the rain begins, adequate irrigation must be supplied in the field. Bring only the seedlings planned for planting, leaving others in the nursery until they can be planted.
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At the site, make sure seedlings are kept in the shade, the roots stay moist, and seedlings remain upright until they are ready to be put in the ground. Remove seedlings from their containers only immediately prior to planting. Be gentle as some seedlings may have roots that are not firmly bound together and the roots can be damaged when the seedling is removed from the container. Set hard plastic containers (such as Deepots) aside so they can be returned to the nursery to be sanitized and reused.

Planting Tools

There are a variety of hand and power tools that can be used to plant seedlings and using the right tool for the project is important for seedling survival and to keep the project within budget. Hand tools such as planting hoes, dibble sticks, planting bars, and shovels are relatively inexpensive and can be used with little training. Power tools such as augers can be useful when working with larger seedlings or in conditions that make for inefficient hand planting, but they are expensive and require training and expertise. It may also be useful to invest in a planter bag to allow planters to carry many seedlings with them across a planting site.

Planting Methods

It is important to plant seedlings correctly. Seedlings should be planted in mineral soil, being careful not to plant them too shallow or too deep. Seedlings should be planted upright in a hole that is free of air pockets and debris such as rocks or sticks. Begin by digging a hole twice as wide and slightly deeper than the root system of the seedling to be planted. Remove rocks and sticks from the hole and place the seedling into the hole so that the root ball sits just under the soil surface. Fill the hole with soil, keeping sticks and rocks out. Tamp the soil down firmly to remove air pockets and, if possible, water seedlings immediately after planting. A gentle pull on the tip of the seedling after planting is a quick way to check if the seedling has been firmly planted. If the seedling comes out of the ground after the gentle pull it is too loose in the soil and you should try again.

Caring for Planted Seedlings

Monitor planted seedlings regularly to ensure they are getting enough water and are protected from animal and insect damage. Clear vegetation growing around the planted seedlings as often as necessary and possible to allow seedlings to grow to maturity. All monitoring and post-planting activities should be documented for future propagation and nursery planning needs.

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