Deep-Root Strategies for Propagating and Planting Seedlings for Arid Sites

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Abstract

Establishing trees and shrubs in arid and semiarid lands is difficult. With climate change and more severe droughts, the challenge will increase. Developing strong, deep roots will often improve survival. Wick irrigation can minimize water use for tall containers in the nursery and increase water availability in the field.

Introduction

Despite the increasing recognition of the global impacts of drought and desertification, revegetation in arid and semiarid environments has not been extensively studied. Extreme temperatures, intense solar radiation, limited moisture, and the low fertility of desert soils combine to make natural recovery of these areas very slow after disturbance. One key to improve seedling establishment and success is the use of tall containers (Bainbridge 1987, 2007; Dreesen and Fenchel 2014; Rodgers 1994). In addition, water delivery during establishment could further increase outplanting successes.

Improving field survival with minimal water use is challenging. Wick irrigation has been used in greenhouse water-use studies (figure 1), and interest in its use for greenhouse and field applications has grown (Berkelaar 2012, Junejo et al. 2022, Kamalam 2016, Semananda et al. 2018). Yeager and Henley (2004) showed that capillary wick irrigation systems reduced water use an average 86 and 81 percent when compared with overhead and capillary mat irrigation, respectively.

A traditional Indian system that combined buried clay pots and wicks for tree planting (figure 2) (Mari Gowda 1974) inspired tests of wick irrigation (Bainbridge 2001). The first proof of concept was growing a blue paloverde (*Parkinsonia florida* [Benth. ex A. Gray] S. Watson) seedling in a container of 16-grit silica sand with a capillary wick from a reservoir below the container. This seedling grew well with water consumption of just 20 to 30 ml/day. The second field test used vertical 9-mm wicks rising from an inverted 7.5-cm buried drainpipe filled from a standpipe at one end (Bainbridge and Virginia 1989). This method improved survival, but the 9-mm wicks failed to provide sufficient water when temperatures soared. A later experiment used solid-braid nylon rope (50-cm long, 11-mm diameter, and washed in hot water with detergent) as

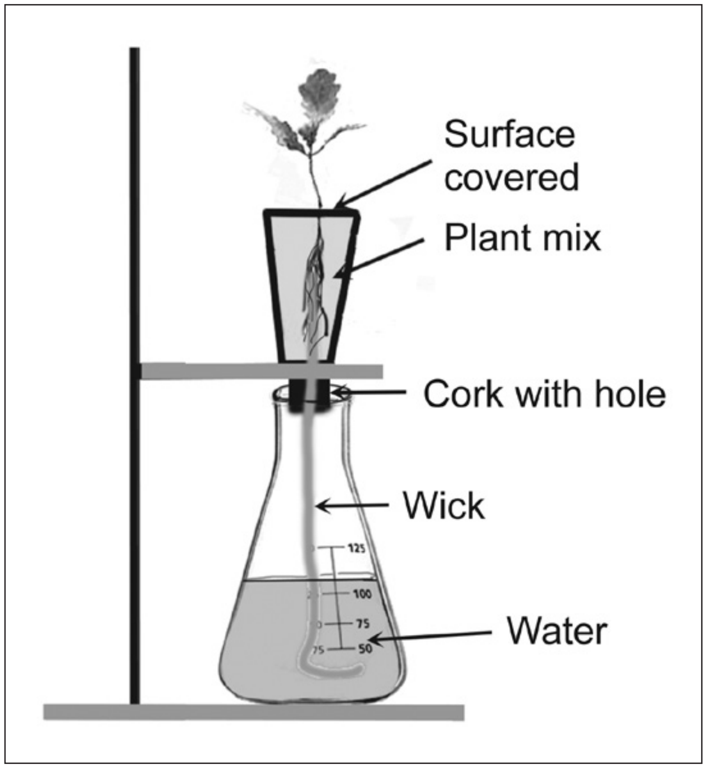

Figure 1. Simple wick irrigation has been researched in water efficiency trials.

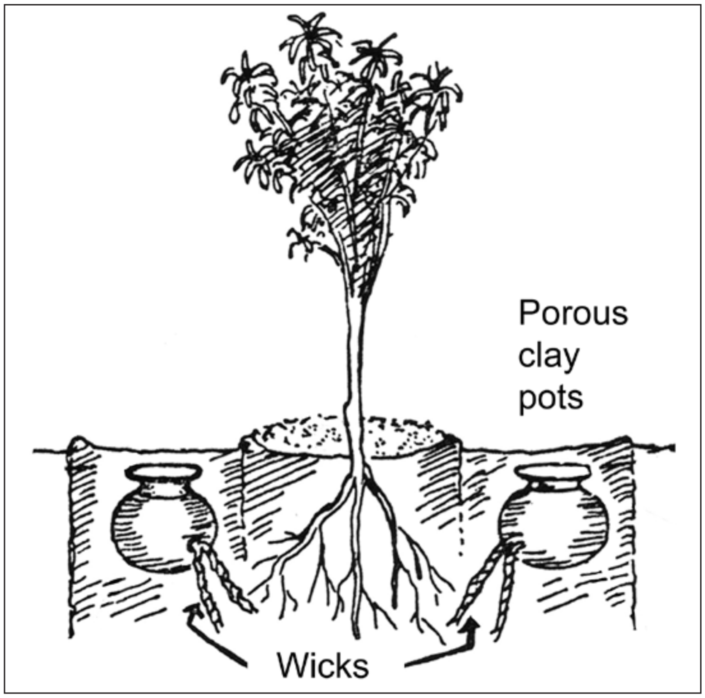

Figure 2. An early study using clay pots and wicks inspired additional research. Adapted from Mari Gowda 1974.

the wick (Bainbridge 2012) for mesquite (*Prosopis juliflora* [Sw.] DC.) seedlings. The wick was covered with a vinyl sleeve and ran from an 8-L water reservoir to the soil at each seedling. After receiving less than 120 L of water per plant (and less than 7.5 cm of rain), all mesquite seedlings were alive and well after 3 years.

The success of gravity wicks led to consideration of bringing wicks together with tall containers. This combination would minimize water use and encourage taproot development in the nursery. The wick could also be connected to a water supply in the field after the seedling is planted.

Wick Irrigation for Tall Containers

Initial tests of wick flow rates in tall containers used blue food coloring to track the wetted area of the wick. The wetting rate for gravity flow in washed, 11-mm solid-braid nylon rope (Lehigh Group, Macungie, PA) was 6 cm/min. Capillary rise reached 45 cm after 24 h. In October 2021, the author built a jig to hold the wicks in the center of a Treepots™ container (TP430, 10 cm wide and 76 cm tall; Stuewe & Sons, Inc., Tangent, OR) (figure 3) and then set up one container with a cork oak (*Quercus suber* L.) acorn and one with a willow (*Salix* spp.) cutting. Both did very well with water use of less than 250 ml/week. The acorn sprouted

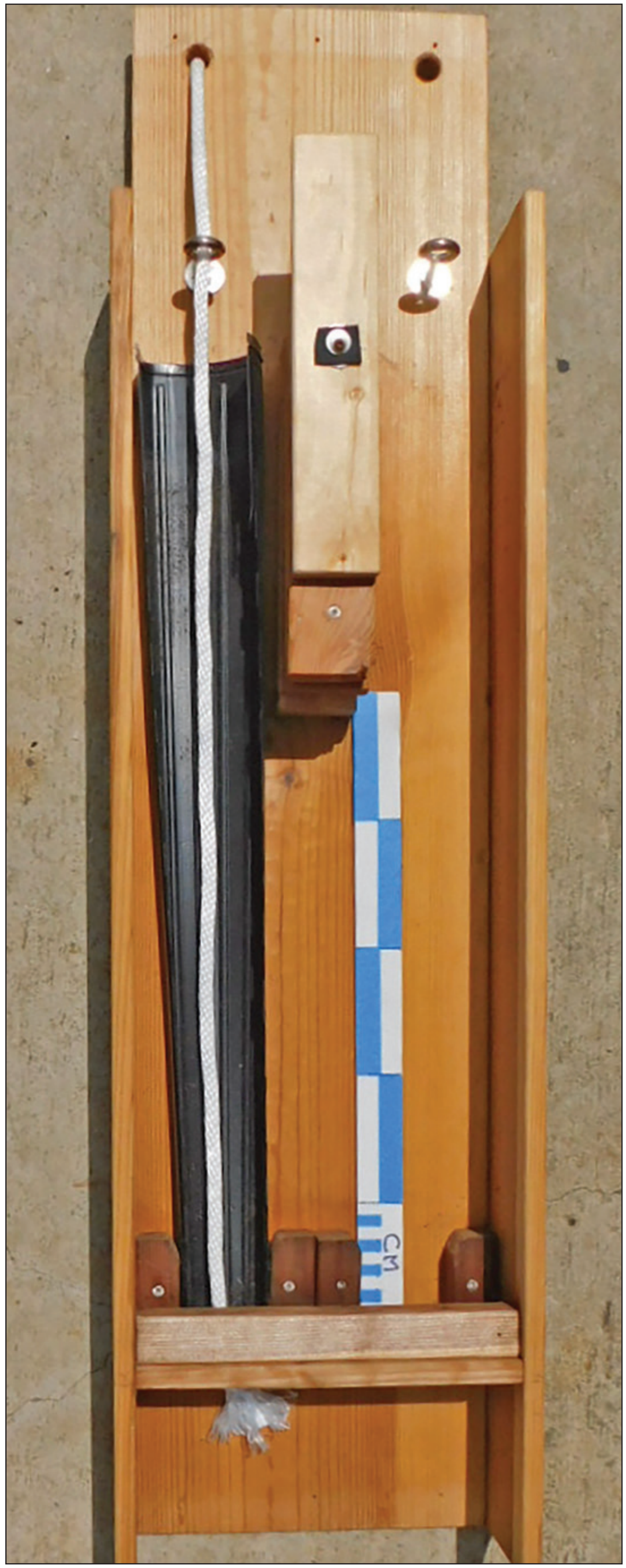

Figure 3. To study the use of wick irrigation in tall pots, the author built this jig before planting oak and willow to evaluate their performance. (Photo by David Bainbridge)

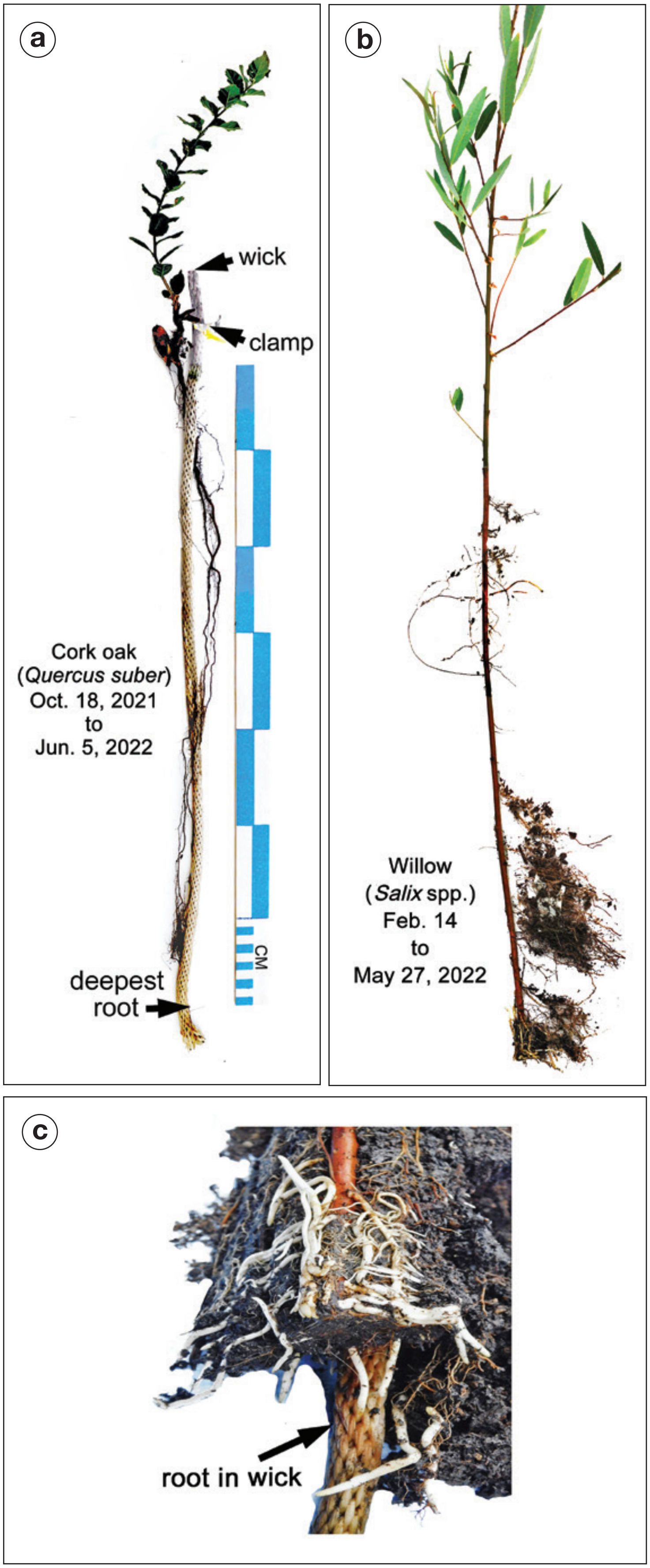

Figure 4. Growth and root development of (a) cork oak and (b) willow seedlings were excellent using wick irrigation in a tall pot. In fact, (c) roots grew near and through the wick.

and grew well. The root development was excellent, and roots were even integrated in the wick (figure 4), suggesting these seedlings would do well in the field. This method may result in robust seedlings that would be less easily damaged during transport or planting. Studies with much larger numbers of seedlings are needed (two are better than none in this case), but 100 or 200 would be better.

Research is needed to determine the best wicks and wick systems and to more fully evaluate the most appropriate uses of capillary and gravity-fed wicks. One possibility is that a wick would enable plants, cuttings, and pole plantings to reach groundwater with the combination of gravity and capillary rise (figure 5).

Deep Roots for Successful Dryland Tree Planting

Plants for drylands often depend on deep roots to endure droughts (Bainbridge 1987, Stone and Kalisz 1991). Living roots of mesquite and camel thorn (*Vachellia erioloba* [E. Mey.] P.J.H. Hurter) have been found more than 50 m deep (Canadell et al. 1996, Phillips 1963). Many dryland-adapted species

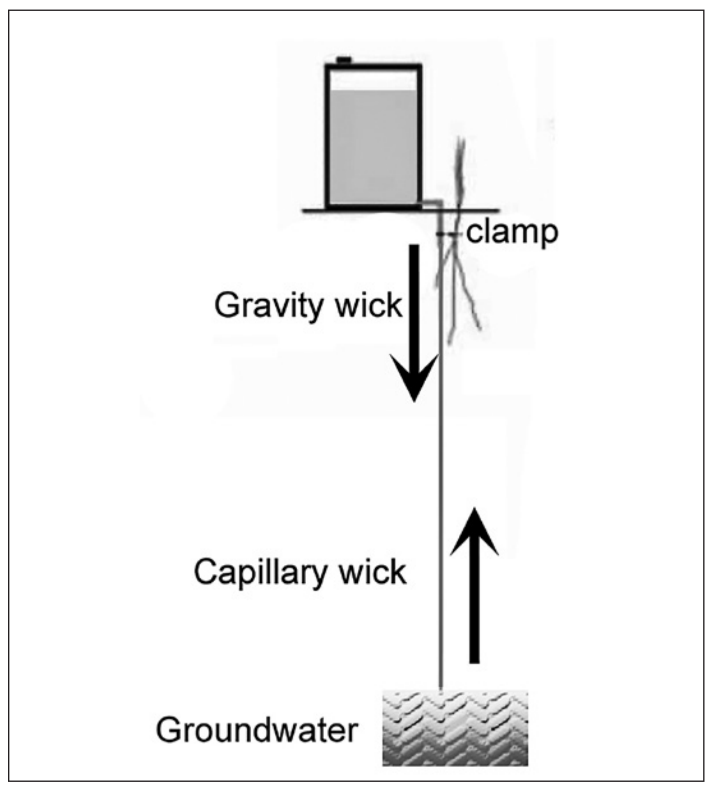

Figure 5. Wick irrigation has potential to enable access to groundwater to support plant establishment and growth.

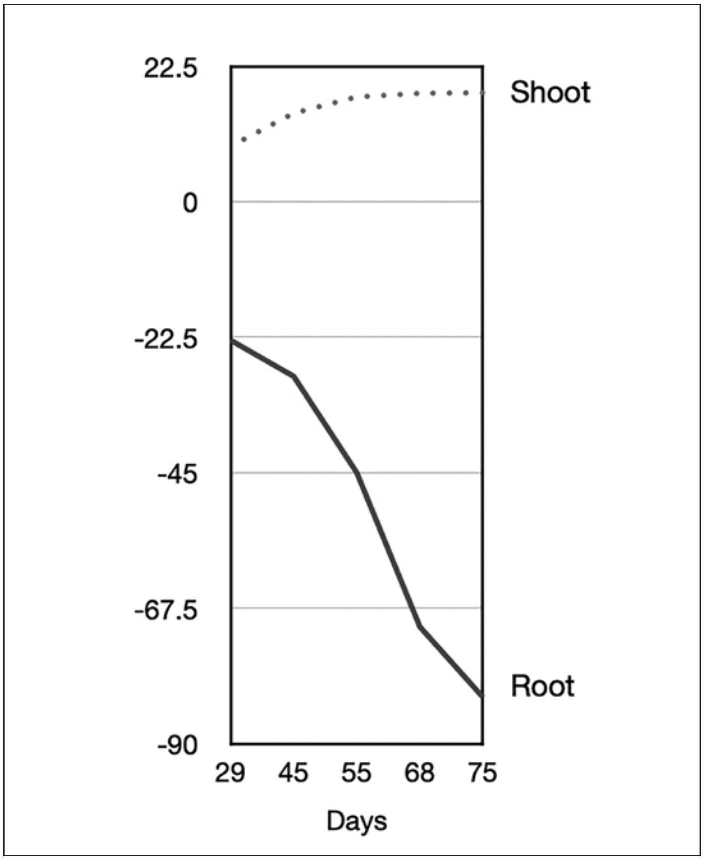

Figure 6. Dryland plants (e.g., *Parkinsonia florida*) often have rapid development of root systems relative to the shoot.

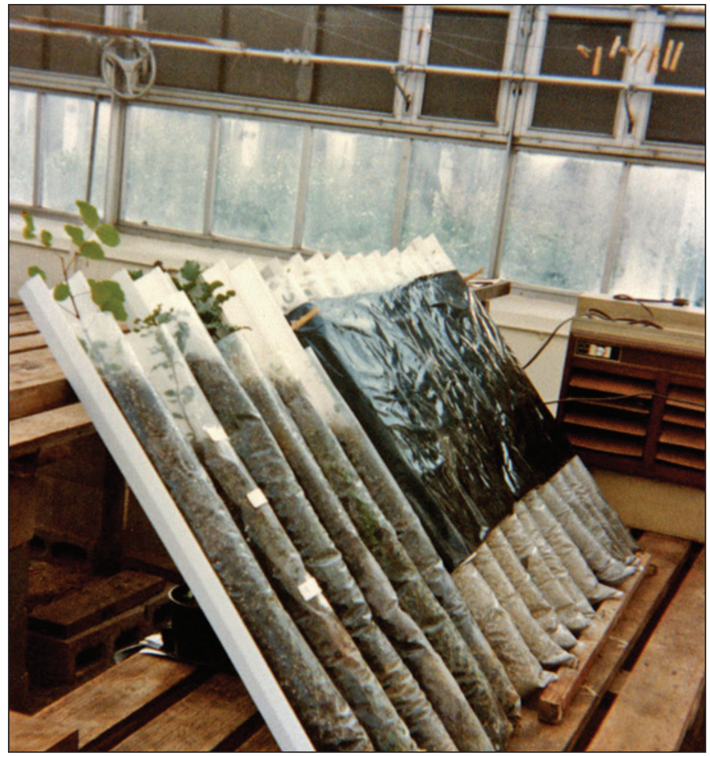

Figure 7. Plastic tubes can aid researchers in observing root development of dryland plants. (Photo by David Bainbridge)

are hard seeded and rely on flood events or artificial means for scarification and subsequent germination. The developing seedling taproot must then keep up with the soil's drying front. The rate of taproot growth for these species can be quite impressive and highlights the need for tall containers. A velvet mesquite (*Prosopis velutina* Wooton) root grew 51 mm in 12 h at 32.5 to 34.0 °C (Cannon 1917).

The pattern of root and shoot development in dryland trees and plants is often very conservative, with root-to-shoot ratios of 5:1 or much higher (figure 6). For example, 2.5-cm-tall seedlings may have roots 100 cm deep. Root growth can be assessed using 6-ml polyethylene plastic tubes (ULine, Pleasant Prairie, WI) filled with a growing medium and laid in a steeply inclined gutter section (figure 7). Observing root-growth rates can be very instructive and help determine the preferred medium and moisture for container production.

Protecting and encouraging taproot development for many dryland species in the nursery demand tall containers. When planted in areas with deep sand or soil (no caliche layer), plants grown in tall containers have improved survival compared with those grown in shorter containers (Bainbridge 2007). A wide variety of tall containers have been used with success, such as 15- by 81-cm pots at Joshua Tree National Monument (now Park) native plant nursery at Twentynine Palms, CA (Rodgers 1994) and 10- by 100-cm slit pipes developed at the Los Lunas Plant Material Center at Los Lunas, NM (Dreeson and Fenchel 2014). Treepots™ (figure 8) come in a variety of sizes and are easy to work with at relatively low cost. Taproot-dominant plants do not need a very wide container. Narrow containers also take up less space, use less planting media, and are easier to handle than wider containers.

Planting holes for seedlings grown with deep roots can be dug by hand or powered auger. A tractor-mounted auger is recommended. Outplanting should include addition of soil from healthy plants in the area to the planting hole to encourage colonization of beneficial mycorrhizal fungi (Allen 2007) and nitrogen-fixing rhizobial bacteria to help plants access water and nutrients. Woody legumes are a major source of nitrogen in many dryland ecosystems (Bainbridge 2007). Early investigators found

Figure 8. Treepots™ work well for production of deep-rooted plants to be outplanted to dry sites. (Photo by Laurie Lippitt)

few or no nodules while excavating the surface root systems, but deep drilling demonstrated that active nodules were common in deep soil (3 to 7 m) in the vadose zone just above the water table (Virginia et al. 1986). Root-eating nematodes have also been found at equally great depths (Freckman and Virginia 1989). Considering the deep-soil ecosystem in outplanting studies is important.

Further studies of deep-root development and deep-soil ecosystems are needed including development after outplanting from tall containers with and without wick irrigation. Such studies require labor-intensive excavation. Water jets can sometimes work better than shovels. Roots can also be studied with minirhizotrons (cameras that fit down clear tubes), dye, radioactive tracers, and more (Maeght et al. 2013).

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