Root:Shoot Ratios in a Changing Climate

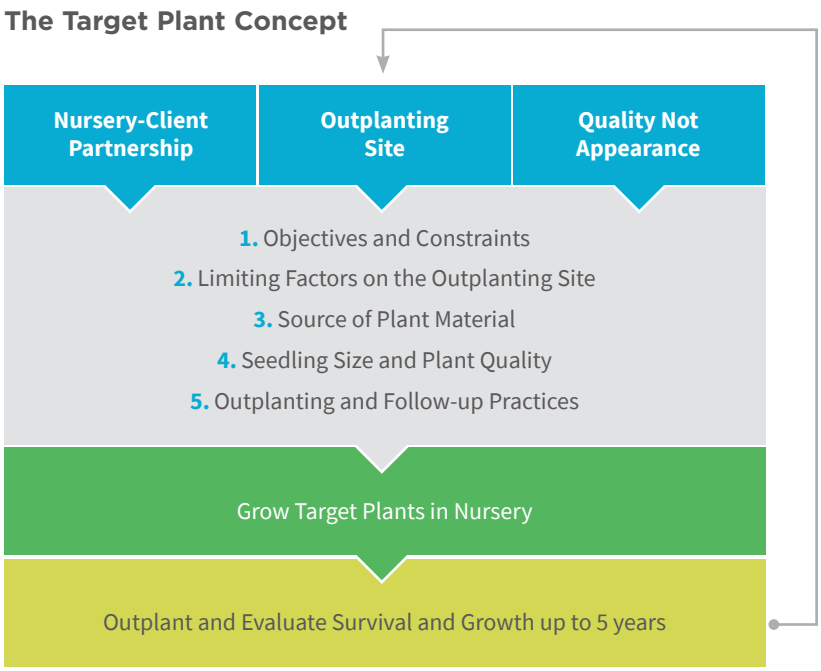
By Kayla Seaforth

A 2021 survey of restoration practitioners indicated that 56% of respondents were interested in learning more about root:shoot ratios and plant survival. Here, we look at this concept, and how it may factor into collaboration among growers and restoration practitioners.

The Root:Shoot ratio describes the amount of plant tissues that have supportive functions (root) relative to the amount of those that have growth functions (shoot), and is a proxy measurement for a seedling's above and below-ground performance, including photosynthesis, water and nutrient uptake. While standardized ratios can ensure quality plants, especially in large nursery contracts with multiple growers where millions of plants are sold and planted each season, some research has pointed to inconsistent utility of the specification when taken together with planting site characteristics, differences in species, and the nature of container vs. bare root stock types.

The implementation of root:shoot ratios has its basis in the Target Plant Concept (previously the Target Seedling Concept), which has gone through several iterations since it was developed in the first half of the 20th century. In addition to root:shoot ratio, other morphological characteristics including height and stem caliper and physiological characteristics like plant water potential, nutrient content and cold hardiness were prescribed to develop uniform seedlings for reforestation. These recommendations are rooted in a goal of promoting "fitness for purpose," that is, seedling metrics should be determined through collaboration between growers and outplanting site managers based on the goals of the site (reforestation, reclamation, afforestation, etc.). This concept served as a jumping off point for large scale nursery contract development in the Willamette Valley starting in the mid 2000s, and while they have undergone significant revisions, the blueprint developed nearly 75 years ago is still in use today.

FIGURE 1: *The target plant concept provides a framework to adapt growing and planting regimes to meet the needs of the outplanting site. It will be an important tool as sites change with the climate. Adapted from Landis, 2011.*



The Target Plant Concept is a framework for adaptive plant growth that relies upon regular communication between growers and practitioners, and regular monitoring of outplanting sites to inform future plant specifications. This framework tends to become both more important (in terms of potential losses if the feedback loop breaks down) and less detailed as scale increases due to the standardization that large scale operations prescribe. There is significant room for flexibility within the Target Plant Concept, as long as those engaged in the process have the time, willingness and resources to engage in the observation and dialogue necessary to inform beneficial change.

According to Forest Service Research Plant Physiologist and Tribal Nursery Specialist, Jeremy Pinto, "with larger contracts, that's where the communication piece comes into play. You're trying to leverage the strengths of the grower and the revegetation specialist. In building the [growing] targets, you could hone in on a lot

of different specifics in terms of optimizing plant material for a specific outplanting site, but as with anything you have to adjust with scale. If you think about the difference between local farming and mass produced farming it's the same thing."

He goes on to share how the Forest Service communicates with growers in the Coeur d'Alene, Idaho region, where collectively, nurseries produce 7.2 million seedlings per year for reforestation and research projects on federal lands. "The forest nursery in Coeur d'Alene has a client's meeting. Every year the Forest Service gets together with growers to talk about what's working and what isn't. This is really closing the Target Plant Concept loop in practice. It's human nature; we like to know how we're doing, how the puzzle pieces are fitting together."

As the restoration industry experiences and responds to climate change, some practitioners, researchers and growers are reexamining how they may adjust their expectations and standards. Naturally occurring root:shoot ratios vary from species to species, and as a response to site characteristics. A study of Douglas fir seedlings found that post-planting survival and root growth is largely dependent on Douglas-fir variety, stock type and site conditions. One finding of this study was a difference in root:shoot ratio after planting among coast and interior variety Douglas-fir, with coast varieties exhibiting reduced ratios and interior varieties showing higher root:shoot ratios. They also found that in bare root plants a high root:shoot ratio is negatively correlated with survivorship, and is positively correlated in container plants, which complicates the assumption that more roots are always better (Sheridan and Davis, 2021).

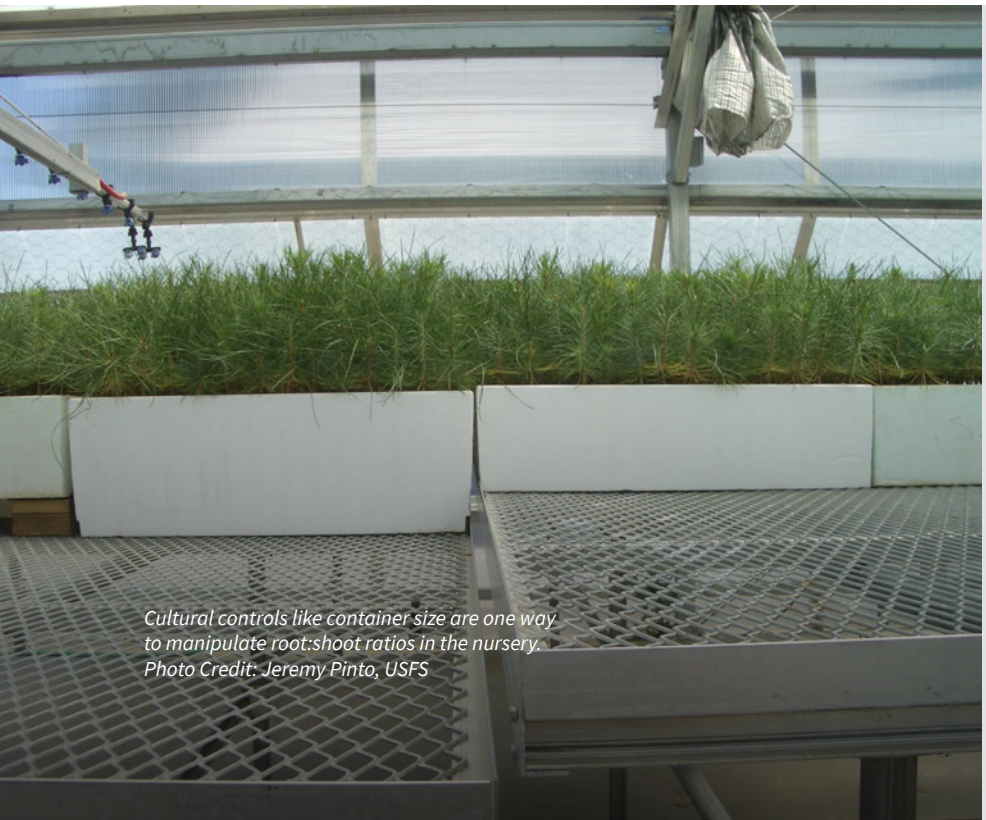
In addition to overall survival, conventional wisdom suggests that the larger a plant's root system is, the more drought tolerant it will be. However, the way that plants respond to environmental stressors varies greatly from species to species, and sometimes also varies between growing environments.

"When you're thinking about drought adaptation or dry planting scenarios, where you have high evapotranspiration demands, and the root system is what supplies the water, the thinking goes: the more roots we have, the more insurance that we have, but the way [plants] adapt and shift can be vastly different and understanding that is important. Some plants are capable of shifting and compensating much more rapidly than others.

There are certainly some population dynamics across species with climate and growing regimes. I had a student named Emily Rhoades, whose research will be published soon, looking at Wyoming big sagebrush from a broad regional distribution, all grown in a greenhouse under uniform propagation regimes, and the question was: "will these populations grow differently based on a uniform regime?" She had sagebrush from Idaho, Nevada, down into New Mexico. The root:shoot expressions in these greenhouse regimes ended up being completely opposite of what we would have expected; the [sagebrush] from New Mexico is a little more top heavy than the [sagebrush] from Idaho. The growing seasons are much different, with vastly different moisture regime cycles, which might affect the root expressions."

—Jeremy Pinto, USFS

The scale of the climate crisis, biodiversity loss and deforestation is enormous, and requires a mighty response. It is wise to remember though, in this herculean effort to protect and restore different forest systems, that one of the greatest tools that we can lean on is the simple act of talking to and learning from one another. It is tempting to prescribe uniform growing metrics so nurseries can standardize and scale their operations to meet this great need, but what might be better is an adaptive approach that emphasizes monitoring and communication. The truth is, we don't know what plant specs will perform best in future conditions, and nimbleness will be essential in responding to new information.



Cultural controls like container size are one way to manipulate root:shoot ratios in the nursery. Photo Credit: Jeremy Pinto, USFS

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