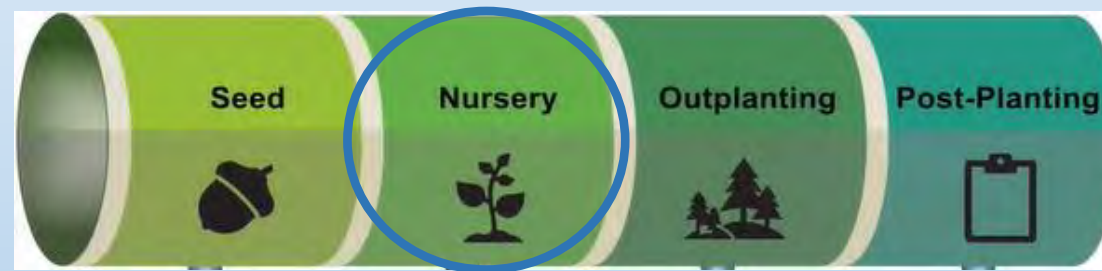


# Establishing a Sustainable Seedling Supply:

## Economic, Environmental and Social Challenges for Nurseries



Nabil Khadduri (nabil.khadduri@dnr.wa.gov)

The Reforestation Pipeline in the Western United States

September 27-29, 2022

Missoula, MT



Intermountain  
Container  
Seedling  
Growers

# Seedlings are Sexy!



Nabil Khadduri (nabil.khadduri@dnr.wa.gov)  
The Reforestation Pipeline in the Western United States  
September 27-29, 2022  
Missoula, MT



Intermountain  
Container  
Seedling  
Growers

# Seedlings are Having a Moment



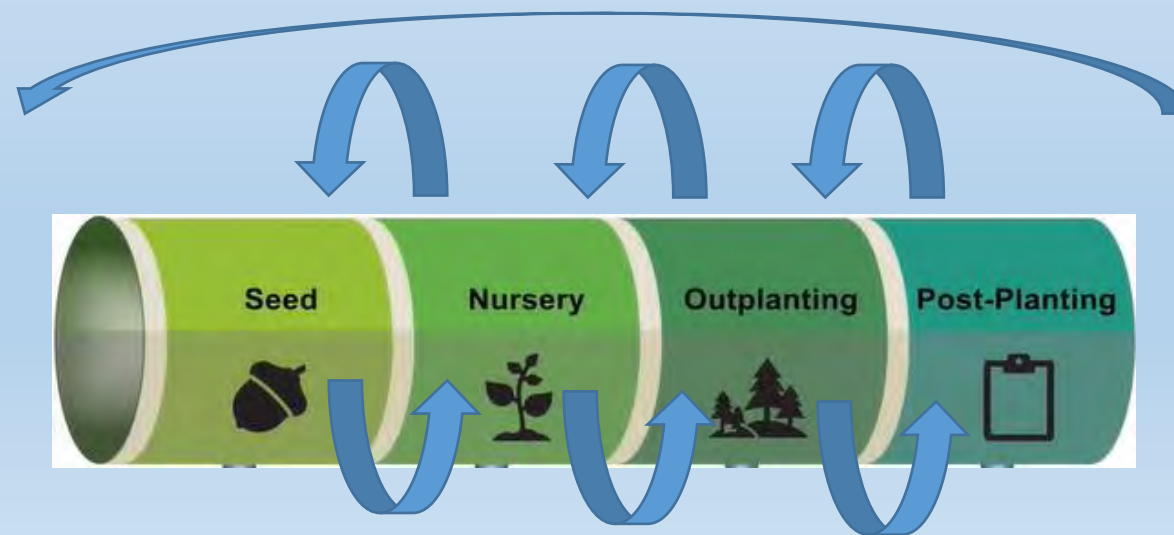
Nabil Khadduri (nabil.khadduri@dnr.wa.gov)  
The Reforestation Pipeline in the Western United States  
September 27-29, 2022  
Missoula, MT



Intermountain  
Container  
Seedling  
Growers

# Outline

- Part 1: How nurseries can improve seed use efficiency
- Part 2: How nurseries can recruit and retain their workforce
- Part 3: How nurseries can strengthen end-user partnerships



# Part 1: How nurseries can improve seed use efficiency



# WADNR Webster Forest Nursery



70% Douglas-fir  
seedlings

2-3 million  
plugs/year

6 million  
bareroot/year

Additional spp.:

W redcedar

W hemlock

W larch

Ponderosa pine

Interior DF

True firs

W white pine

Lodgepole pine

Sitka spruce

Red alder

# Nursery adjacent to Seed Center

Cold storage

\$9MM seed  
inventory



Seed  
processing  
and lab  
testing



# Space efficiency vs. seed use efficiency



Greenhouse space is expensive...



...but so is this!



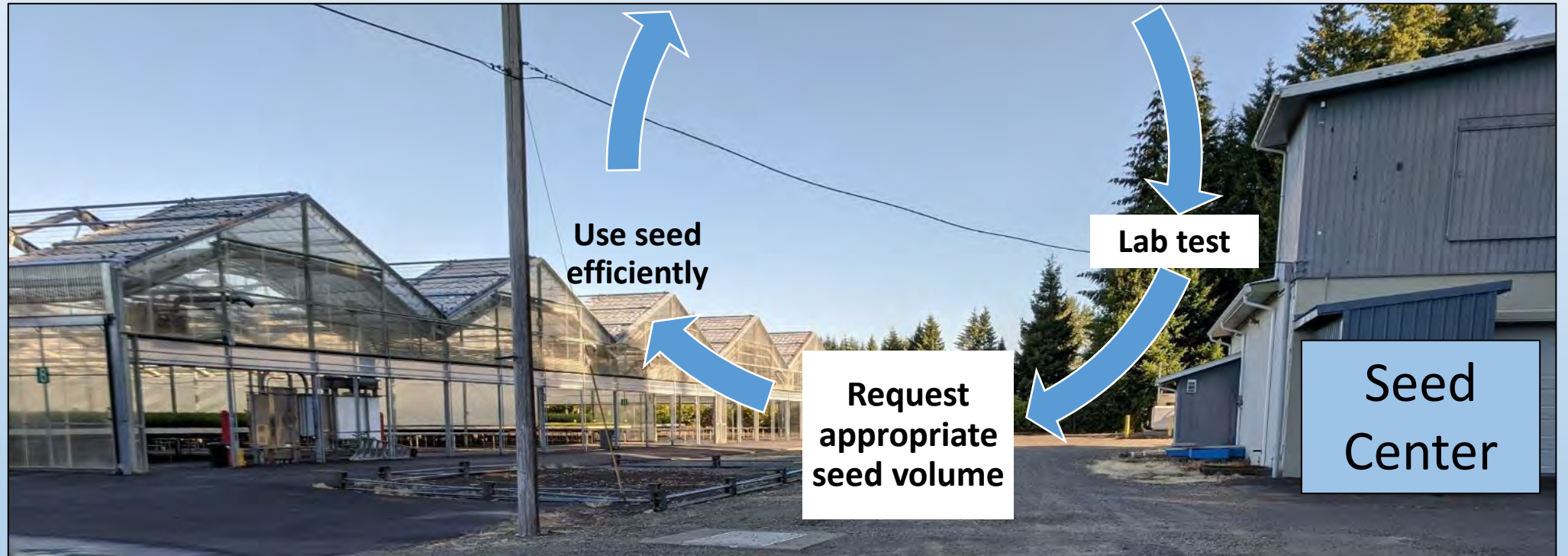
# Proximity facilitates exchange of ideas

We need high germ, clean seed!

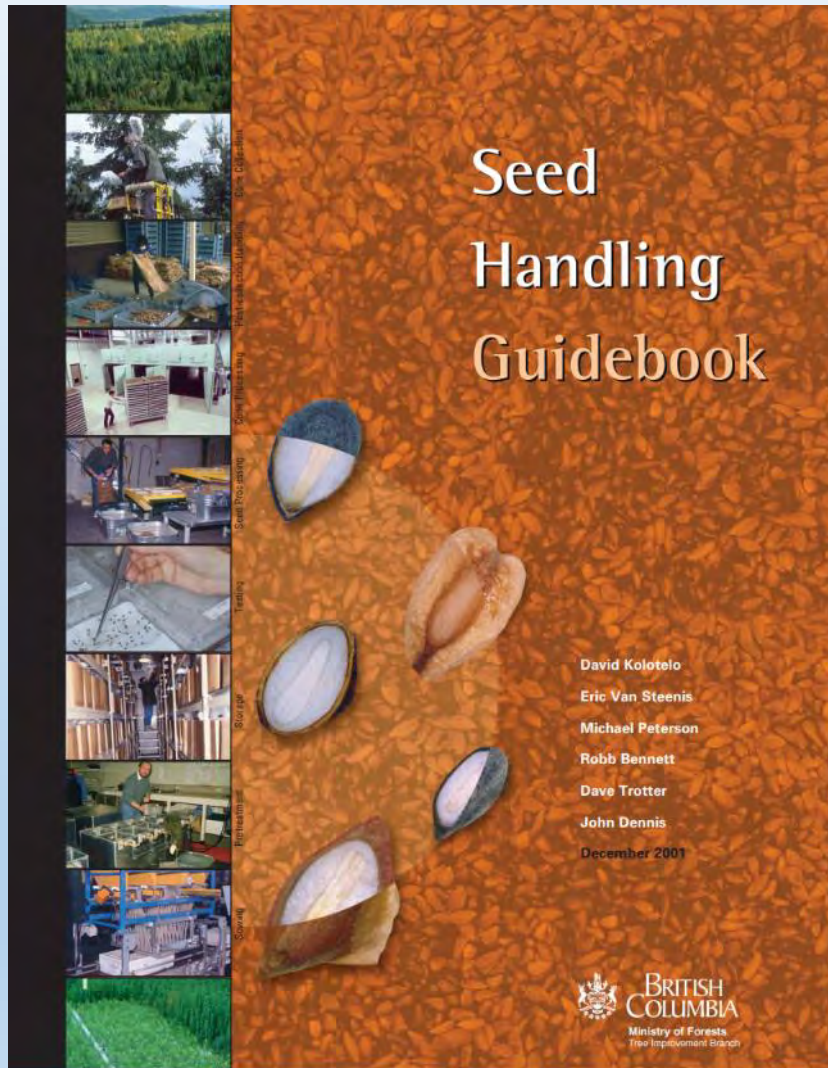
We need the nursery to use seed efficiently!

Analyze seed use

Process high germ, clean seed



# Sowing guidelines in nurseries



Kolotelo, D. et al. 2001  
BC Ministry of Forests

Tech updates in Tree Seed  
Working Group Newsbulletin  
(Canadian Forest Genetics  
Association)

Calculating seeds requested per seedling:  
(sowing factor\*oversow factor) + (NHF\*OF)



- **Germination capacity:** for example, 90%
- **Sowing factor:** 2.0 seeds per cell at 90%  $(0.9) = (0.1 \times 0.1) = 0.01$
- **Empty cells expected:** 1.0%
- **Green stem count:** example 125% green stems to pack 100% of order
- **Oversow factor (OF):** green stem count, taking into account expected empty cells (with empties, oversow at 127%)
- **Nursery handling factor (NHF):** 0.2 (extra seeds required by nursery to account for sowing inefficiencies)

**13% rule:** For every 13% drop in germination capacity, expect a grower to request roughly 1 additional seed per cell

Germination %	Sowing factor (seeds/cell)	Empty cavities (%)	Seeds per seedling
90	2.0	1.0	2.8
77	3.0	1.2	4.0
64	4.0	1.7	4.8

# Why does grower ask for x # of seeds over request?

Germ %	Sowing factor	Empty cavities	Nursery handling factor	Desired green stem count (%)	Oversow factor (# extra cavities to sow)	Seeds per seedling
90	2.0	1.0	0.20	125	127%	<b>2.78</b>

Fractional sowing?

How valuable is space?

How accurate is germ test, falldown from lab to greenhouse?

How precise is sow line at placing correct # seeds/cell?

Skill of grower/species challenge to meet specs?

# How can we reduce the number of seeds used per seedling produced?

- Determine lab vs. nursery germination values
- Apply germination techniques
- Invest in sowing line upgrades
- Value the importance of growers



# Why do lab and greenhouse germ results differ?

## Lab testing

- Controlled environment
  - 8hr/16 hr day/night, 86°F/68°F
  - Only seedborne pathogens
  - Germination: radicle extension 4x length of coat
  - 4 reps of 100 seed

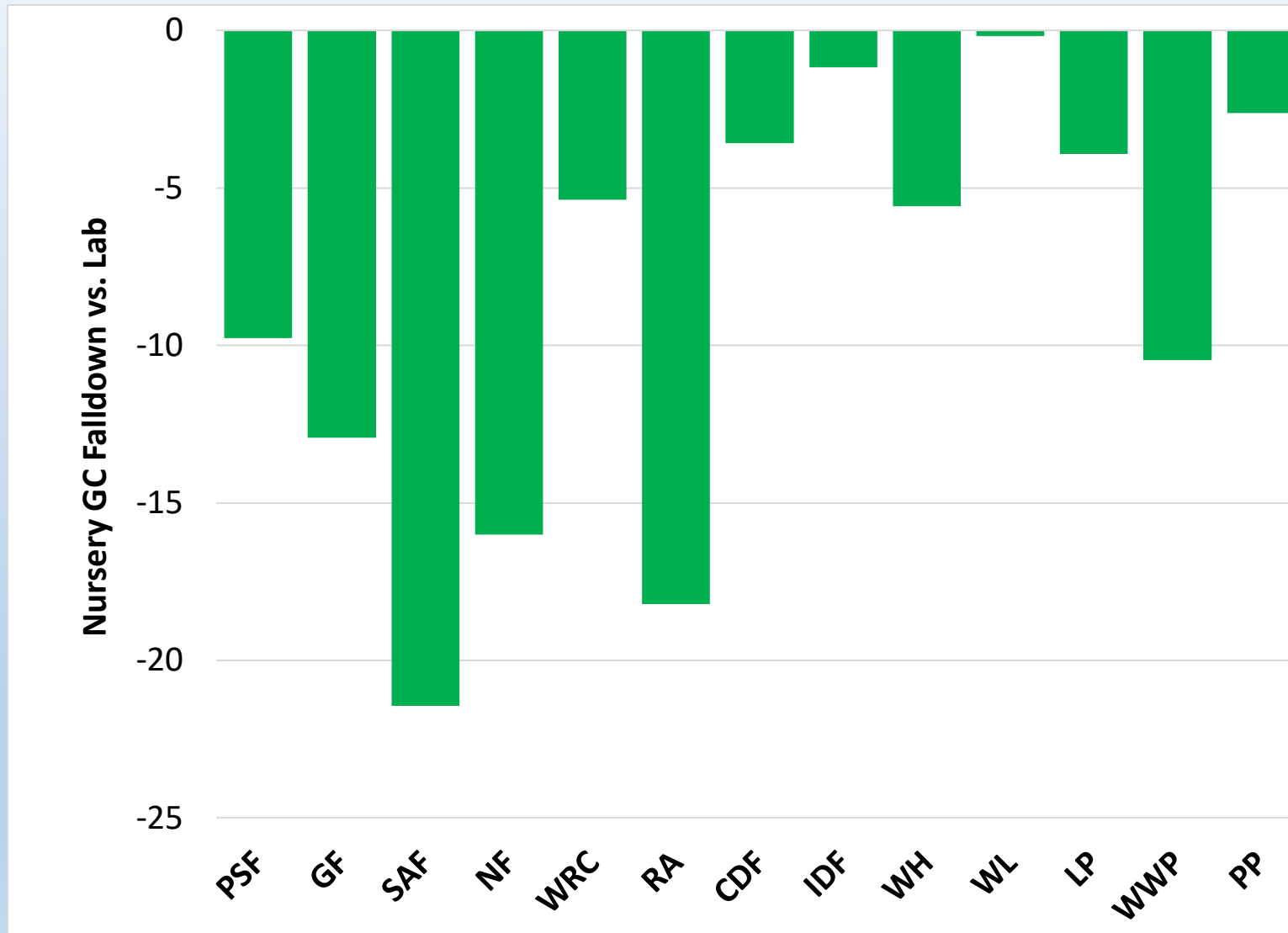


## Greenhouse evaluation

- Semi-controlled environment
  - Temperature and irrigation variation
  - Additional pest pressures
  - Germination called later
  - Media, seed depth can vary
  - Variability in tracking



# Nursery germ capacity usually lower than lab





# Methods to improve operational germination

- Seed sanitation
- Targeted moisture content
- Extended stratification
- Delayed dryback
- Mid-strat high-grading
- Thermal priming



Surface drying



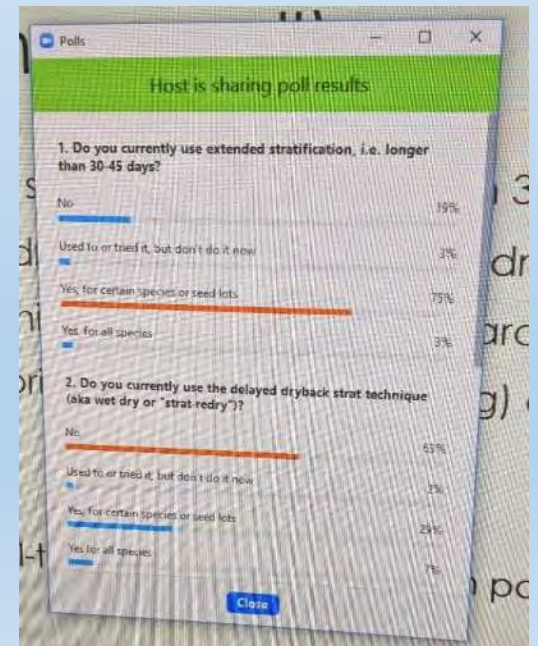
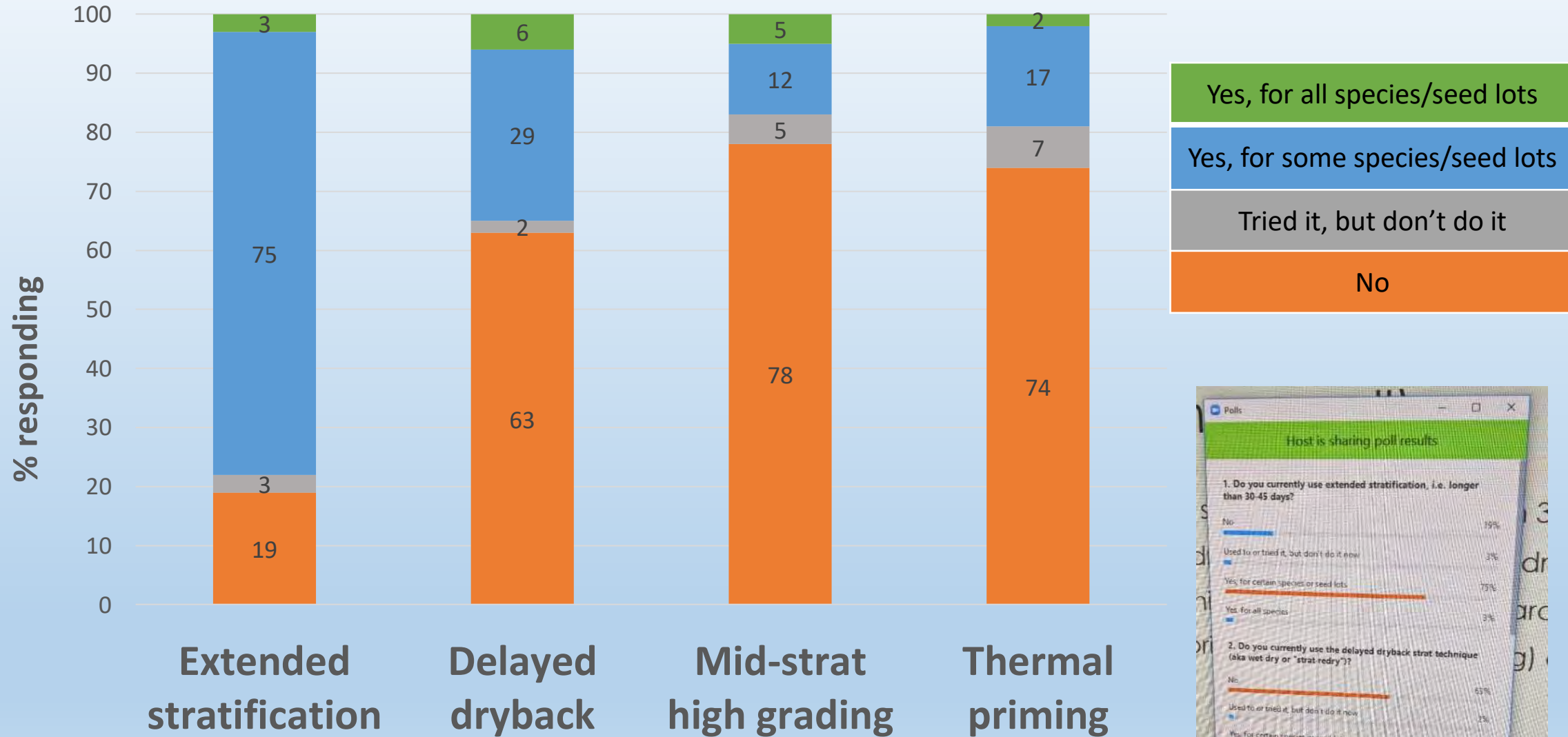
High-grading



Thermal priming

Dawes

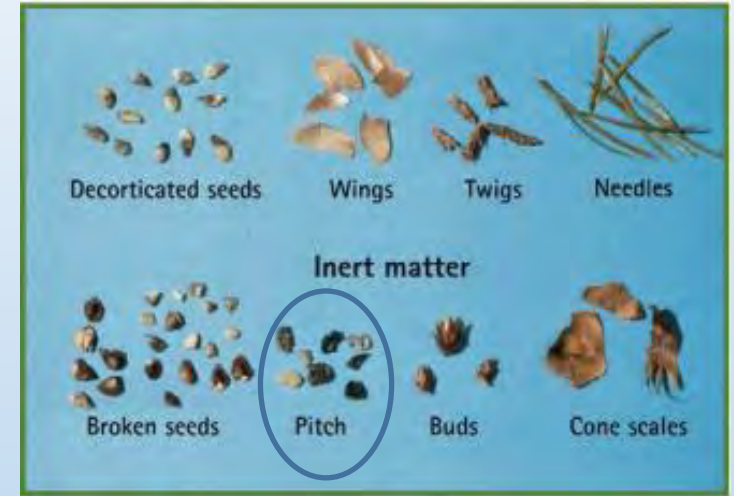
# n = 59 US and Canadian respondents during 2020 webinar live poll



As value of seed increases, so should sowing equipment



B&L needle seeder



Clean seed particularly important for automated sowing

# Experienced and skilled operator for advanced equipment



Mosa drum seeder



# Many strategies for how a lot may be sown

- Some will conserve space (increase seeds/cell)
- Some will conserve seed (single or fractional sowing)



# Many strategies for how a lot may be grown

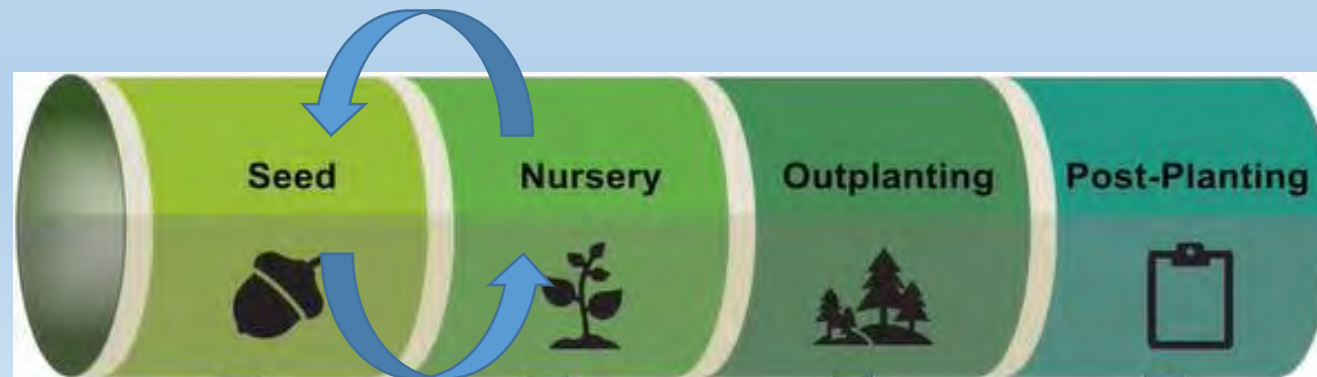
Experienced and skilled grower more likely to achieve contract specs

- Species
- Seedlot history
- Container size
- Greenhouse style



# Takeaways: seed use efficiency

- In the reforestation pipeline, from seed production to post-planting, the greatest opportunity to improve seed use efficiency is at the nursery
- A nursery can best improve seed use efficiency when active and ongoing feedback exists with its seed supplier: exchange germination data
- Along with equipment investments, sowing, germination and growing techniques will help conserve seed



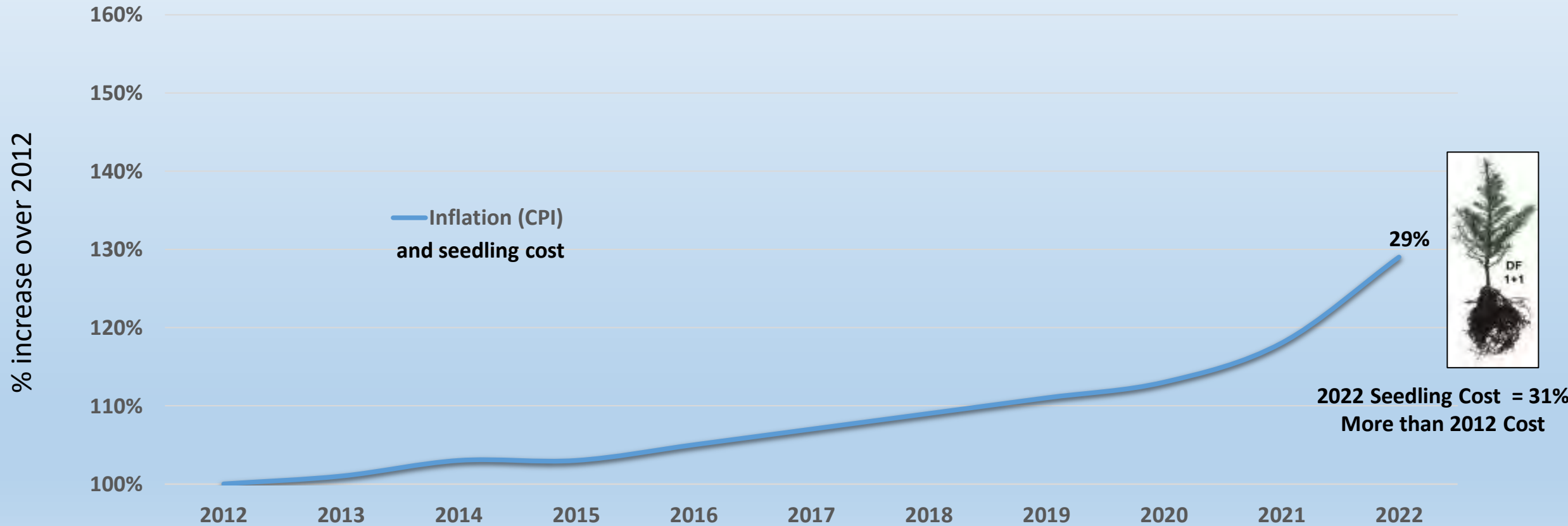
## Part 2: Recruiting and retaining nursery staff



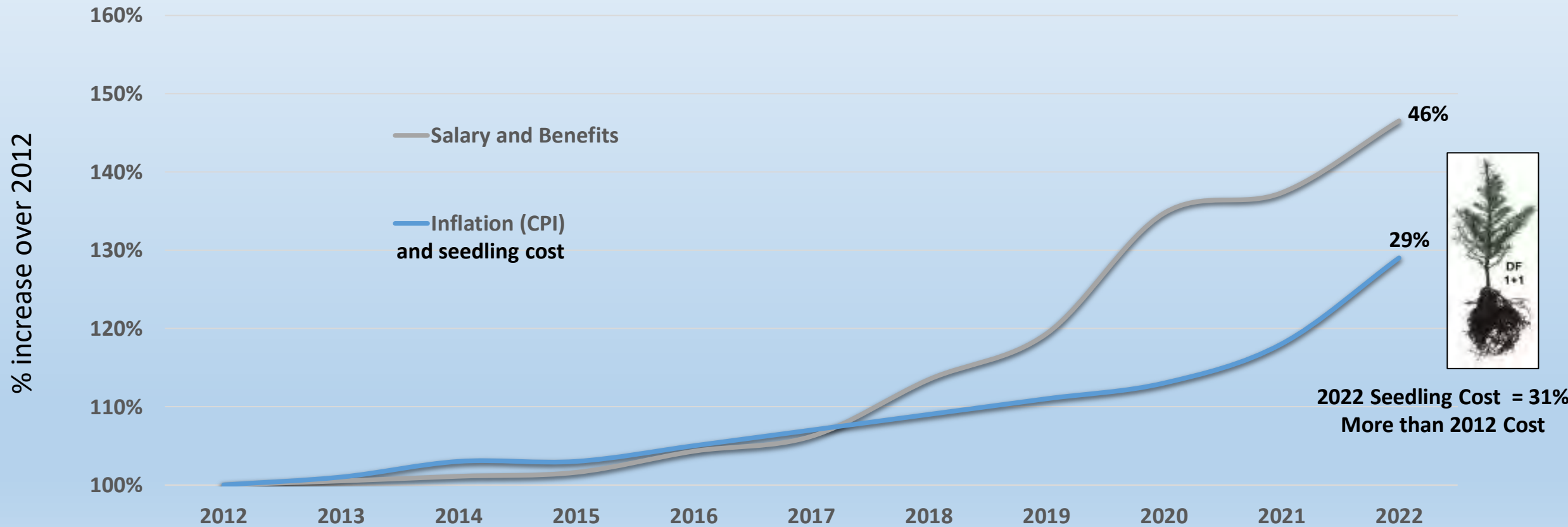
- Recruitment through pay
- Cast wide net for internship programs
- Reward and retain employees through continuing education



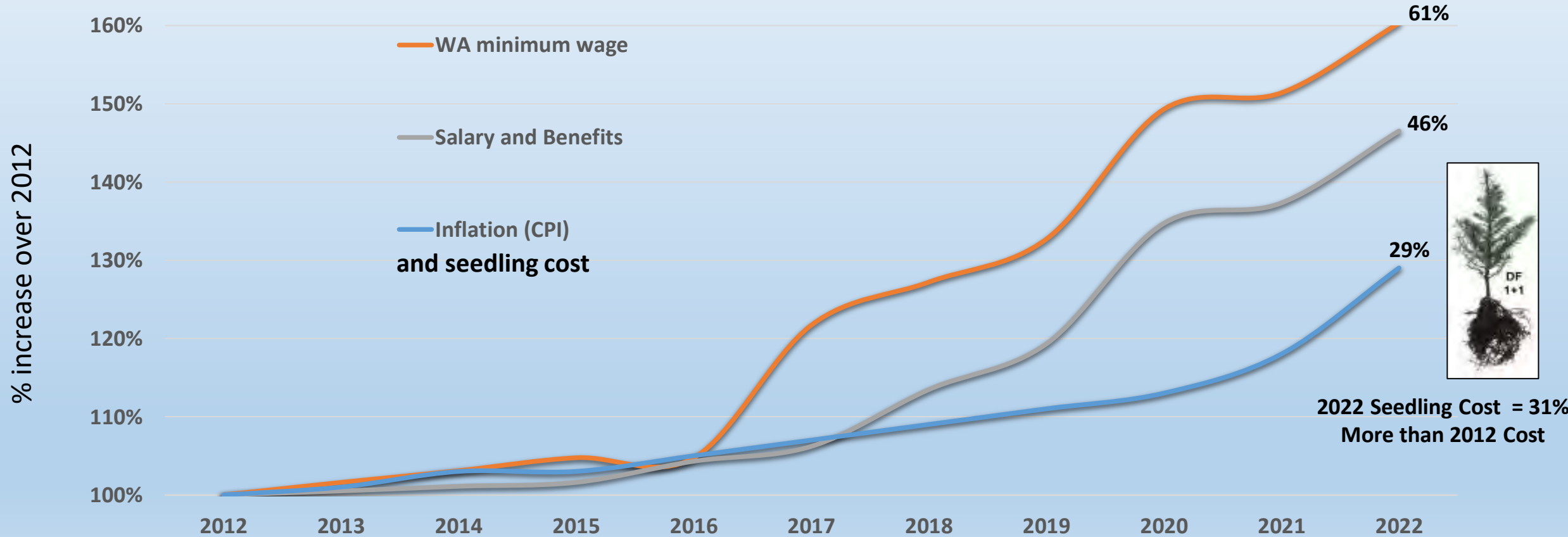
# WADNR nursery wages are increasing faster than inflation and seedling prices



# WADNR nursery wages are increasing faster than inflation and seedling prices

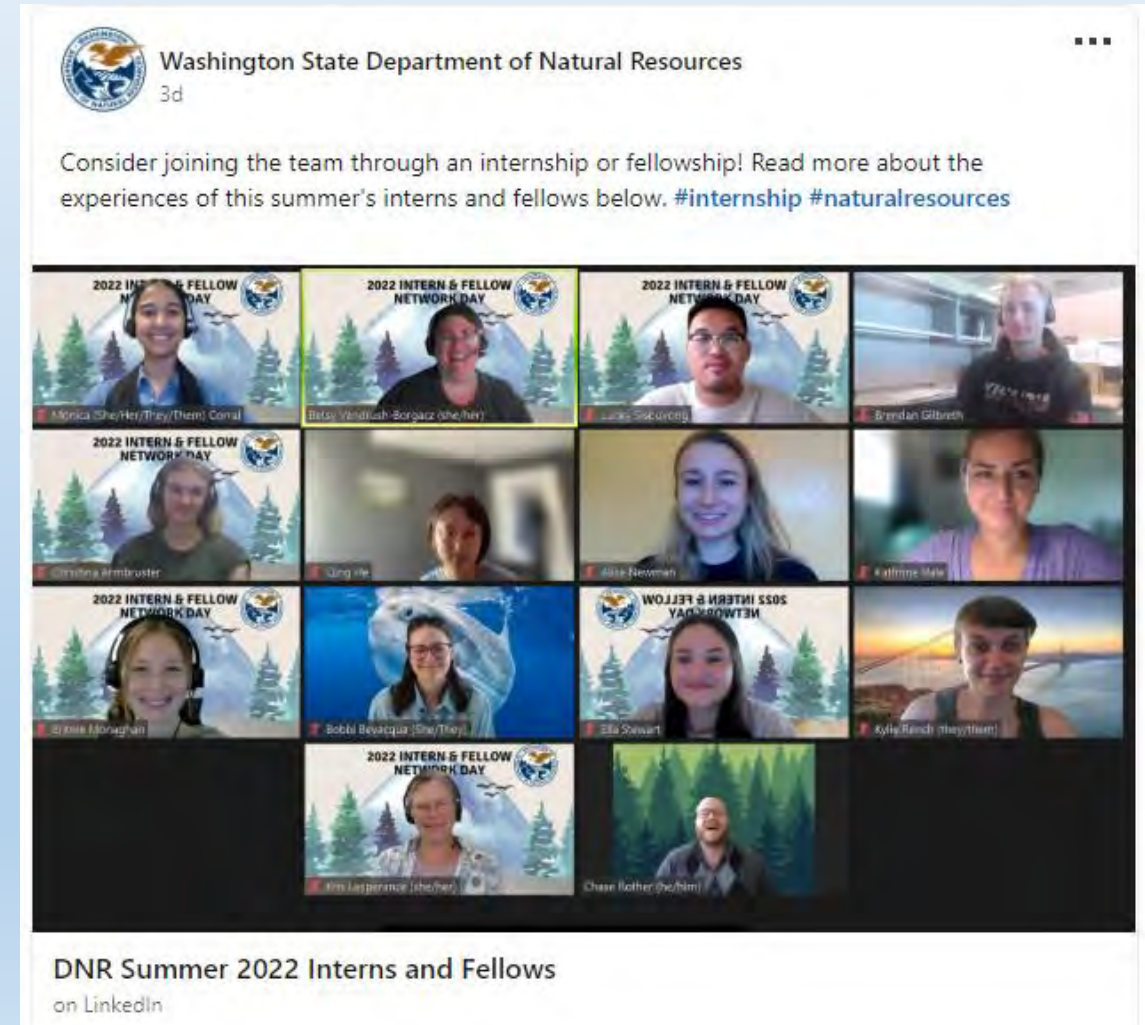


# WADNR nursery wages are increasing faster than inflation and seedling prices



# Recruit students through intern programs

- Need to market through competitive internships (hourly rate, housing stipend)
- Extended two-way interviews:
  - Is this someone we really want?
  - Is this a place I want to work?

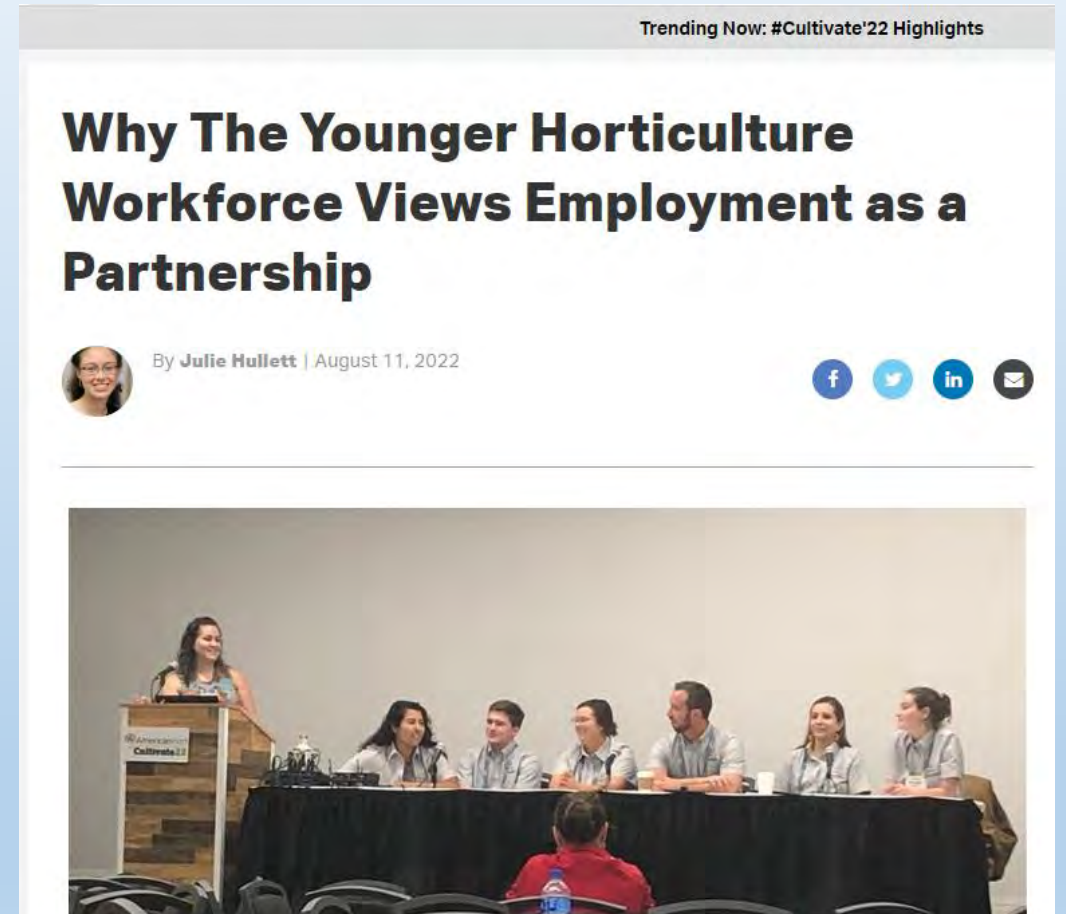


# A two-way relationship

**“The younger generation in today’s workforce will be loyal to their employer, but they expect their employer to build a positive work environment and help them reach their goals.”**

**If you don’t give them the same amount of energy, they will quit,” Knuth said of the younger members of the workforce. “It’s a partnership and they will be loyal to you.”**

-Dr. Melinda Knuth of North Carolina State University



Greenhouse Grower, August 2022

# How do we reward and retain employees?

- Competitive wage
- Not in it for the money, rather for the cause - our best selling point
- Continuing education can show that you care about current employees' development



# Some suggested continuing ed resources

- RNGR website
- Online U of Florida/MSU extension greenhouse courses and [backpocketgrower.org](http://backpocketgrower.org) website/app
- New U of Idaho A.S. Degree in Forest Nursery Management and Technology, some courses may be offered in hybrid format
- 2018 Extension hort publication: Water, Root Media, and Nutrient Management for Greenhouse Crops
- Other hort industry print and online resources



RNGR is a leading source of technical information for nurseries and land managers regarding production and planting of trees and other native plants for reforestation, restoration, and conservation.

## Popular Resources

- [National Nursery and Seed Directory](#)
- [Intertribal Nursery Council](#)
- [Subscribe to Tree Planters' Notes](#)
- [Native Plant Network](#)
- [Webinars](#)
- [Employment and Education Opportunities](#)

## Upcoming Events



### The Reforestation Pipeline in the Western United States

Missoula, MT  
September 27<sup>th</sup> – September 29<sup>th</sup>

For more information, [click here](#).

## Webinar Series

- **2021 Root Development Symposium**  
October 19<sup>th</sup> – October 21<sup>st</sup>, 2021
- **2021 Northern Forest Genetics Association Zoom Meeting**  
September 8<sup>th</sup> – September 9<sup>th</sup>, 2021

## Publications

- **Tree Planters' Notes**

This publication is dedicated to technology transfer and publication of research information relating to nursery production and outplanting of trees, shrubs, and native plants for reforestation, conservation, and restoration.

- **A Nursery Guide for the Production of Bareroot Hardwood Seedlings**

This guidebook is designed to provide an overview of topics related to the bareroot production of hardwood tree seedlings. It is highly revised from the previous guidebook published in 1994 (Agricultural handbook No. 473).

- **The Container Tree Nursery Manual**

This seven volume set provides a comprehensive overview of topics concerning the production of tree and woody shrub seedlings in containers.

- **Tropical Nursery Manual**

*A Guide to Starting and Operating a Nursery for Native and Traditional Plants*

This comprehensive manual serves people who are starting or operating a nursery for native and traditional species in the tropics. Key concepts, principles, and processes are presented, based on proven practices and the best science available.

- **The Woody Plant Seed Manual**

General principles such as seed biology, harvesting, storage, testing as well as nursery practices.

---

*RNGR.net includes a repository of approximately 12,000 searchable and downloadable articles relevant to nursery production, seedling quality, reforestation, tree improvement, germplasm conservation, and native plant restoration. Click [here](#) for more publications.*



# Extension short courses: \$250/4-5 wks



## Course Subjects/Temas de los Cursos

Title/Titulo	Level/Nivel
Greenhouse 101/Invernadero 101	1
Disease Management/Manejo de Enfermedades	2
Nutrient Management 1 (Intro)/Manejo de Nutrientes 1 (Introdutorio)	2
Weed Management/Manejo de Malezas	2
Costing and Profitability/Costos y Rentabilidad	3
Nutrient Management 2 (Advanced)/Manejo de Nutrientes 2 (Avanzado)	3
Irrigation Water Quality and Treatment/Calidad y Remediacion de Agua	3

# Backpocketgrower.org

- Free
- Referenced often in classes, stands alone
- University and industry-supported
- Practical, updated

The screenshot shows the mobile application interface for Back Pocket Grower. At the top, there is a navigation bar with the title "Back Pocket Grower" and icons for back, home, and search. Below the navigation bar, there are two tabs: "Tools" (selected) and "Training". The main content area is titled "Interactive tools" and includes the subtitle "Supporting your decisions with calculators and research". The tools are organized into several categories:

- Nutrient solutions - Soluciones de nutrientes**
  - ppm to fertilizer recipe - ppm a receta de fertilizante
  - Fertilizer recipe to ppm - Receta de fertilizante a ppm
  - Convert between NPK and N-P2O5-K2O - Convertir entre NPK y N-P2O5-K2O
  - Nitrogen form effect on pH - Efecto de forma de nitrógeno en pH
- Substrates - Sustratos**
  - Substrate cost and volume - Costo y volumen de sustrato
  - Substrate volume for paper pots - Volumen de sustrato para macetas de papel
- Economics of production - Economía de la producción**
  - Crop budget with overhead by area weeks - Presupuesto del cultivo con gastos generales por area por semana
  - Crop budget with overhead by container units - Presupuesto del cultivo con gastos generales por unidades de macetas
- Climate - Clima**
  - Daily Light Integral - Luz Diaria Integral

Each tool entry features the UF IFAS Extension logo and a right-pointing arrow. The bottom of the screen has a navigation bar with links for "About", "Legal", "Search", and "Sign in".

# Plant health certificate program

- Nutrient management 1 (UF)
- Disease management (UF)
- Weed management (UF)
- Water quality and treatment (UF)
- Abiotic disorders (MSU/University of Kentucky)
- Biological control (MSU/Kansas State University)



UF | UNIVERSITY of FLORIDA

 MICHIGAN STATE UNIVERSITY

MSU Extension  
Online College of Knowledge

# U of I Associates Degree

## A.S. Curriculum – Forest Nursery Management & Technology

Required course work includes:

Course No.	Course Name	
• ENGL 101	Writing and Rhetoric I	• FOR 152* Careers in Forest Nursery Management & Technology
• ENGL 102	<i>Writing and Rhetoric II</i>	• FOR 153* Forest Nurseries Tour
• COMM 101	<i>Fundamentals of Oral Communication</i>	• PLSC 201 Principles of Horticulture
• CHEM 101/101L	Introduction to Chemistry and Lab	• FOR 206* Properties of Artificial Growth Media
• SOIL 205	The Soil Ecosystem	• FOR 220 Forest Biology and Dendrology
• SOIL 206	<i>The Soil Ecosystem Lab</i>	• FOR 251* Nursery Insects and Disease
• MATH 123 or	Math in Modern Society or	• ASM 112 Introduction to Agricultural Systems Management
• MATH 143	College Algebra	• FOR 255 Nursery Irrigation and Fertilization
• ECON 201 or	Principles of Macroeconomics or	• LARC 288 Plant Materials and Design 1
• ECON 202	Principles of Microeconomics	• PLSC 300 Plant Propagation
• MKTG 321	Marketing	• FOR 257* Sustainable Nursery Design and Management
		• FOR 298* Forest Nursery Internship



University of Idaho

Center for Forest Nursery and Seedling Research

# U of I Hybrid Option/Extension Courses?

- Careers in Forest Nursery Management and Technology
- Properties of Artificial Growth Media
- Nursery Insects and Disease
- Sustainable Nursery Design and Management



**University of Idaho**

**Center for Forest Nursery and Seedling Research**

# Water, Root Media, and Nutrient Management for Greenhouse Crops

- Merhaut, Williams and Mangiafico, editors, UC Press
- 17 extension hort and industry authors
- Very applied, up-to-date and practical knowledge
- \$52-\$65, also available as ebook, preview chapter available online



**Water, Root Media, and Nutrient  
Management for Greenhouse Crops**



DONALD J. MERHAUT, KIMBERLY A. WILLIAMS, and SALVATORE S. MANGIAFICO, Editors



Publication 3551

**University of California**  
Agriculture and Natural Resources



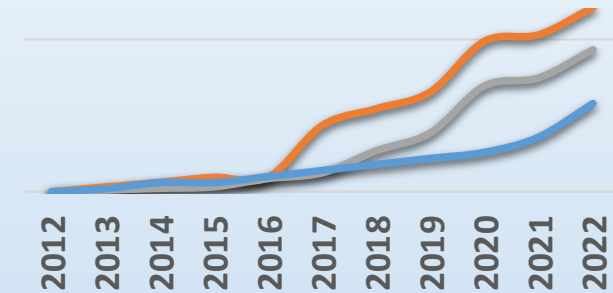
# GROWERTALKS



- Latest methods, technologies, and trends in horticulture
- Articles, webinars by industry and university experts
- Excellent search function of past articles

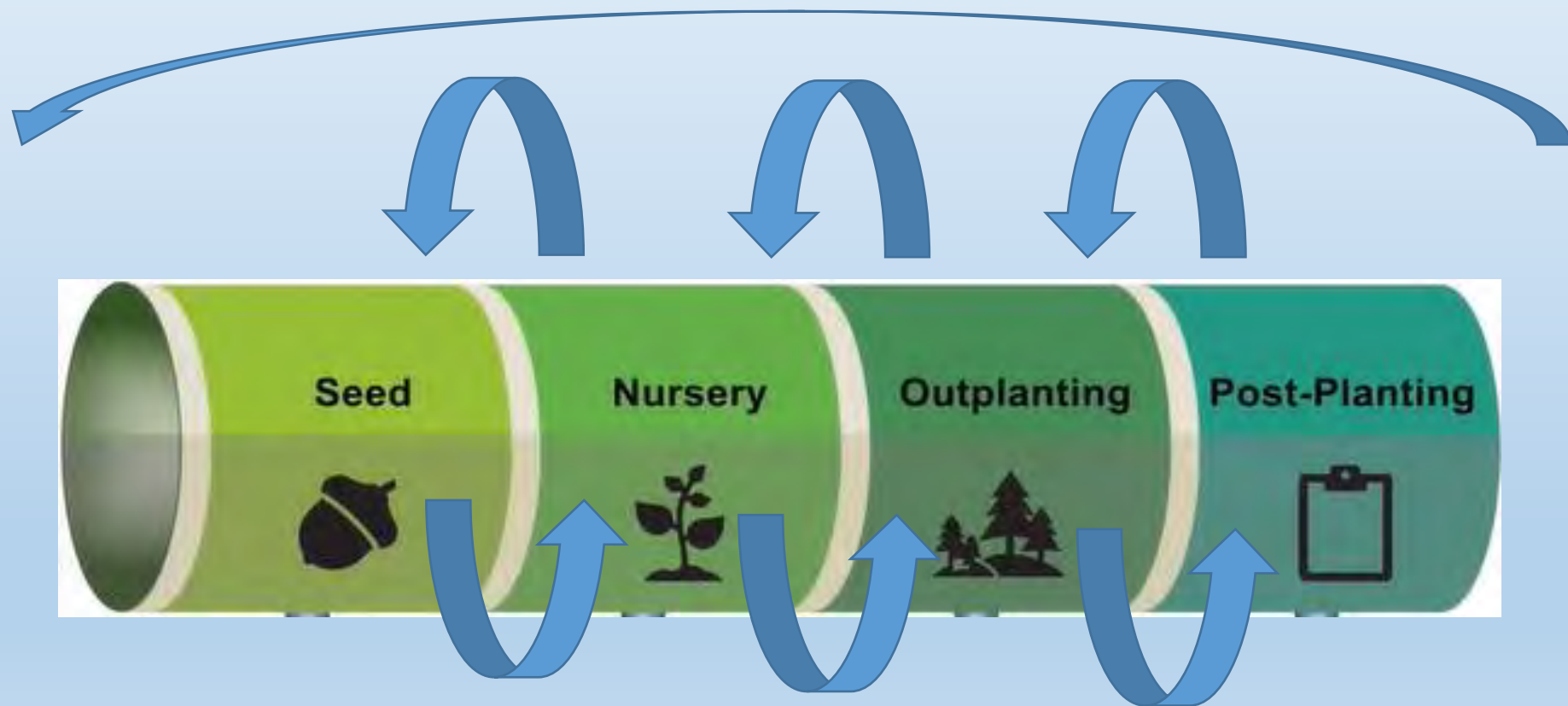
# Takeaways: nursery recruitment and retention

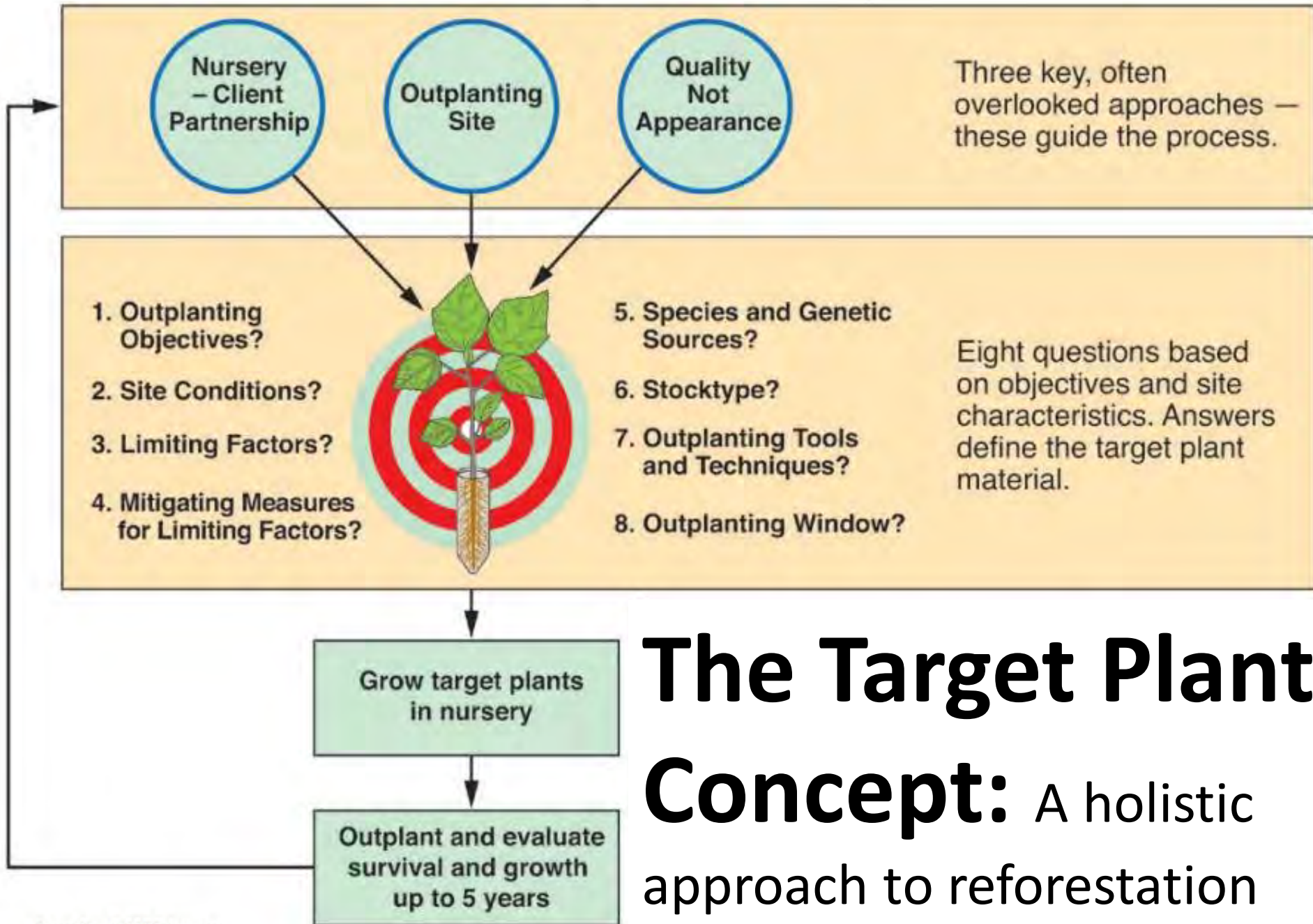
- Reforestation nursery sector has to keep up with competitive wages, seedling prices will need to keep up as well
- Workforce is more mobile than ever, how will you build a lasting partnership?
  - Invest in prospective employees through competitive internships and other recruiting mechanisms
  - Reward and retain existing employees by offering continuing education opportunities





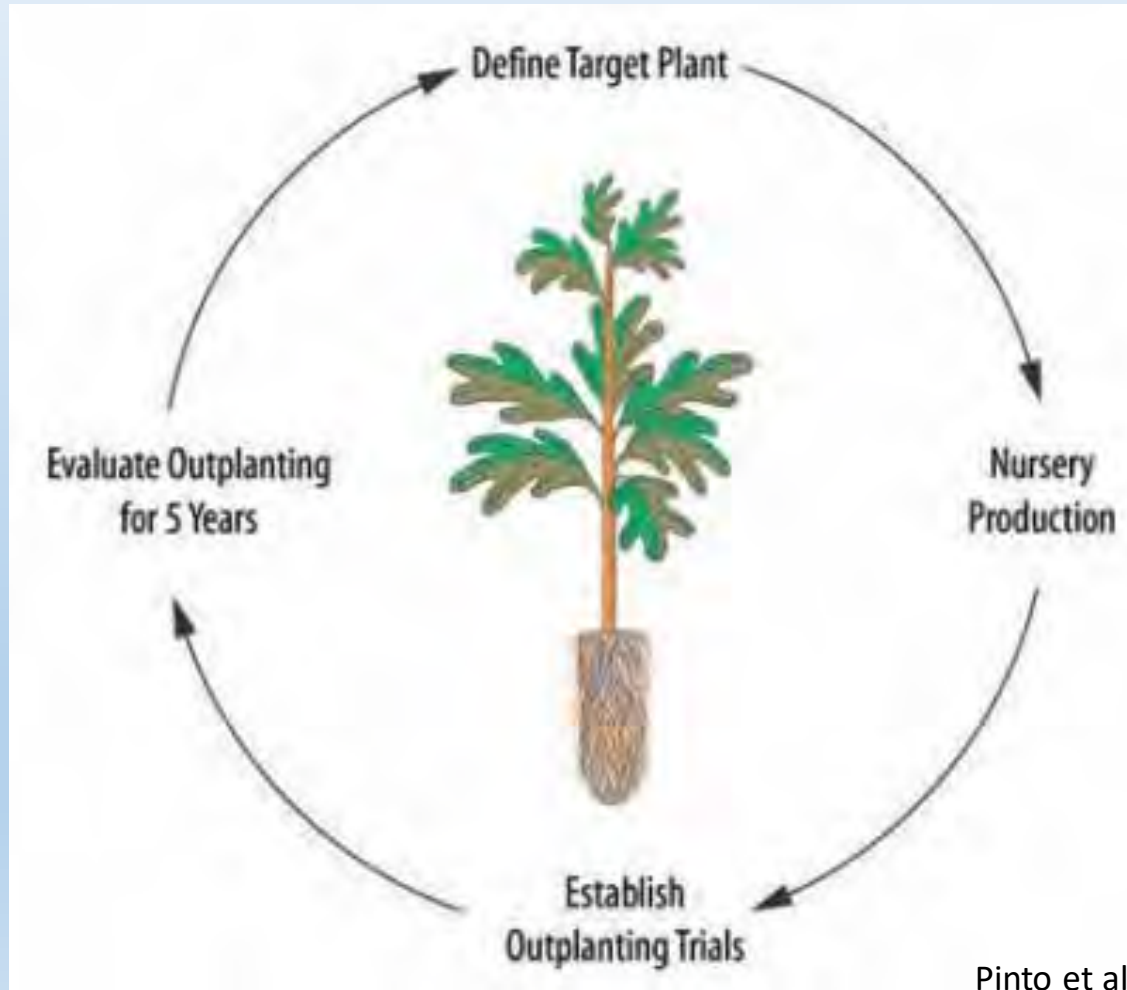
# Part 3: How nurseries can strengthen end-user partnerships: stocktype trials using a paper-wrapped plug vs. styroblock plug example





**The Target Plant Concept:** A holistic approach to reforestation

Target morphological and physiological characteristics that can be quantitatively linked to outplant success



# Bareroot

- Less expensive
- Longer timeframe
- More difficult to plant
- More vulnerable during shipping
- More root damage
- **More “natural” roots**

# Containers

- More expensive
- Shorter timeframe
- Easier to plant
- Less vulnerable during shipping
- Less root damage
- **More root deformation**

# Stocktype trials: can paper-wrapped plugs enhance outplant survival and growth vs. styroblock plugs?



Paper-wrapped plugs

Styroblock plugs



# What are paper-wrapped plugs?

- Use a degradable paper to wrap around a “tube” of growing media
- BCC Fibercell is a similar paper-style system



Because they are self-contained, plugs can sit loose in a container and be air-pruned the entire length



# Root structure



STANDARD PLASTIC POT



AIR TRAY®





# Compared to styroblock plugs:

- **More balanced root:shoot ratio?**  
evaluate at nursery
- **Higher root growth potential?**  
evaluate at nursery
- **Improved root architecture?**  
evaluate at nursery and field
- **Faster root establishment, improved survival/growth?**  
evaluate at field



# Paper-wrapped plug root properties will be highly influenced by the type of tray used

- Rigid trays optimize air pruning and potentially root structure, also:
- Heavy, \$\$, but sturdy, should last longer than styroblocks
- Can do deeper cells than thermoform
- Can only partially nest, nesting tray decreases shelf-life to around styroblock
- Higher cell density/sq ft than thermoform, approaching styroblocks



Rigid, injection molded tray



thermoform plastic tray



injection molded tray      thermoform plastic tray

Paper-wrapped plug root properties will be highly influenced by the quality of production



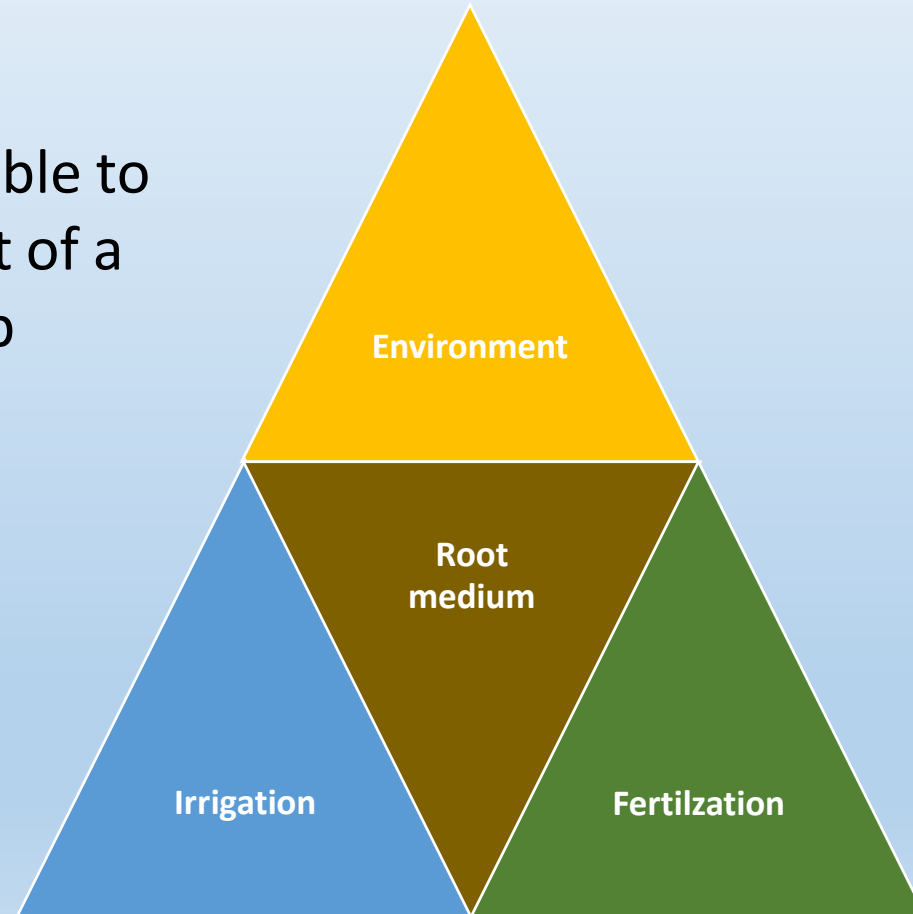
# How the sausage is made



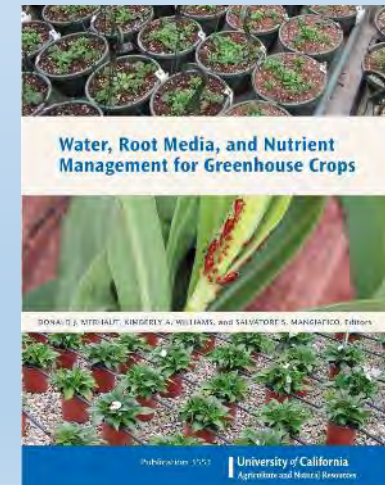
How more sausage is made

# Root medium is central to container growing

Match each variable to the requirement of a specific crop



**If one component is altered, crop requirements may necessitate a change in other components**



# Make sure to track soil media parameters during plug production

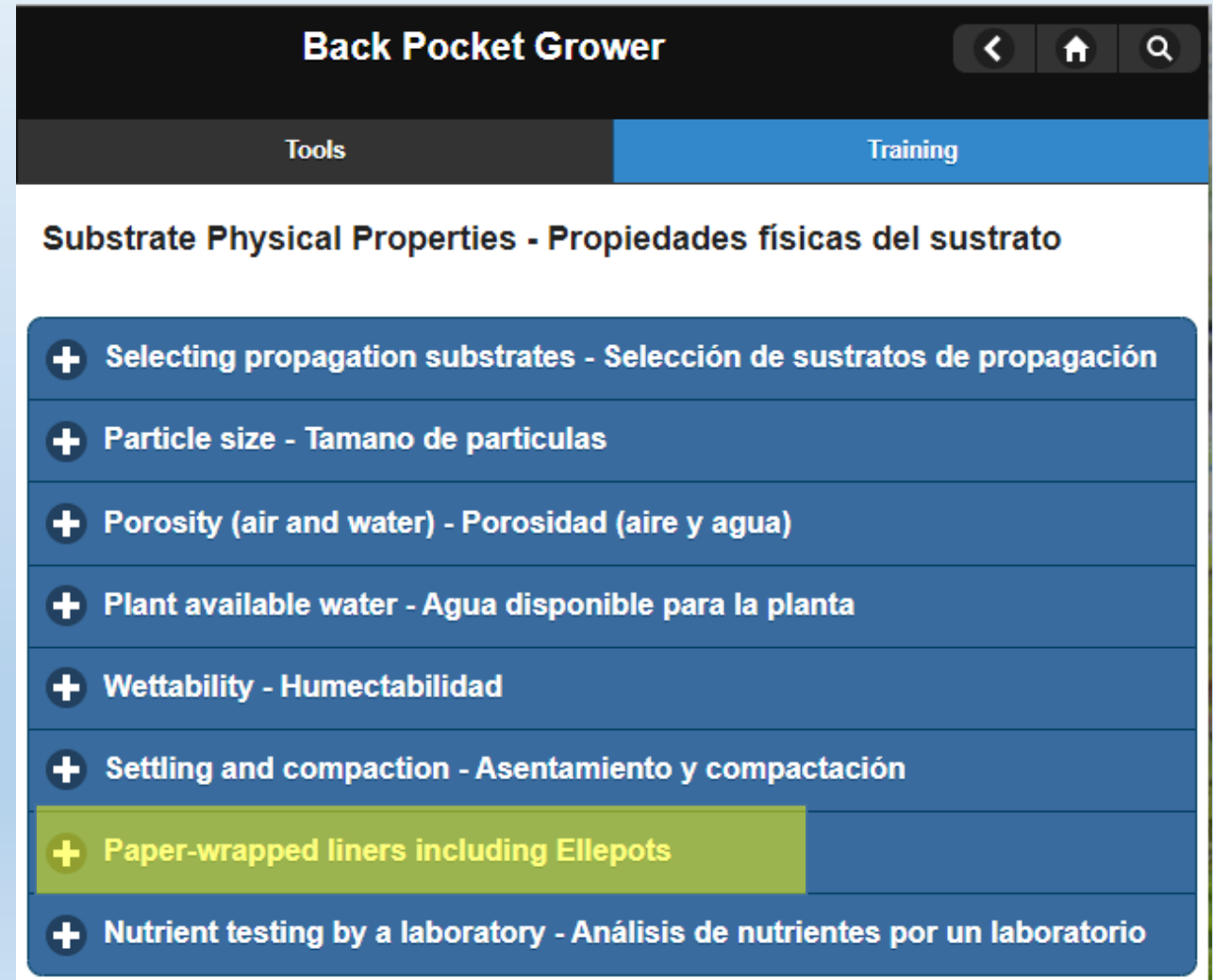


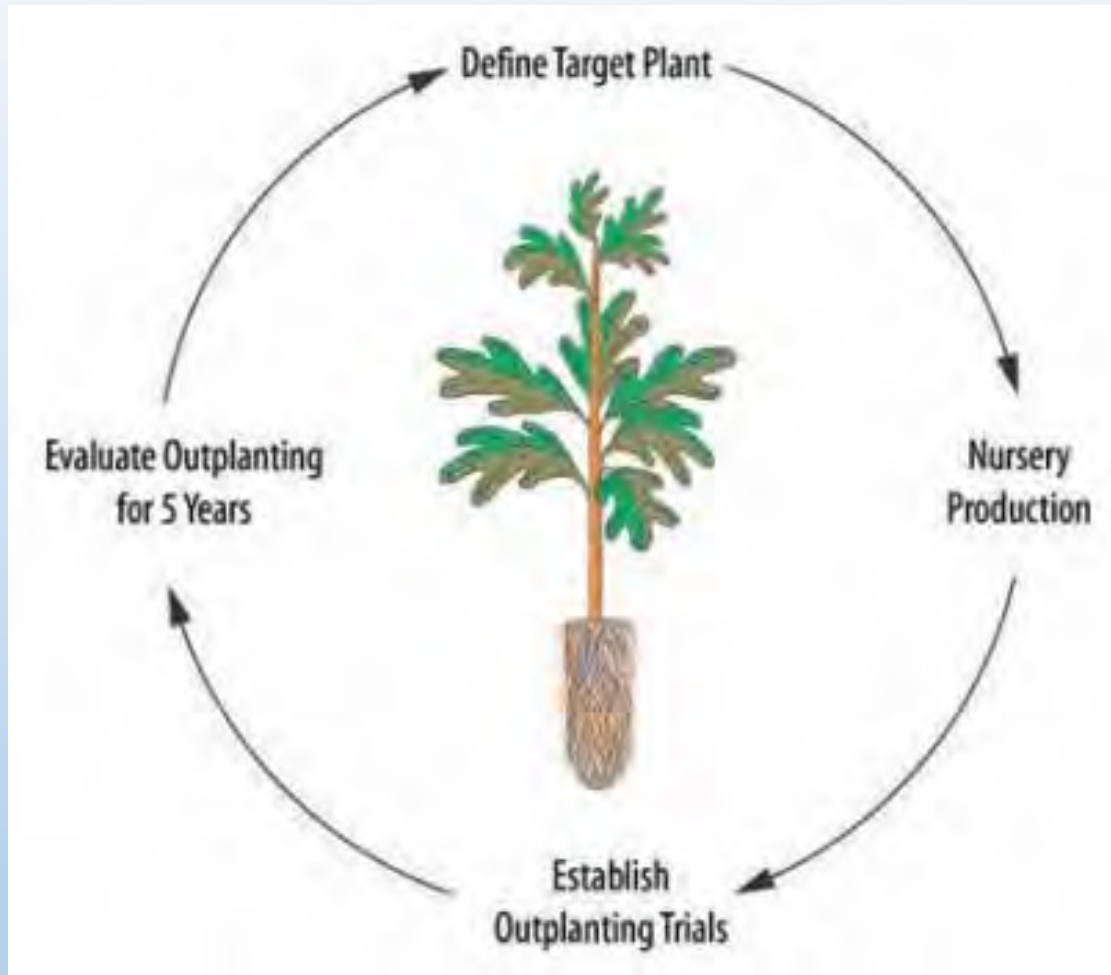
- Soil media moisture
- Vacuum level
- Quantify and track physical parameters

# Soil media quality control? There's an app for that

- **Backpocketgrower.org**

- How to operate paper plug machines to optimize media properties
- How to test media properties of paper-wrapped plugs
- Plug-squeeze method for testing media pH/EC







# Stocktype trials are hard to do well

PRACTICE OF FORESTRY

## Conducting Seedling Stocktype Trials: A New Approach to an Old Question

Jeremiah R. Pinto, R. Kasten Dumroese, Anthony S. Davis,  
and Thomas D. Landis

ABSTRACT

Seedlings for reforestation and restoration come in many shapes and sizes, i.e., a variety of stocktypes. With so many choices available, land managers commonly ask which stocktype will best meet their management objectives. For years, stocktype studies have been initiated in search of an answer to this question, but few have been done without some degree of confounding. Past studies often confounded seed sources, nurseries, and culturing regimes, and/or failed to address differences in initial seedling quality, which sometimes led to inappropriate conclusions. This article reviews the reasoning behind stocktype studies, reviews common pitfalls of past studies, and suggests some key considerations to making future stocktype studies a viable resource to the practicing forester.

**Keywords:** target plant concept, outplanting, seedling quality, container, bareroot

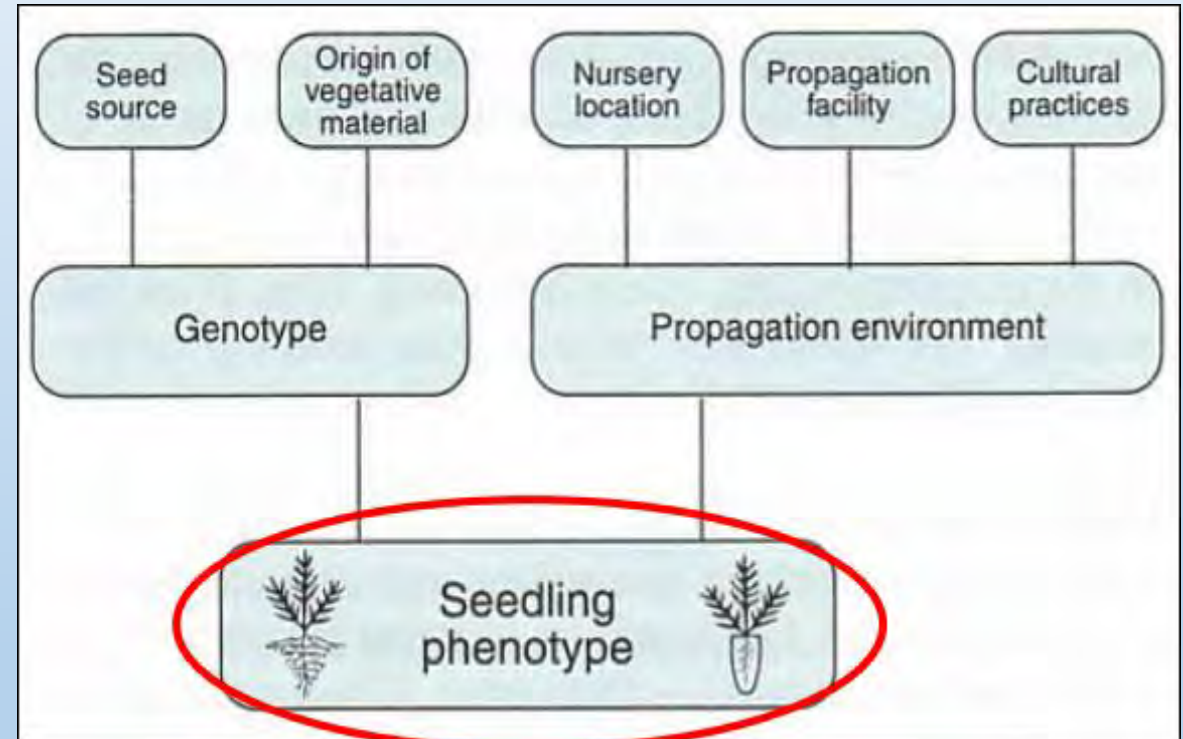
materials for a site. The defined target plant material can then be produced by the nursery manager through manipulation of the growing environment to influence resulting phenotype. By varying, e.g., bareroot seedling density or container type, seedling phenotype can be modified, even among seedlings coming from the same seed source grown the same year (Endean and Carlson 1975, Simpson 1991, Pinto et al. 2008).

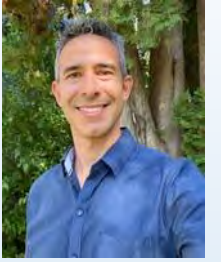
Phenotypic variation of seedlings (e.g., height, branching pattern, root collar diam-



# Pinto's confounding pitfalls:

- Seedling quality
- Seed sources
- Nurseries
- Density effects
- Culturing regimes
- Statistical design
- Single year analyses
- No reference to physiology





# Pinto's points for avoiding confounding:

- Define objective clearly, variable(s) tested
- Match genetic sources
- Similar propagation environment (unless testing differences)
- Seedling physiology/quality should be uniform across stocktypes (adjust nutrition, irrigation as necessary)
- Hardening and storage regimes should be sufficient and similar
- Solid statistical design
- Outplanting to include multiyear analyses to account for wet/dry years or use controlled environments

# PNW Forest Nursery Ellepot Evaluation

- Cascade Timber: comparing Elles vs. styro DF from 2-3 OR nurseries
- WADNR evaluating performance of several species: Elles vs. styros
- USFS PP seed transfer study next year will include Elles vs. styros
- Grad student at U of I, Michael Gilgunn, starting this year!



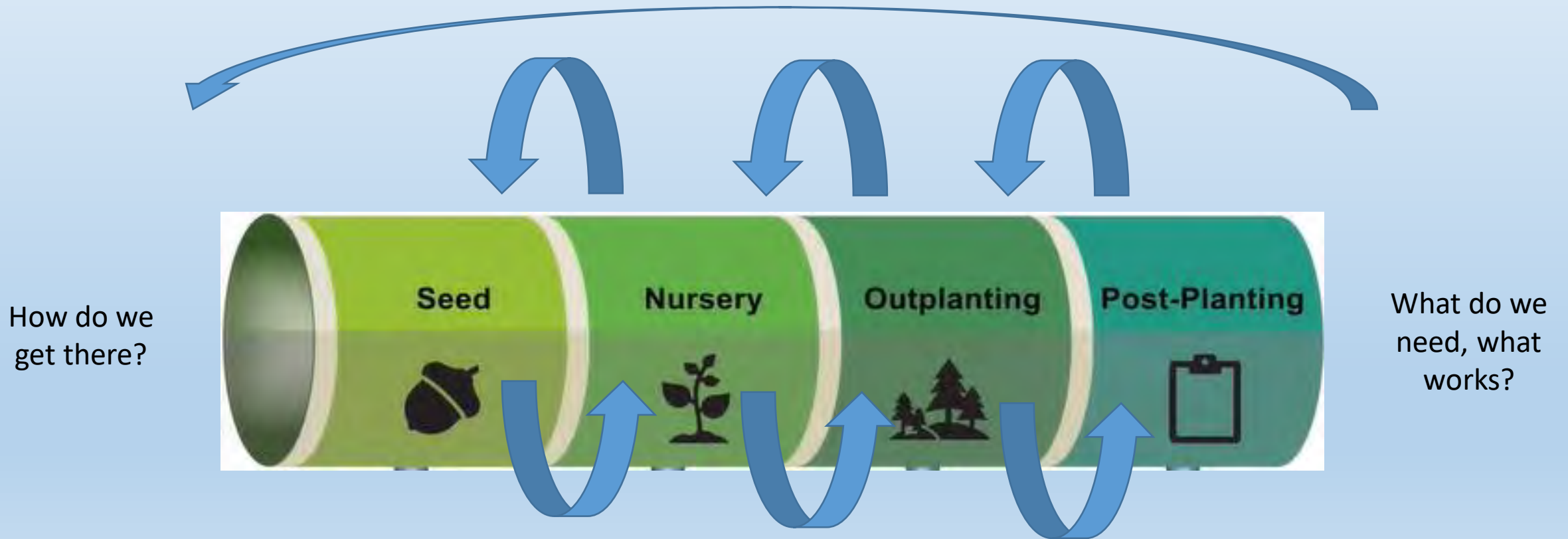
# Takeaways: Can paper system replace styros?

- Mechanization available, but may be difficult to justify for nurseries heavily invested in equipment tailored to styroblocks
- Until tray density is comparable to styroblock, will need to outperform styros in field performance to be cost-competitive
- Evaluations ongoing: sound stocktype trial design and execution needed in both the nursery and the field for reliable conclusions
- Target Plant Concept in action: nursery and forester working together to target seedling specs to the site

# Wrap-up: what do we need to establish a sustainable seedling supply?

- **Invest in infrastructure:** cooler storage, water capacity, nursery expansion
- **Invest in equipment and automation:** more cost-effective than ever, especially in this labor market
- **Invest in people above all:** Hire and retain a staff that will interact and partner with seed and field professionals

# Ultimately, partnerships will determine success



# Acknowledgments and contact info:

- Kila Bengé
- Jeff deGraan
- Kas Dumroese
- Diane Haase
- Dave Kolotelo
- Tom Landis
- Brian Morris
- Andrew Nelson
- Jeremy Pinto
- Tel Vaughn
- Jacob Witcraft

Contact information:

[nabil.khadduri@dnr.wa.gov](mailto:nabil.khadduri@dnr.wa.gov)

360.902.1279