Are plant populations evolving during the process of seed increase for restoration?

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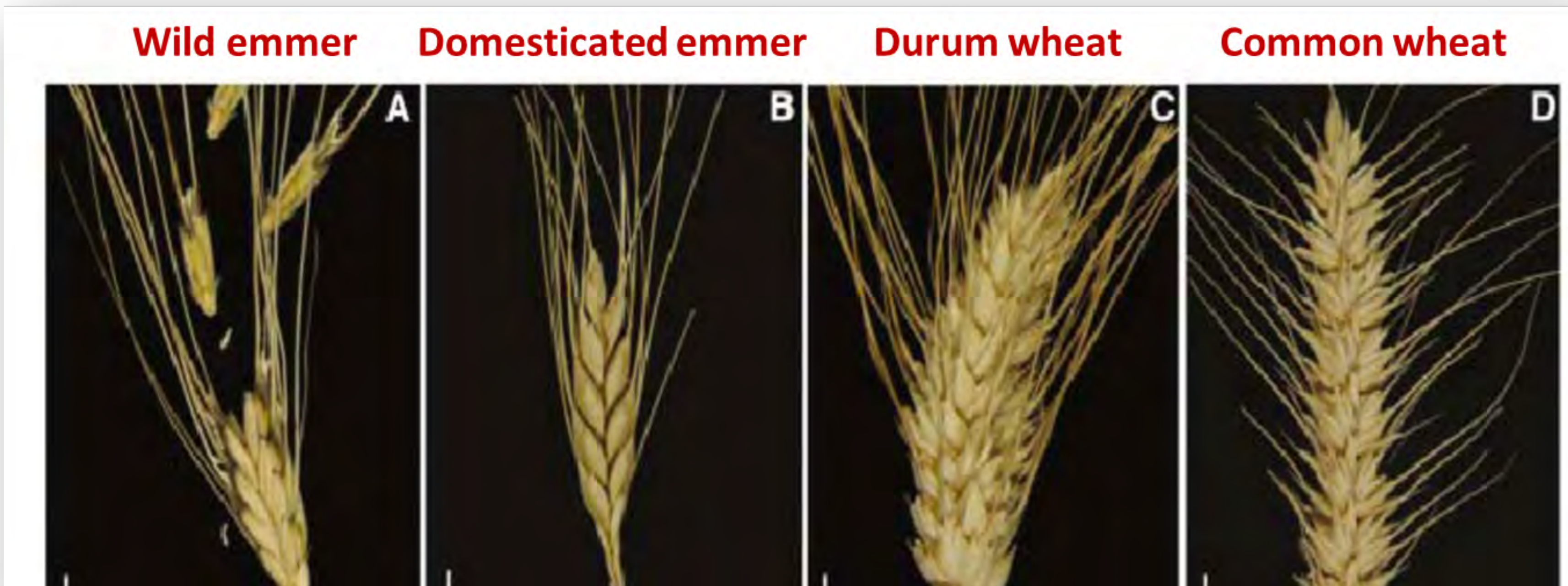
Espeland et al. 2017. Evolution of plant materials for ecological restoration: insights from the applied and basic literature. Journal of Applied Ecology 54:102-115

Are plant populations evolving during the process of seed increase for restoration?

1. Why is it a problem?
2. How does it happen?
3. How can we test for it?
4. How can we avoid it?

1. Why is it a problem?

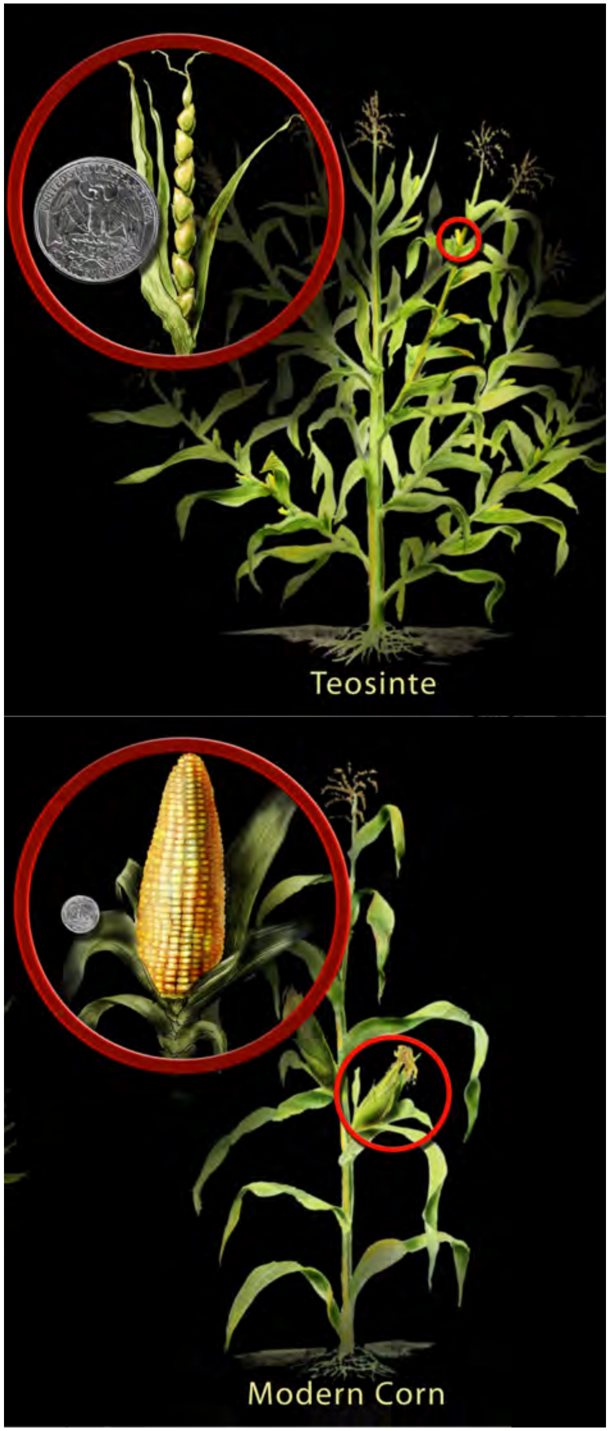
- Genetic diversity fuels evolution into the future
- Traits that are inadvertently selected for in an agronomic setting may be disadvantageous when planted back into a restoration site



1. Why is it a problem?

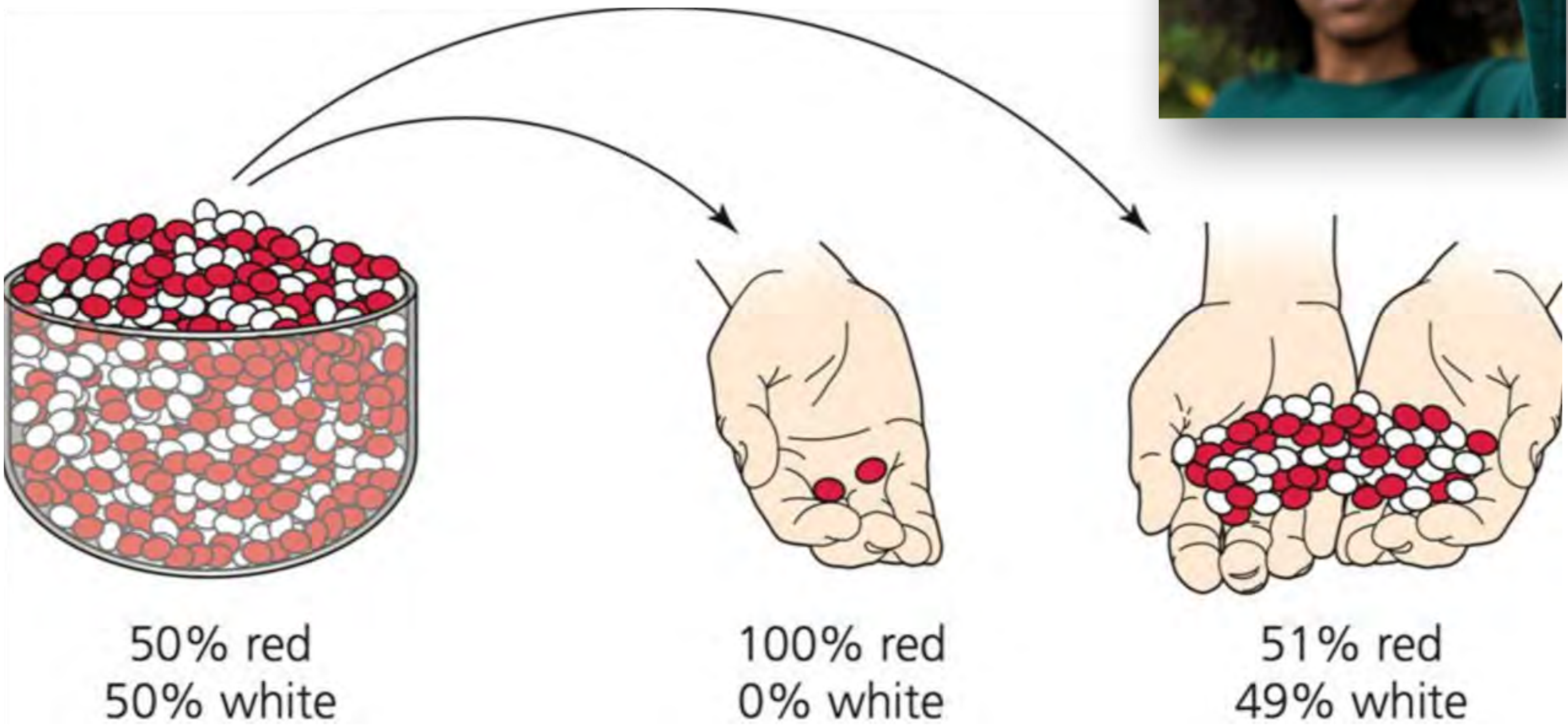
Domestication traits

- Loss of shattering
- Uniform phenology
- Loss of seed dormancy
- Suppressed branching
- Fewer larger seed heads
- Bigger seeds
- Low genetic diversity



1. How does it happen?

- Sampling



Sampling

Nassella viridula,
Green needlegrass

Sampling

Nassella viridula, Green needlegrass

Sampling

Nassella viridula,
Green needlegrass

1. How does it happen?

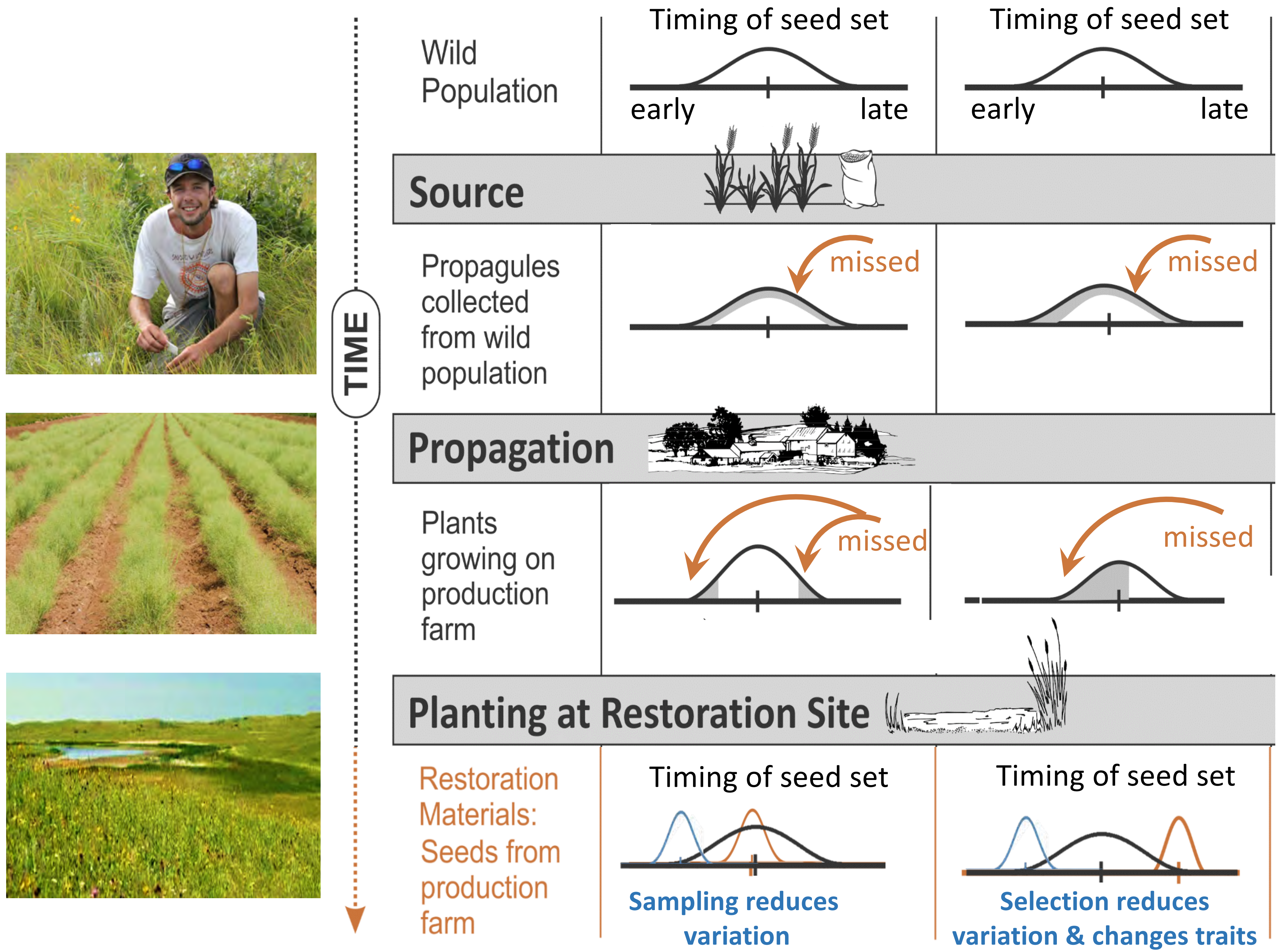
- Sampling
- Selection

1. How does it happen?

- Harvesting once or few times per year
- Mechanical harvesting may favor non-shattering seed heads
- Repeated harvesting of perennials over years as plants die and/or are replaced by their offspring
- Replanting annuals from the same garden population

Harvesting corn

Harvesting native grasses



Wild Population
Timing of seed set
early
late
Timing of seed set
early
late
Source
Propagules collected from wild population
missed
missed
TIME
Propagation
Plants growing on production farm
missed
missed
Planting at Restoration Site
Restoration Materials: Seeds from production farm
Timing of seed set
Timing of seed set
Sampling reduces variation
Selection reduces variation & changes traits

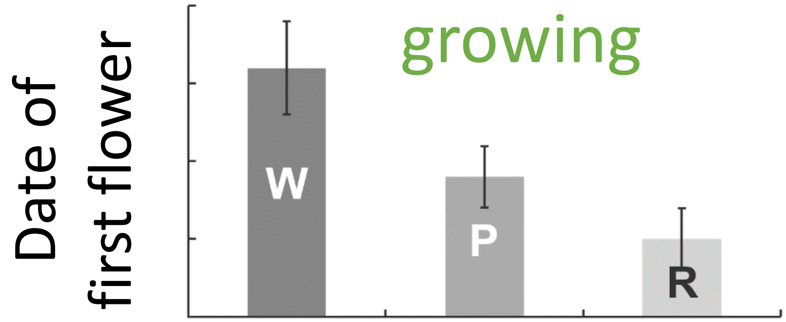
3. How can we test for it?

Wild

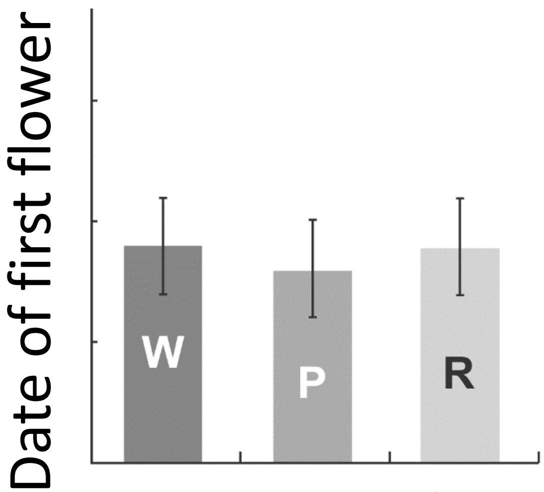
Propagation farm

Restoration site

Measure plants where they are growing



Plant seeds in the same place and then measure them



Propagation farm

3. How can we test for it?

Wild

Propagation farm

Restoration site

Not enough time and money for this?

- Keep good records, collect seed, and donate it to your local academic institution
- jetterso@d.umn.edu
- We have students that would love to do the work!
- Partnerships are valuable

Is propagation for seed increase altering the genetic base of the source material?

Partnership

- Bryce Christiansen and Rebecca Shoemaker of Native Ideals Farm, Arlee MT
- Erin Espeland USDA Agricultural Research Service
- Julie Etterson, U of MN Duluth

Is propagation for seed increase altering the genetic base of the source material?

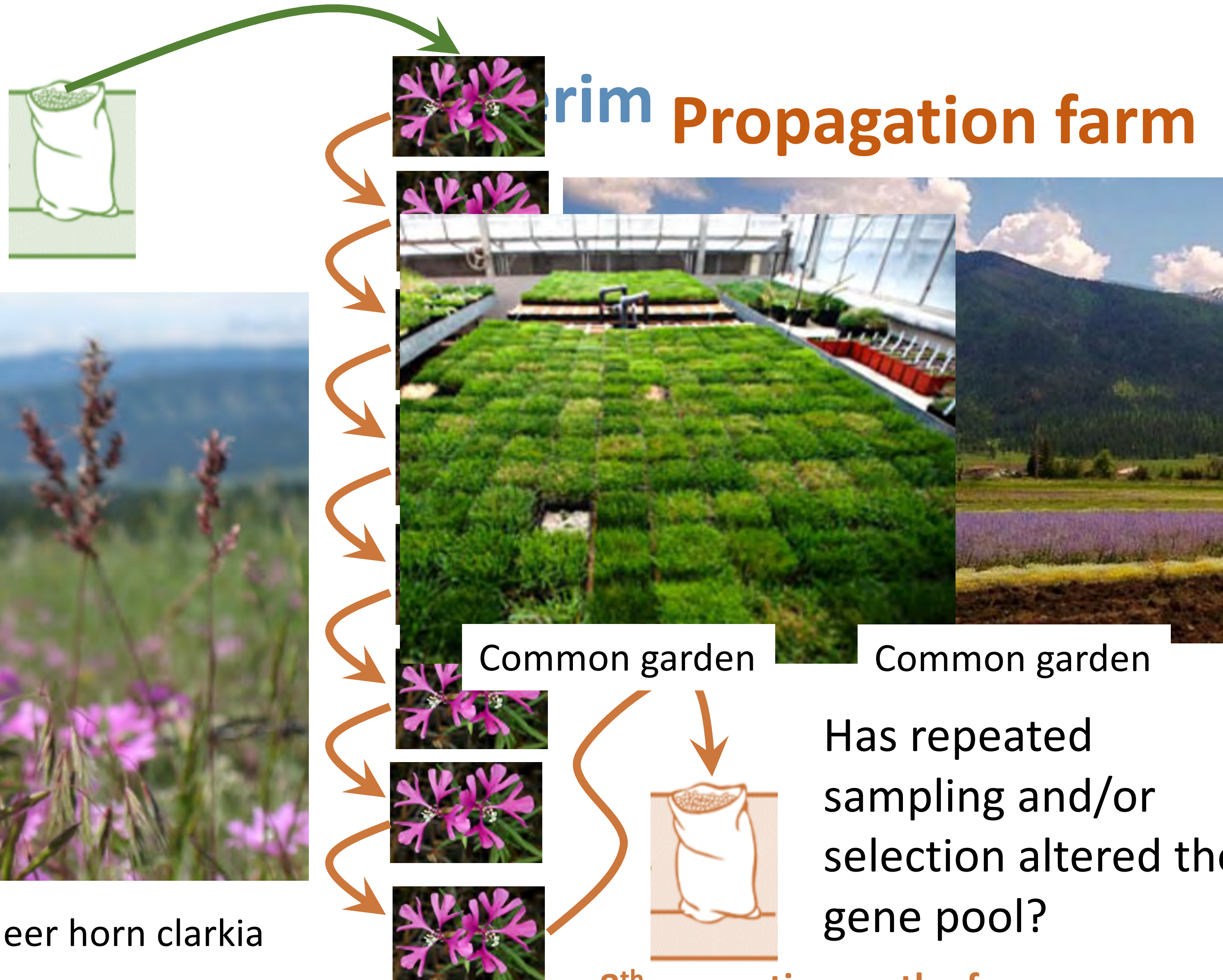
Wild

Propagation farm

Clarkia puchella, deer horn clarkia

Is propagation for seed increase altering the genetic base of the source material?

Wild

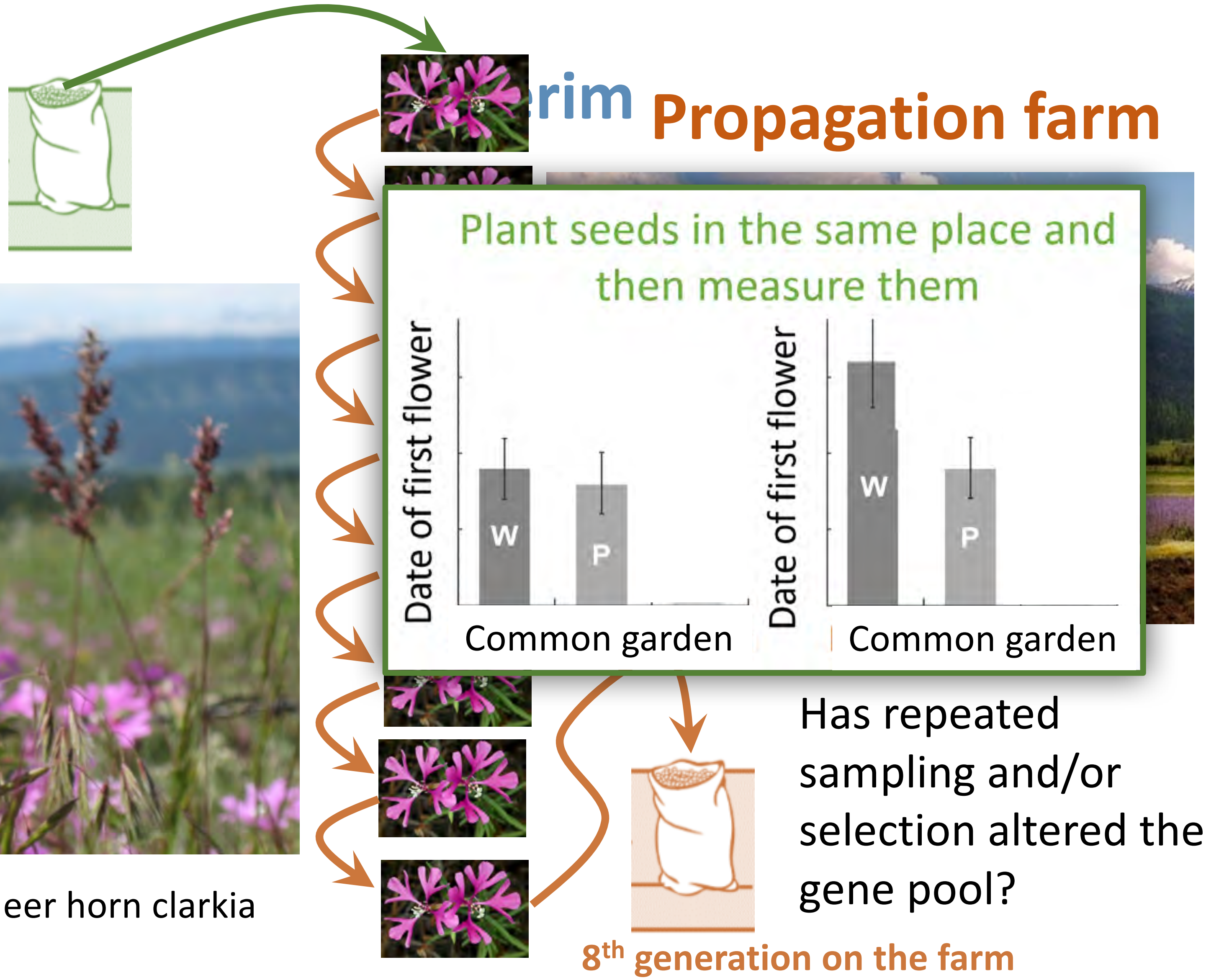


Clarkia puchella, deer horn clarkia

Has repeated sampling and/or selection altered the gene pool?

Is propagation for seed increase altering the genetic base of the source material?

Clarkia puchella, deer horn clarkia



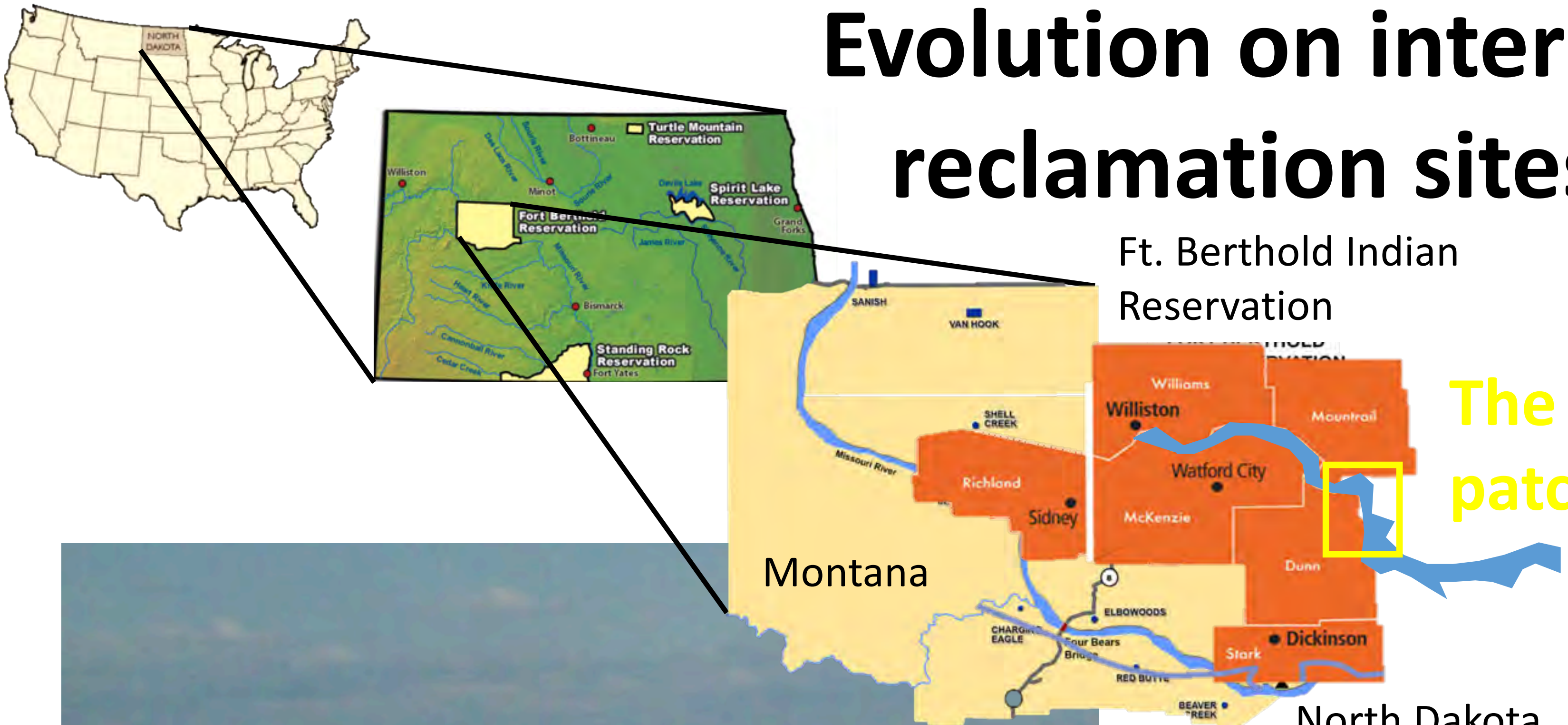
Species that will be tested

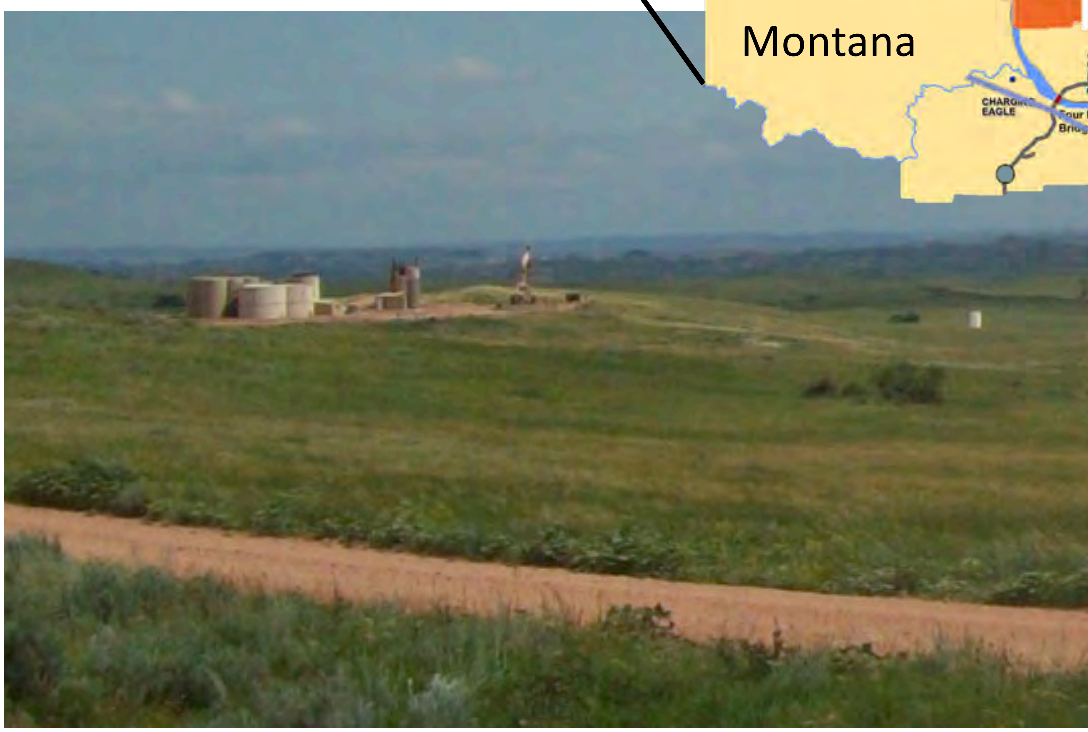
Genus	Species	# of generations on farm
Cerastium	*arvense*	F4
Gaillardia	*aristata*	F4
Penstemon	*eriantherus*	F4
Lewisia	*rediviva*	F2
Camassia	*quamash*	F1





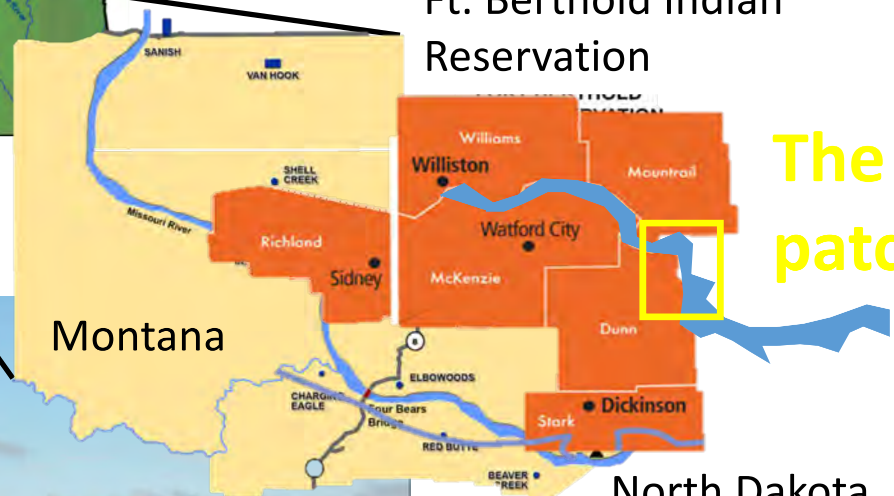
Evolution on interim reclamation sites

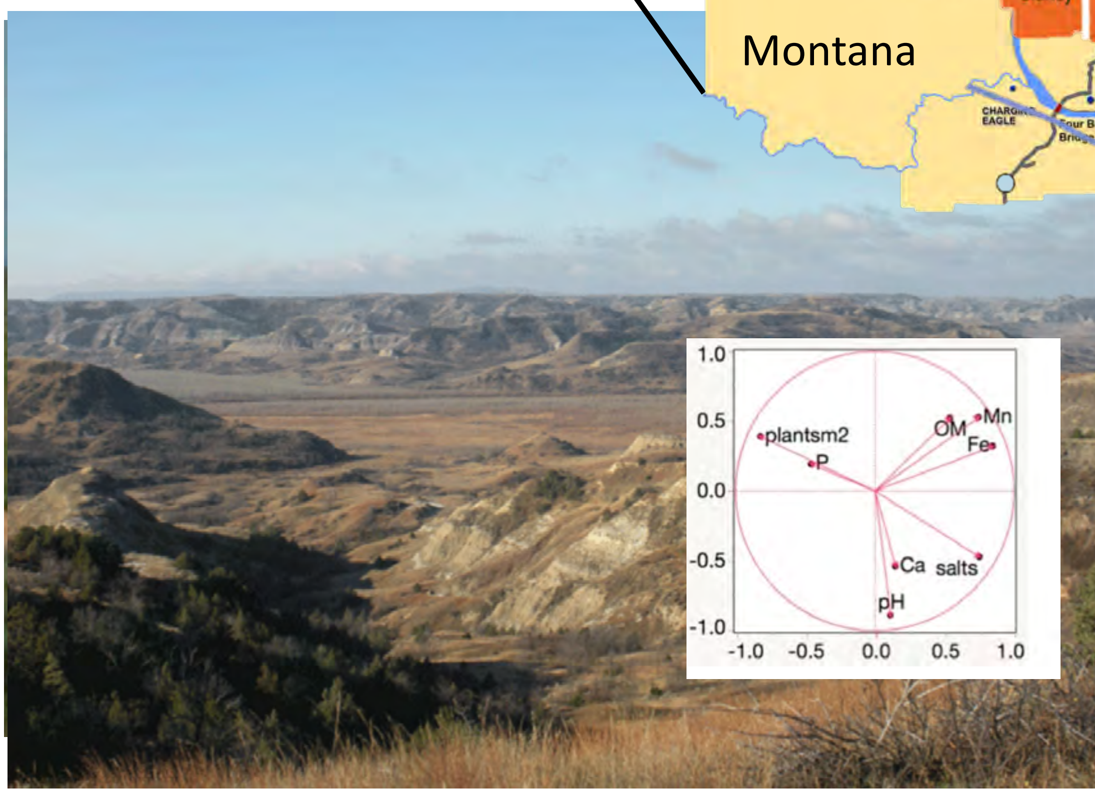




Soils: high pH, salts, and compaction

Evolution on interim reclamation sites





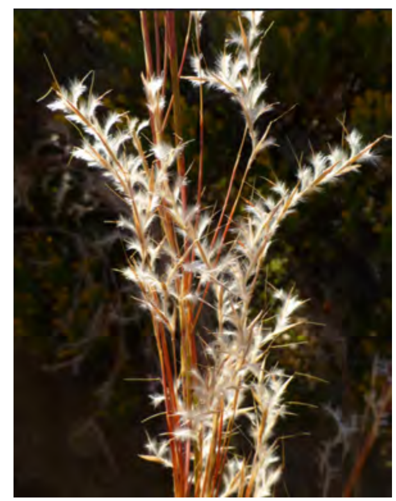
Soils: high pH, salts, and compaction

Cultivars planted into reclamation sites

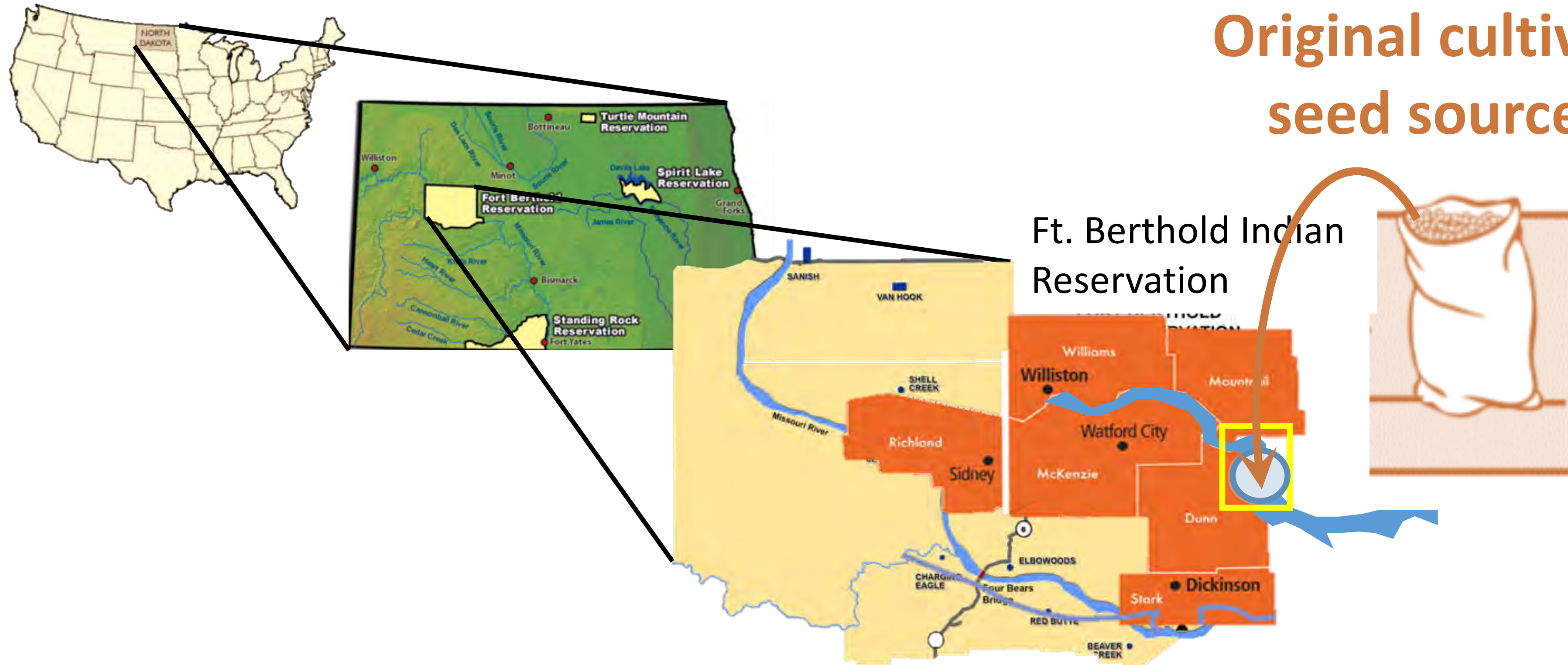
Species	Cultivar
Bouteloua curtipendula	Butte and Pierre
Elymus trachecaulus	Pryor and Revenue
Bouteloua gracilis	Bad River and Native
Nassella viridula	Lodorm
Pascopyrum smithii	Rosana
Schizachyrium scoparium	Aldous
Koeleria macrantha	Blue Mtn



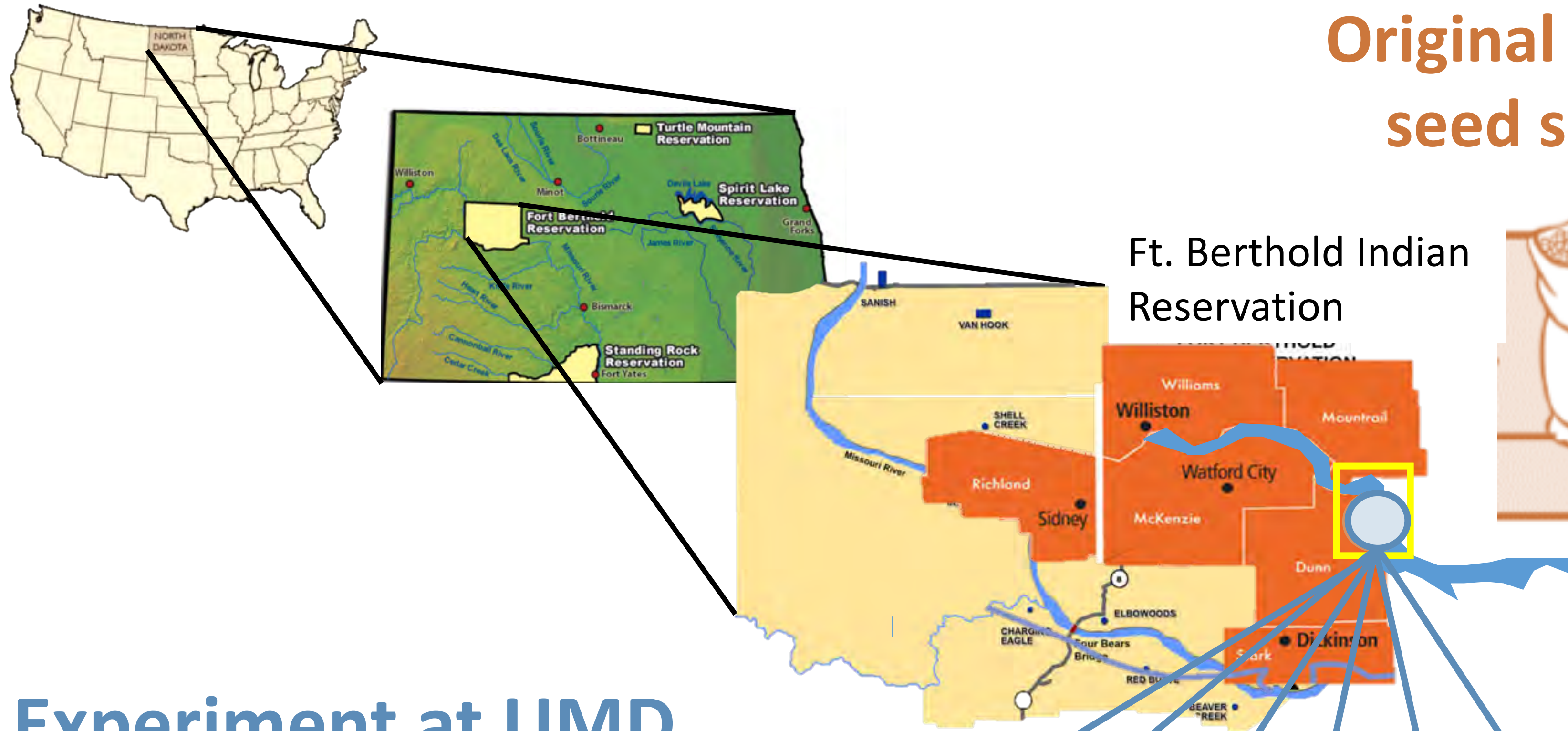


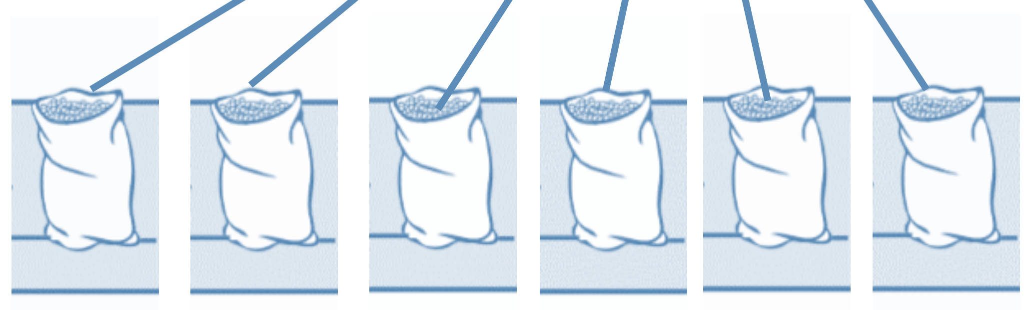

Original cultivar seed source



Original cultivar seed source

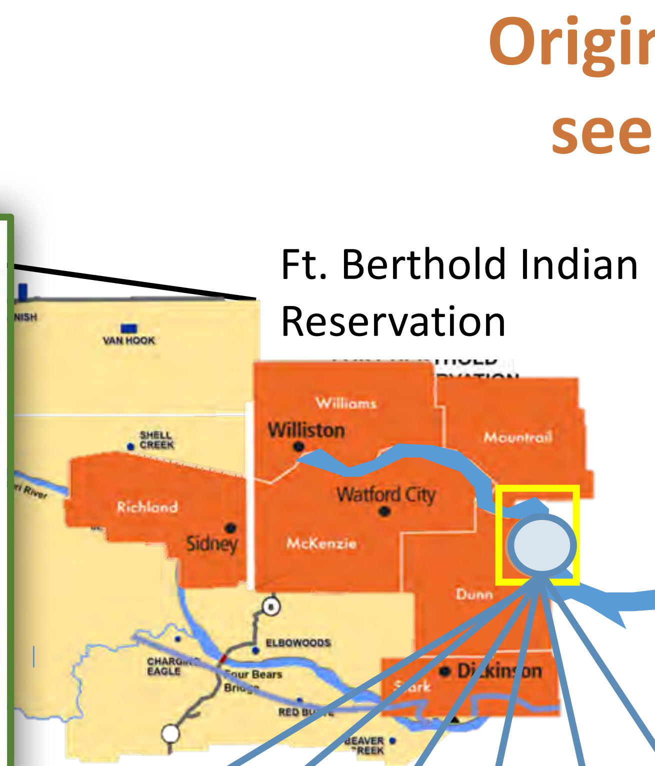


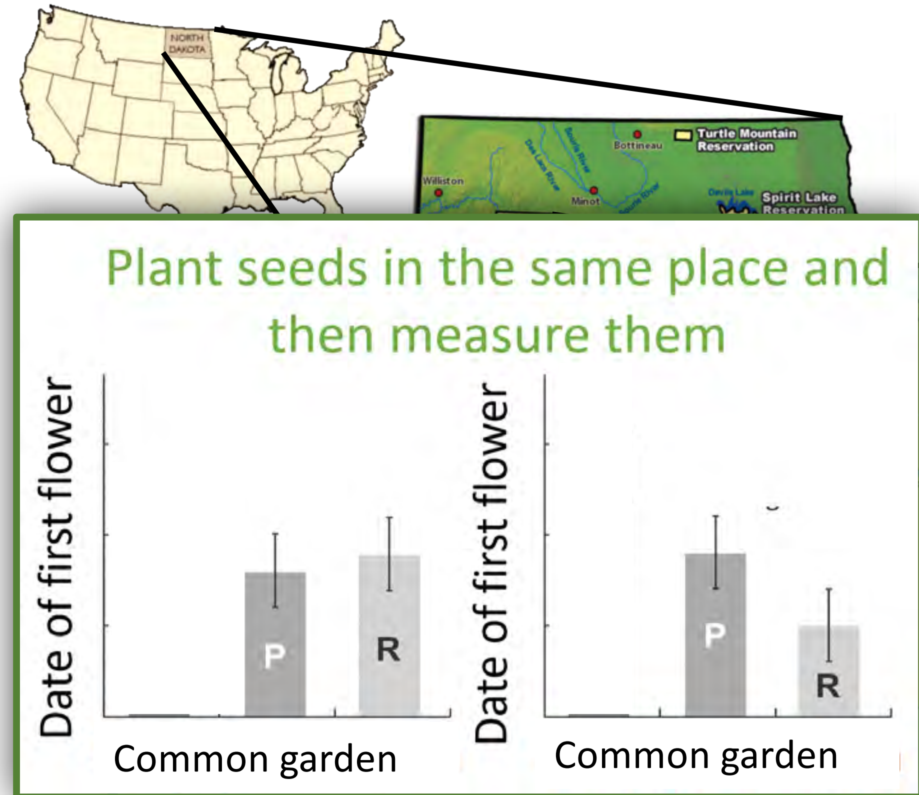
Experiment at UMD

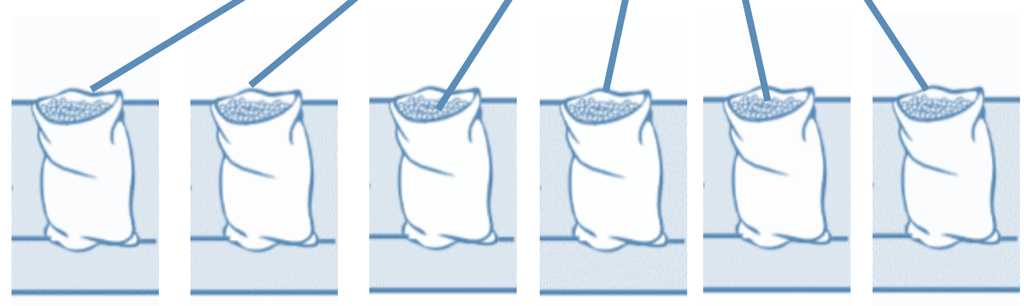


Seed collections from 6 sites after one year in the restoration sites

Original cultivar seed source







Seed collections from 6 sites after one year in the restoration sites

4. How to avoid evolution during the process of seed increase?

Wild

Propagation

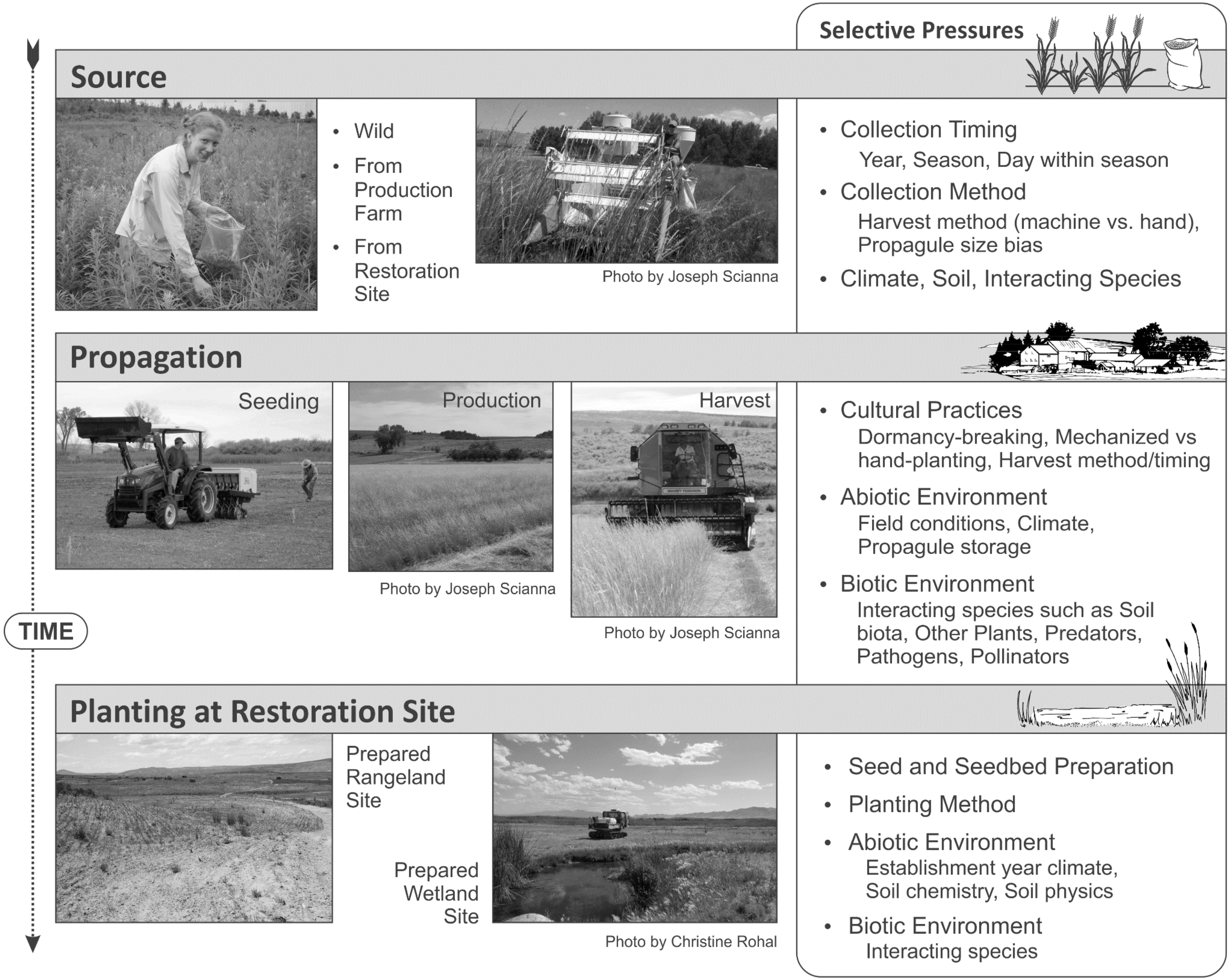
Restoration

- Sample multiple populations within a region
- Sample many mother plants per pop (>100)
- Harvest several times during seed maturation or collect fruits that appear to have matured at different times
- Allow recruitment into gardens of later-germinating seed
- If using mechanical harvesting methods, consider hand harvesting early and late individuals
- Preserve a diversity of seed sizes during cleaning
- Periodically augment gardens with seed (or pollen) from wild populations
- Do a common garden experiment and find out if there is a problem!

A fruitful agency, academic, business partnership – Questions?

USDA United States Department of Agriculture
Agricultural Research Service

University of Minnesota Duluth
Driven to Discover



Selective Pressures
Source
Wild
From Production Farm
From Restoration Site
Photo by Joseph Scianna
Collection Timing
Year, Season, Day within season
Collection Method
Harvest method (machine vs. hand), Propagule size bias
Climate, Soil, Interacting Species
Propagation
Seeding
Production
Harvest
Photo by Joseph Scianna
Photo by Joseph Scianna
Cultural Practices
Dormancy-breaking, Mechanized vs hand-planting, Harvest method/timing
Abiotic Environment
Field conditions, Climate, Propagule storage
Biotic Environment
Interacting species such as Soil biota, Other Plants, Predators, Pathogens, Pollinators
TIME
Planting at Restoration Site
Prepared Rangeland Site
Prepared Wetland Site
Photo by Christine Rohal
Seed and Seedbed Preparation
Planting Method
Abiotic Environment
Establishment year climate, Soil chemistry, Soil physics
Biotic Environment
Interacting species

Seeding rates

Table 1. Seeding rates (PLS/ac) of the perennial grass mixes used in 2014. (Seeding rate doubled if broadcast.) The oat cover crop was planted at 10 PLS/ac. PLS/ac rate doubled if broadcast. Percent frequency (freq) of species occurrence measured in 2015, numbers in parentheses are one standard deviation.

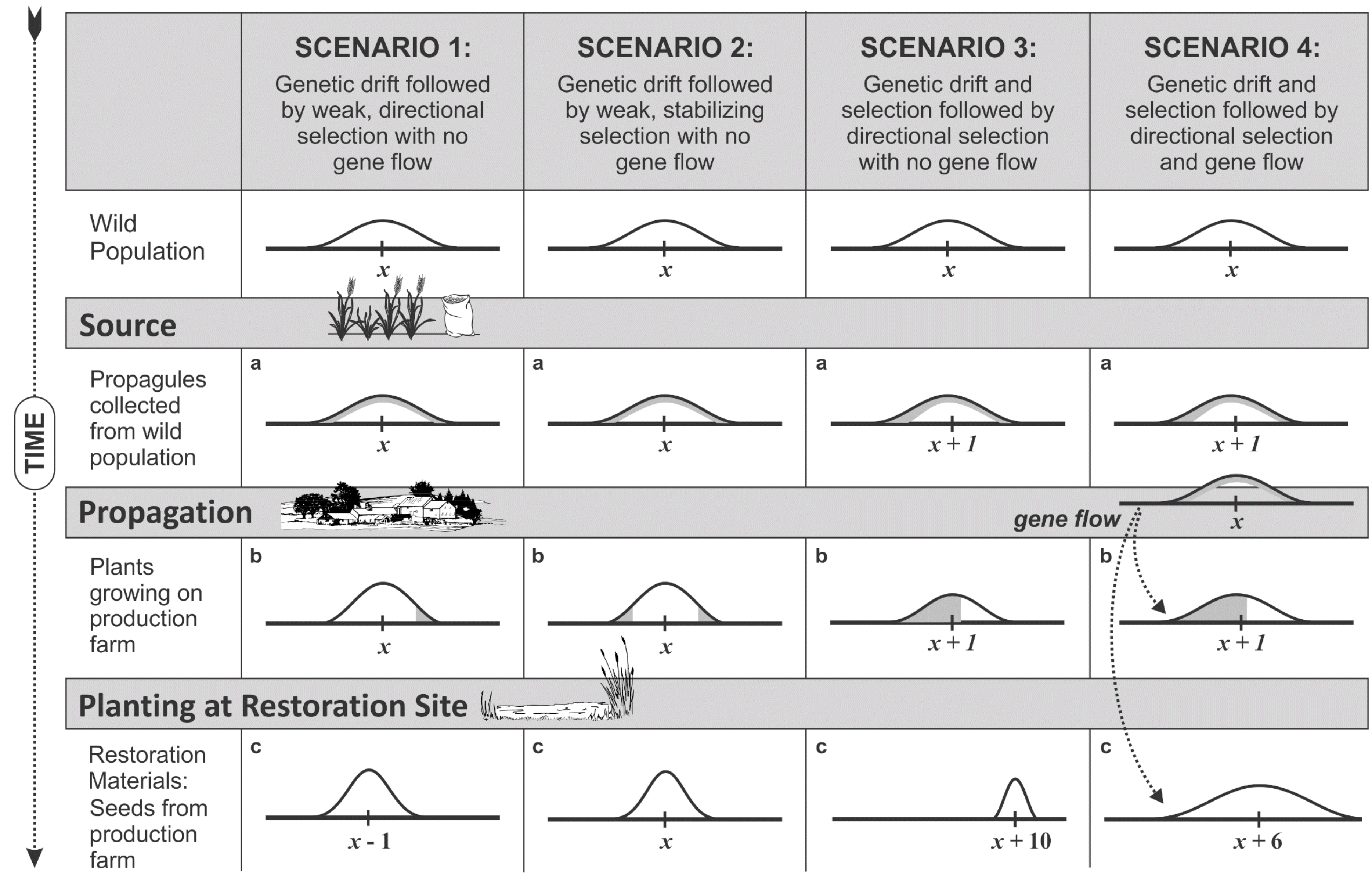
Species	MHA rate	BIA rate	MHA freq	BIA freq
WW	2.4	2.4	95.8 (8.3)	97.5 (5.0)
GNG	1.5	1.2	73.3 (28.3)	57.5 (37.7)
SOG	1.5	0.6	56.7 (39.7)	30.0 (35.6)
SWG*	1	0.5	73.8 (12.5)	85.0 (12.9)
LBS	1	0.4	17.1 (15.3)	20.0 (16.3)
BG	1	0.2	56.7 (27.9)	57.5 (33.0)
PJG	0.1	0.1	39.2 (34.4)	42.5 (22.2)

* Significant difference in SWG frequency between the two planting mixes ($p < 0.05$)

Planting methods

Table 2. Seeding protocols of the 14 experimental units (sites): timing (planting month and year), perennial grass seed mix (Table 1), cover crop type, and planting method along with perennial grass density (plants/m²) measured in August 2015.

Site	Timing	Mix	Cover crop	Method	Plants/m²
AGB	Oct 2014	MHA	Oats	Broadcast	25 (8.8)
BRU	Oct 2014	BIA	None	Broadcast	38 (0.5)
COY	Sep 2014	BIA	Oats	Drilled	32 (6.6)
DAB	Oct 2014	MHA	None	Broadcast	33 (4.8)
FBIR	Oct 2014	BIA	None	Drilled*	22 (6.6)
MAS	Aug 2014	MHA	Oats	Broadcast	35 (5.0)
MRS	Aug 2014	BIA	None	Hydroseed	20 (10.0)
OLS	Aug 2014	MHA	Oats	Broadcast	26 (4.3)
EGB	Jun 2015	MHA	Oats	Broadcast	7 (0.2)
EGB	Jun 2015	MHA	Cocktail	Broadcast	6 (1.8)
SYW	Jun 2015	MHA	Oats	Broadcast	31 (3.7)
SYW	Jun 2015	MHA	Cocktail	Broadcast	29 (11.0)
MBL	Jun 2015	MHA	Oats	Broadcast	24 (14.0)
IND	Jun 2015	MHA	Cocktail	Broadcast	17 (1.6)



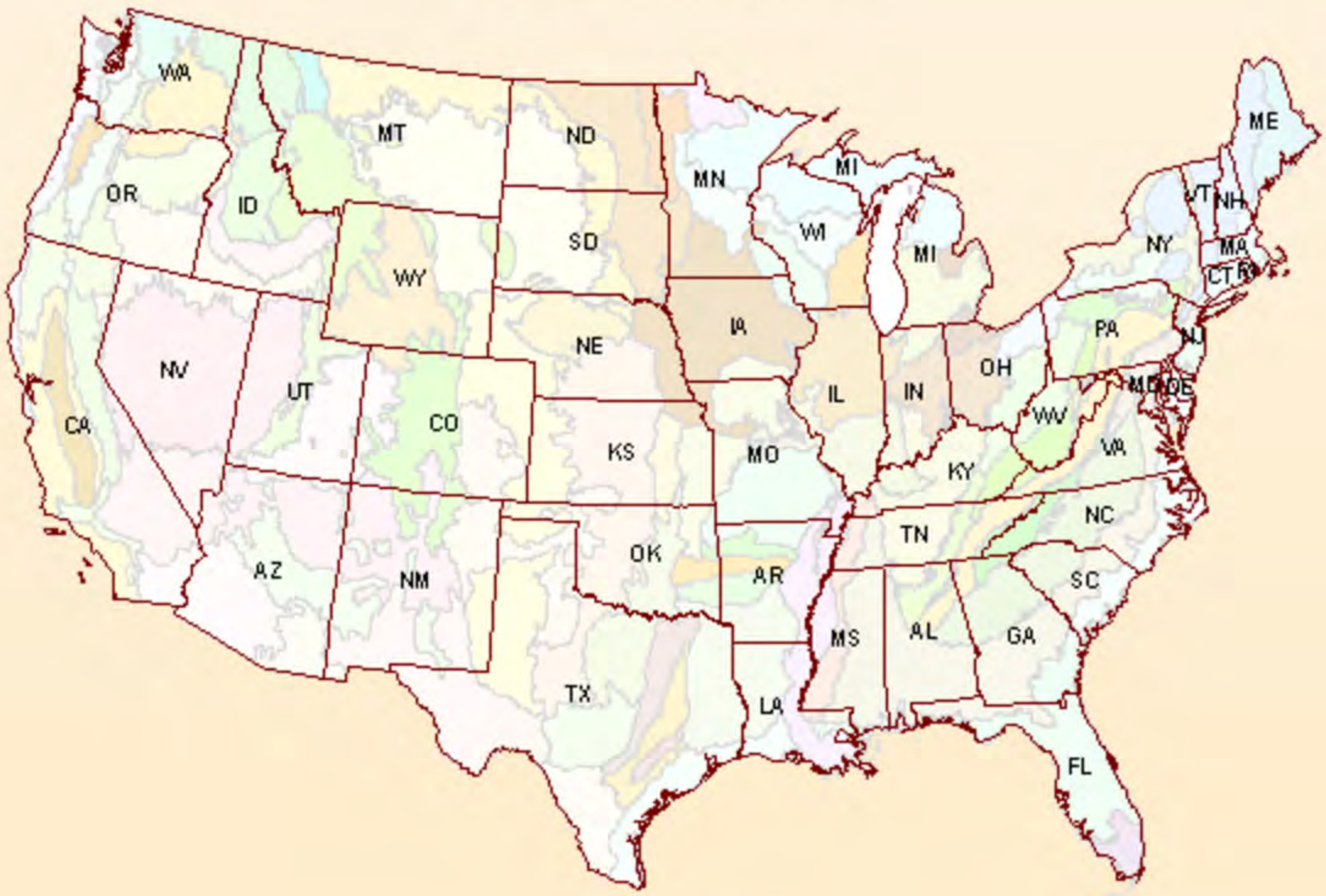
TIME
SCENARIO 1:
Genetic drift followed by weak, directional selection with no gene flow
SCENARIO 2:
Genetic drift followed by weak, stabilizing selection with no gene flow
SCENARIO 3:
Genetic drift and selection followed by directional selection with no gene flow
SCENARIO 4:
Genetic drift and selection followed by directional selection and gene flow
Wild Population
x
x
x
x
Source
Propagules collected from wild population
a
x
a
x
a
x + 1
a
x + 1
Propagation
gene flow
x
Plants growing on production farm
b
x
b
x
b
x + 1
b
x + 1
Planting at Restoration Site
Restoration Materials: Seeds from production farm
c
x - 1
c
x
c
x + 10
c
x + 6


CHICKENSTOCK
Music Festival

NATIVE SEED
NETWORK

Looking for seed?

Select your project area

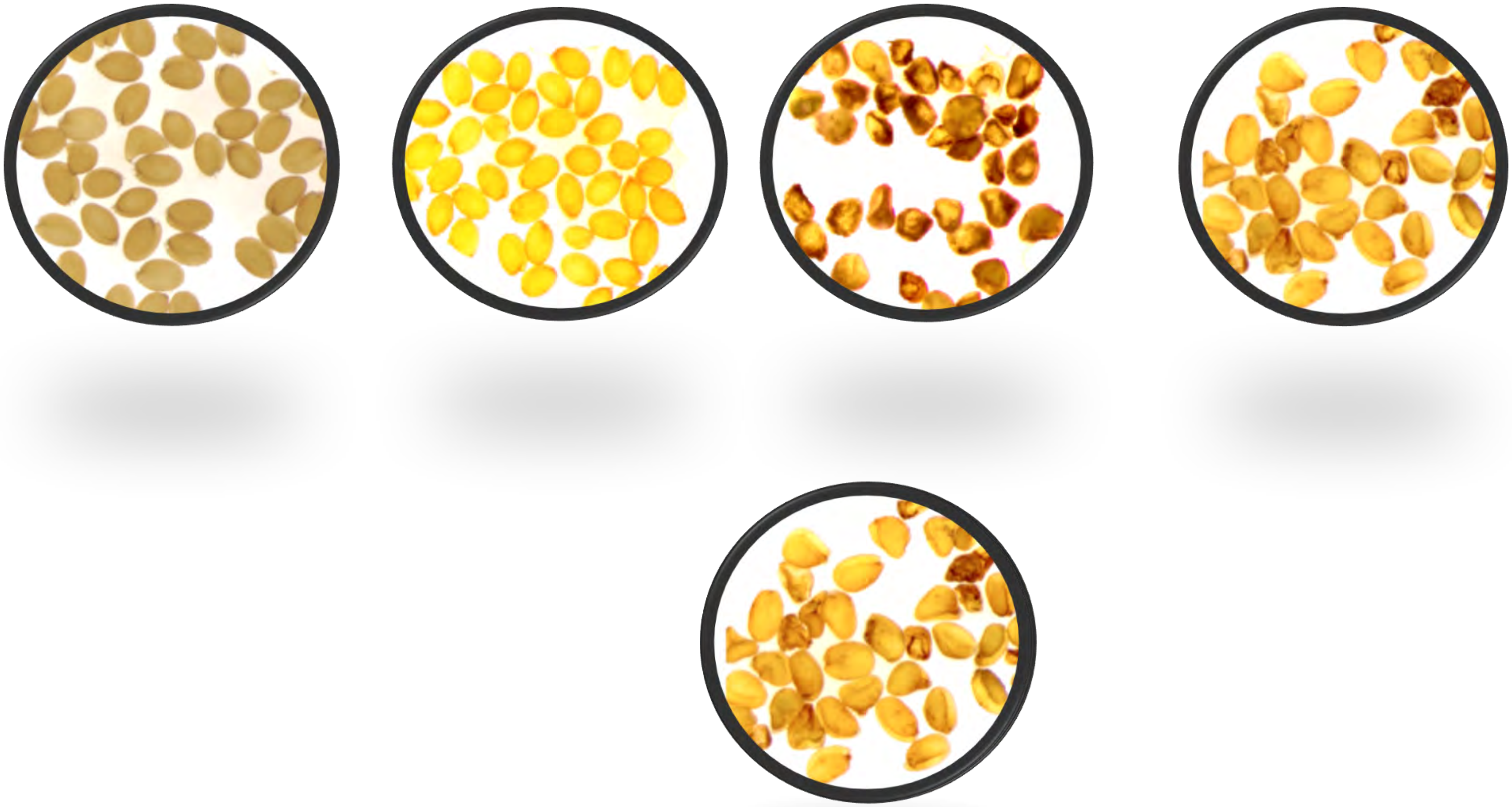


Tuesday 11:40 a.m. - Congressional

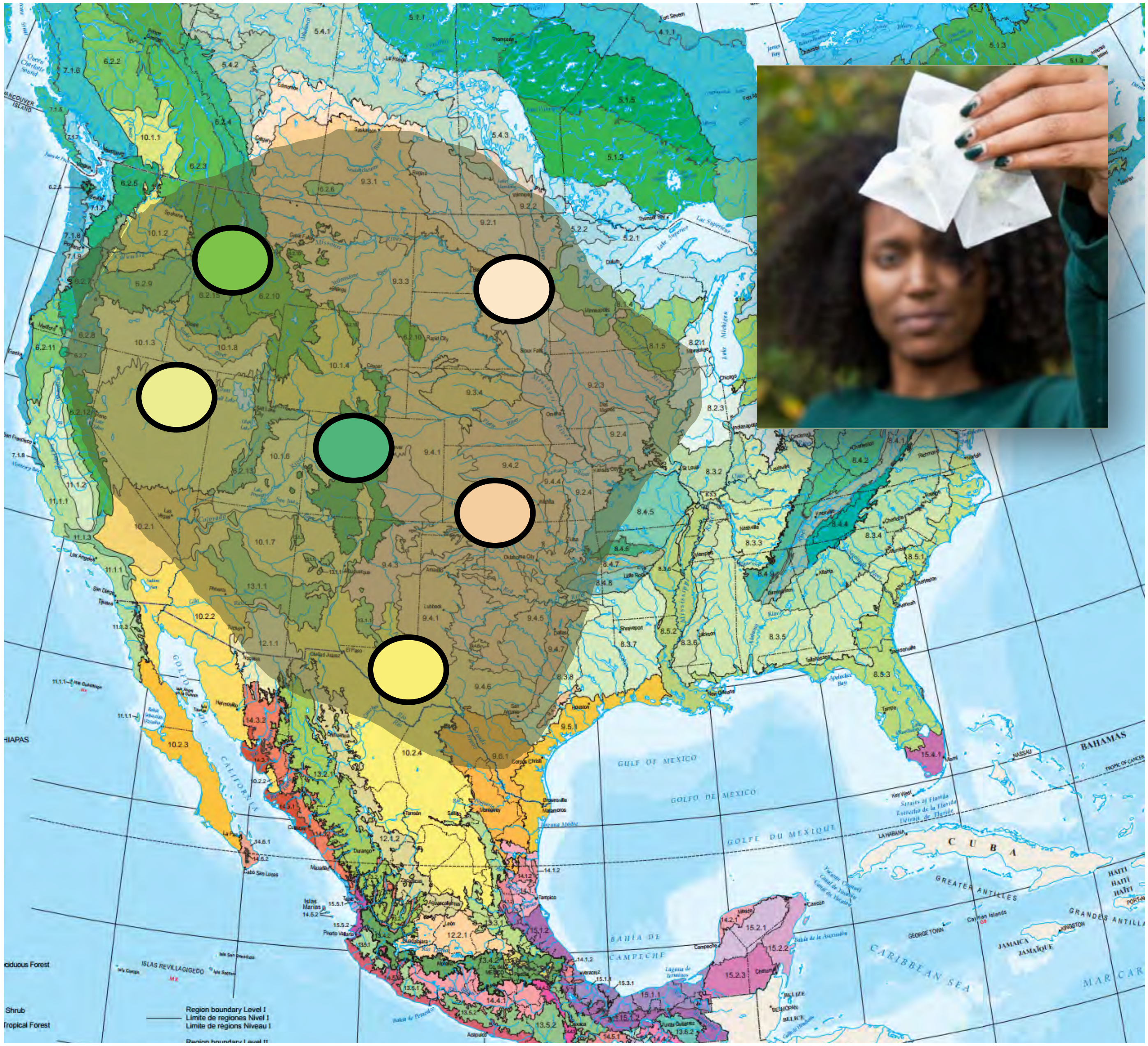
Are plant populations evolving during the process of seed increase for restoration?

Julie R. Etterson*, Erin K. Espeland, Nancy C. Emery, Kristin L. Mercer, Scott A. Woolbright, Karin M. Kettenring

Restoration is normally conducted with the goal of creating plant populations that establish, survive, successfully reproduce, contribute to ecosystem function, and persist in the long term. For large-scale restorations, it is often necessary to rely upon plant materials that have undergone agronomic increase to produce a sufficient number of seeds. During this propagation process, restoration populations are subject to genetic sampling as well as natural and artificial selection that could result in adaptation contrasting sharply with that of native populations. In this seminar, I will draw on insights from the evolutionary and agricultural literature to illustrate how changes in the amount and type of genetic variation in agronomically produced seeds could affect plant performance in restoration. The consequences of intentional and/or inadvertent evolutionary modification of restoration materials will be discussed with respect to population viability and ecosystem function. I will describe two feasible methods to test for evolutionary change in plant materials using neutral molecular markers and/or field observations and six practices decrease the potential for unintentional evolution and maladaptation. Julie Etterson (Department of Biology, UM-Duluth) is an ecological geneticist whose research is focused on understanding whether wild plant populations will be able to adapt fast enough to keep pace with climate change and how restoration can be used as a tool to ameliorate the negative effects of climate change. TUESDAY 10:00 A.M. – 12:00 P.M. CABINET PLANT MATERIALS



Western wheatgrass



The preceding presentation was delivered at the

2017 National Native Seed Conference

Washington, D.C. February 13-16, 2017

This and additional presentations available at http://nativeseed.info

NATIVE SEED NETWORK

Institute for Applied Ecology