Novel Seed Treatments to Reduce the Risk of Post-fire Seeding Failure

Matthew Madsen
William Richardson
Dallin Whitaker
Bruce Roundy
Kirk Davies

- Iron ore mining in Western Australia

- In Ningxia China overgrazing of perennial native vegetation lead to the invasion of the annual weeds *Artemisia scoparia*

- Land desertification in Africa

- Cheatgrass wildfire cycle, Great Basin

- 5-20% seeding success rate in seeding native vegetation in the western US (Sheley et al. 2011)

The expansive, complex nature of rangeland systems produces a diverse array of abiotic and biotic factors that may limit restoration success, such as:

- freezing temperatures
- competition from weeds
- improper planting depth
- drought
- soil crusting
- soil water repellency
- saline and sodic soils
- predation
- infertile soils

James et al. 2011; Boyd and James 2013; Madsen et al. 2012; Sheley et al. 2011; Davies et al. 2010; Sheley and Bates 2008

- Limiting factors impairing establishment generally have their greatest impact during the early stages of plant development
- Restoration practices that can avoid or improve tolerance to limiting abiotic and biotic stresses during early stages of plant development should have a higher likelihood of success

Photo: Lori Ziegenhagen

Seed Enhancement Technologies

- Allow for the physical manipulation and application of materials to the seed for improving seed germination, emergence, and early seedling growth

(Taylor 2003; Halmer 2008)

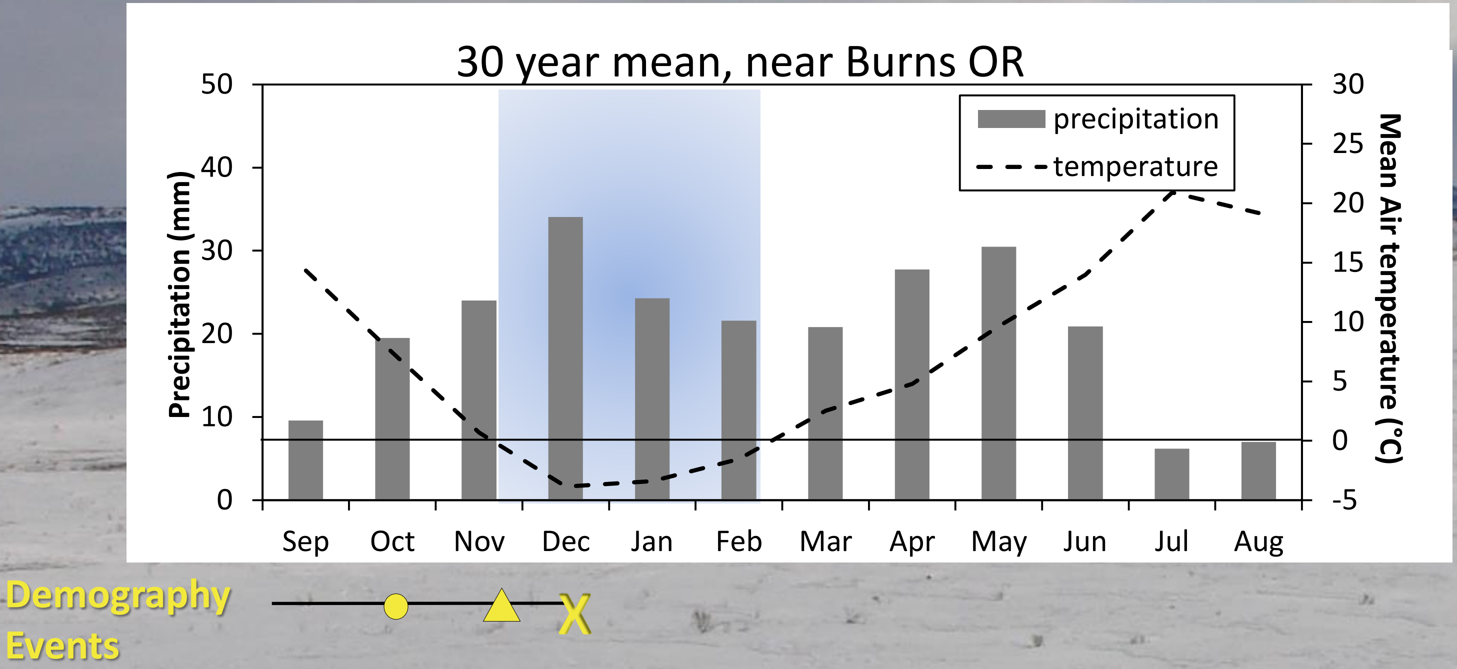
Seed Enhancement Technologies

WORKING HYPOTHESIS

- Restoration success can be improved by applying seed enhancement technologies that are designed to address specific barriers limiting plant establishment

(Taylor 2003; Halmer 2008)

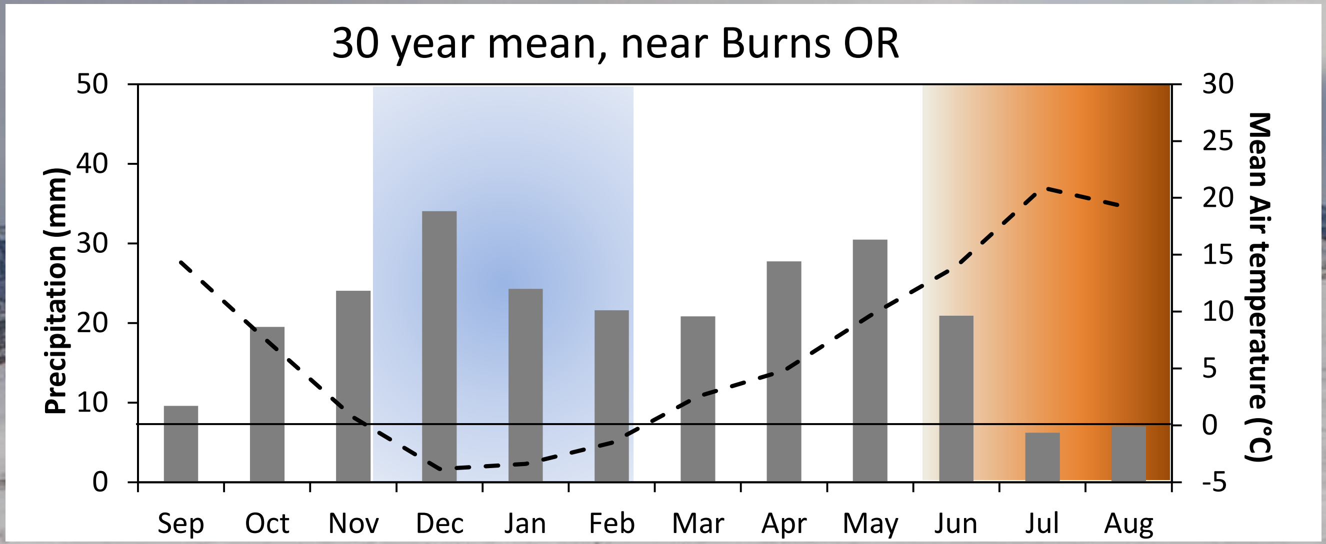
Winter Mortality



James et al. 2011, Boyd and James 2013

- Germination was rapid and high for fall seedings (Sept.-Oct.), with species obtaining up to 50-80% germination by December
- In general <10% of the seeds sown emerged from the soil surface

Winter Mortality

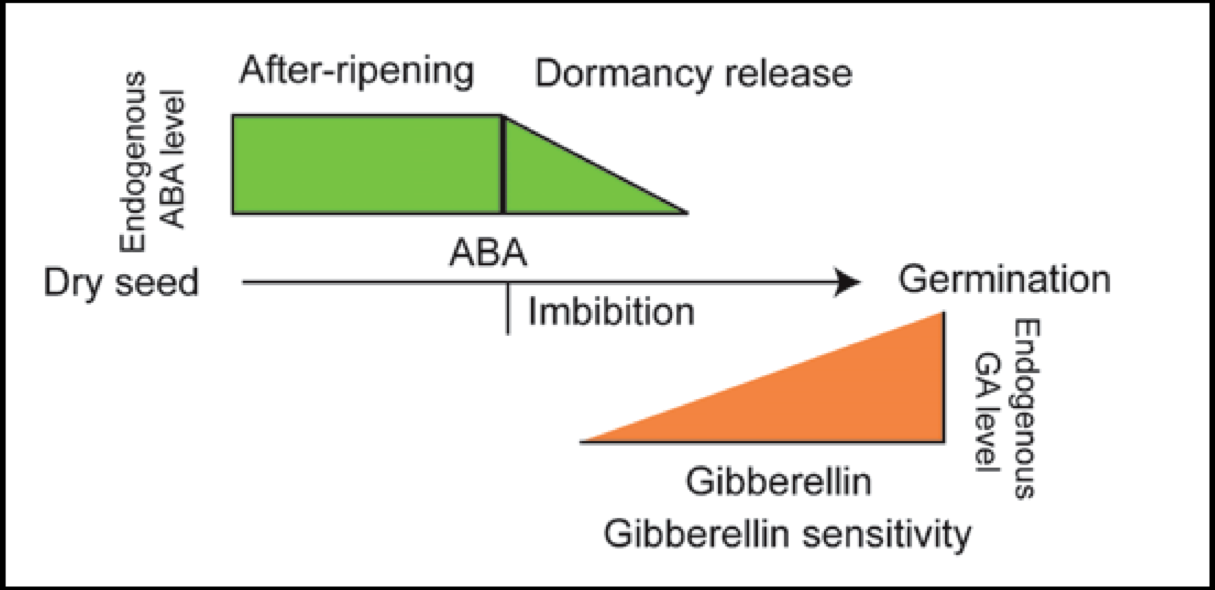


Demography Events

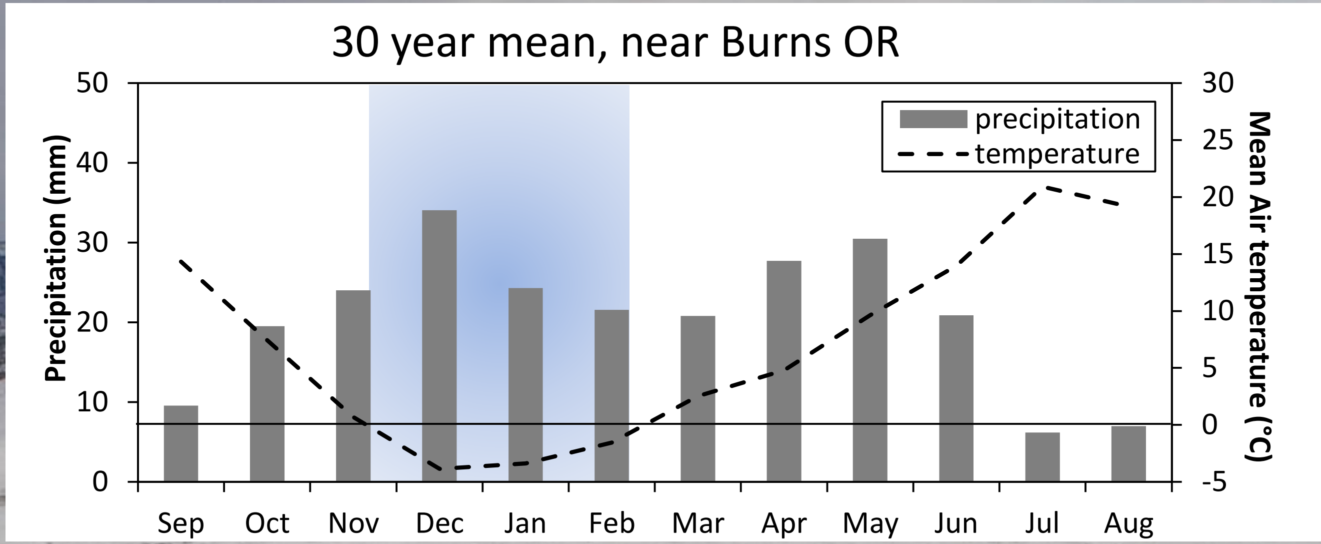
X

Seed Dormancy

- Seed dormancy has been identified as a mechanism for preventing seed germination within a season that is unfavorable for establishing a new plant
- For water-permeable seed, **dormancy** is caused from elevated levels of **abscisic acid (ABA)**
- Dormancy levels decrease as a function of time (dry after-ripening)

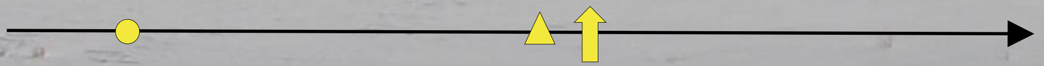


ABA Seed Coating to Delay Seed Germination



Untreated seed

ABA coated seed



Species

- Bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Löve)

Objectives

1. Determine how ABA application rates within a seed coating influences seed germination rate and total germination under a range of constant temperatures

2. Estimate seed germination timing in the field by applying thermal accumulation models to soil moisture and temperature data sets collected within the SageSTEP network

Seed Treatments

- Treated seed with **BioNik**® plant growth regulator, which is a 25% formulation of abscisic acid (ABA).
- Treatments:
  1. left untreated (control)
  2. coated (blank)
  3. 0.25 g of BioNik/ 100 g of seed
  4. 0.5 g of BioNik/ 100 g of seed
  5. 1.0 g of BioNik/ 100 g of seed
  6. 1.5 g of BioNik/ 100 g of seed
  7. 2.0 g of BioNik/ 100 g of seed
  8. 4.0 g of BioNik/ 100 g of seed
  9. 6.0 g of BioNik/ 100 g of seed

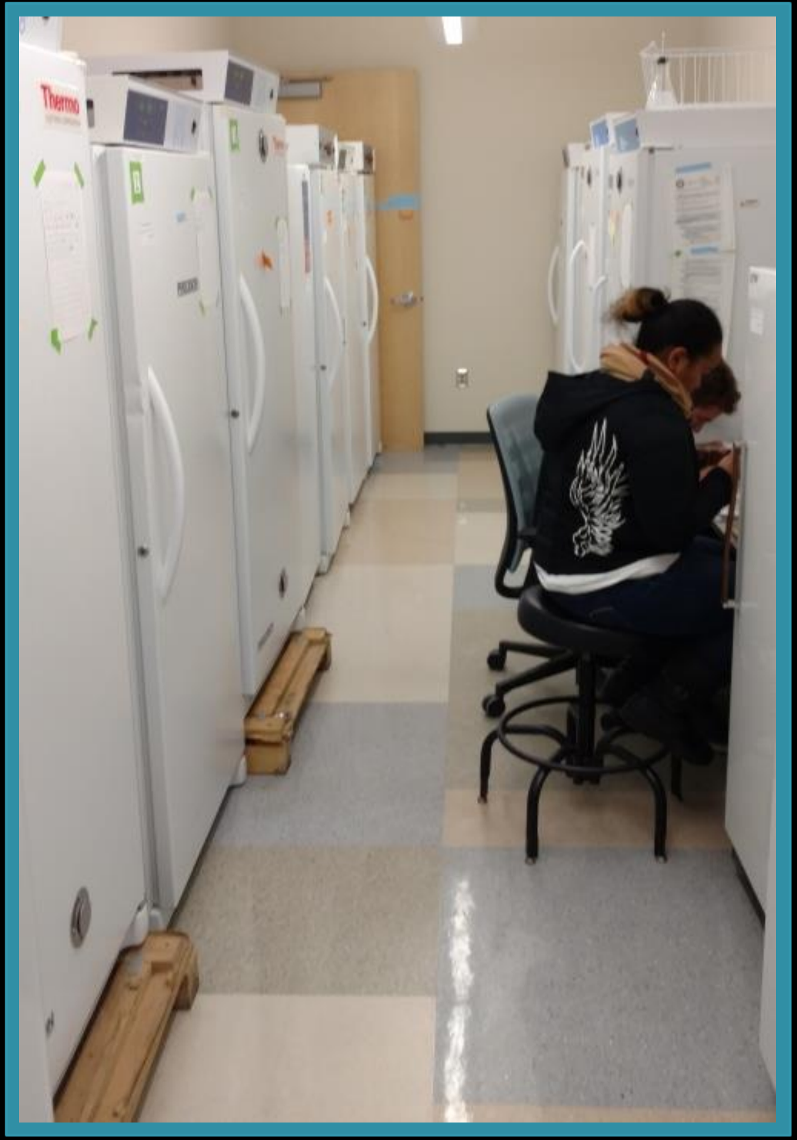
VALENT BIOSCIENCES CORPORATION

BioNik™ PLANT GROWTH REGULATOR

Objective 1: ABA Influence on Germination

STUDY DESIGN

25 seeds/box



Germination medium:

- fine-sand placed in 2cm deep, 13X13 cm acrylic boxes
- Soil moisture = - 0.006 Mpa

Temperatures:

5, 10, 15, 20, 25°C

- 7 repetitions for every treatment in every temperature

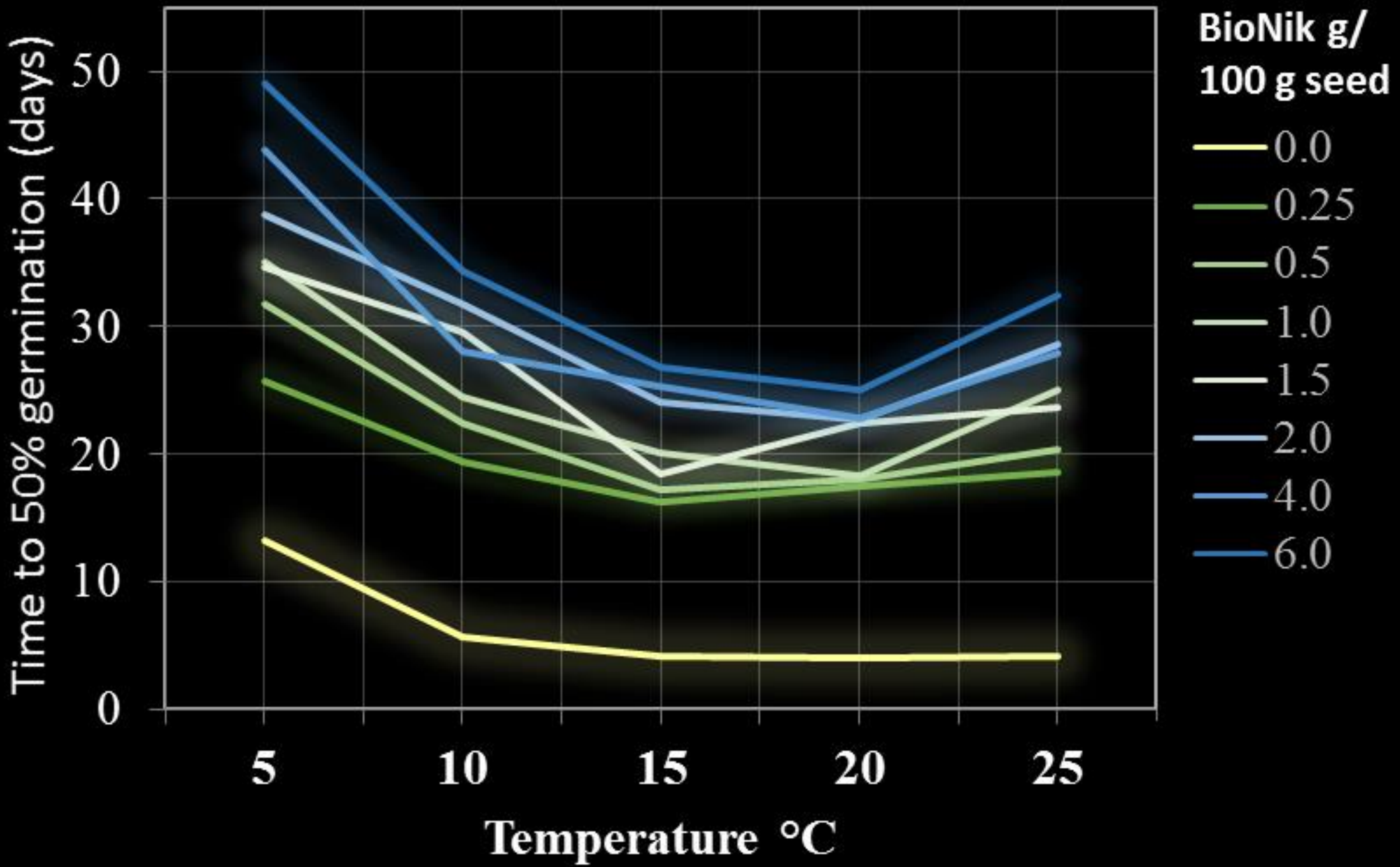
-Total boxes in study: 9 treatments X 5 temperatures X 7 reps = 315

Measurements:

- Germination was recorded every 2-3 days for 101 days

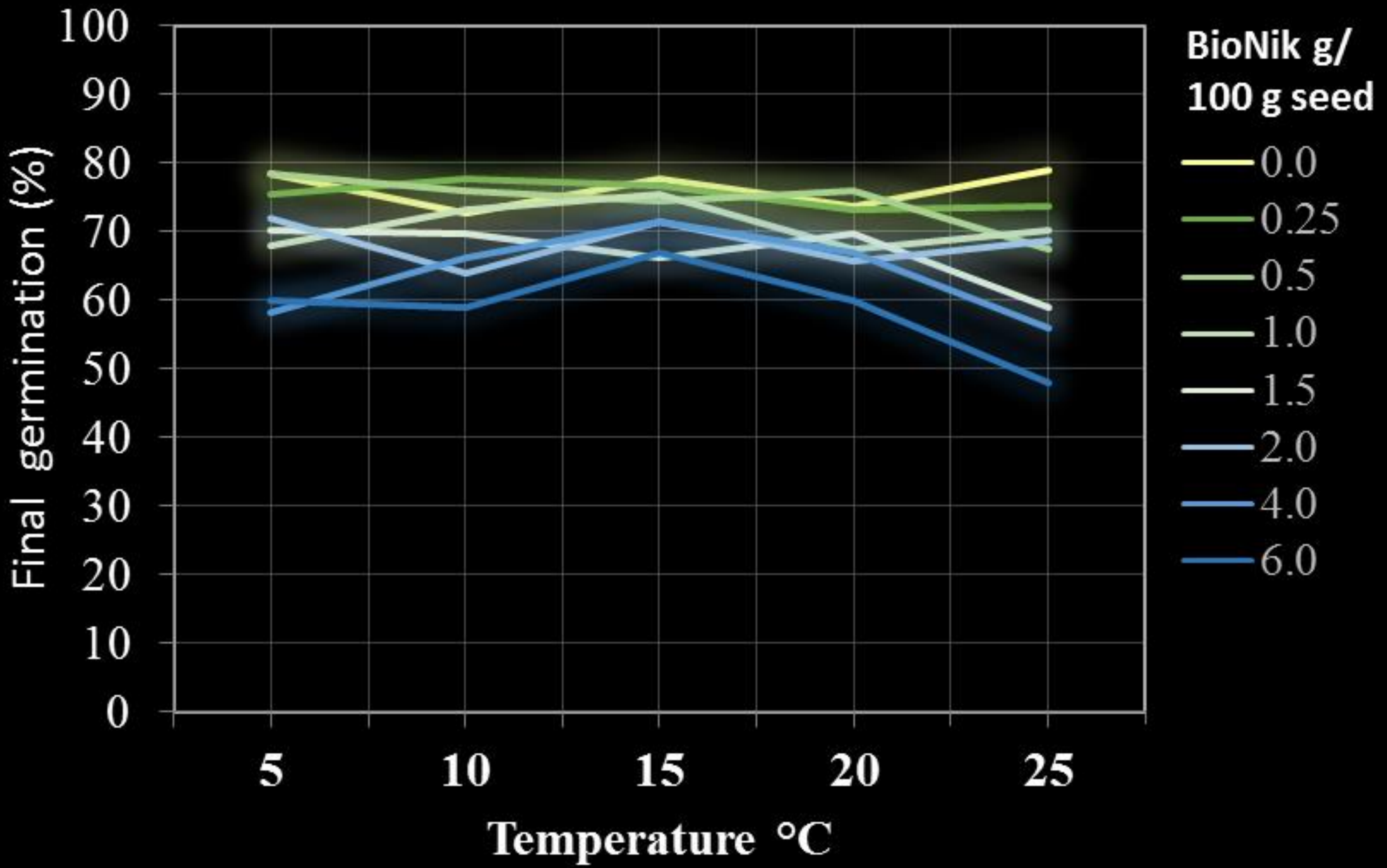
Objective 1: ABA Influence on Germination

RESULTS



Objective 1: ABA Influence on Germination

RESULTS



Objective 2: Predicting Seed Germination Date

METHODS

Environmental and Experimental Botany 76 (2012) 60–67

Contents lists available at SciVerse ScienceDirect

Environmental and Experimental Botany

journal homepage: www.elsevier.com/locate/envexpbot

ELSEVIER

Predicting germination in semi-arid wildland seedbeds. I. Thermal germination models

Jennifer K. Rawlins[a], Bruce A. Roundy[a,*], Scott M. Davis[a], Dennis Egget[b]

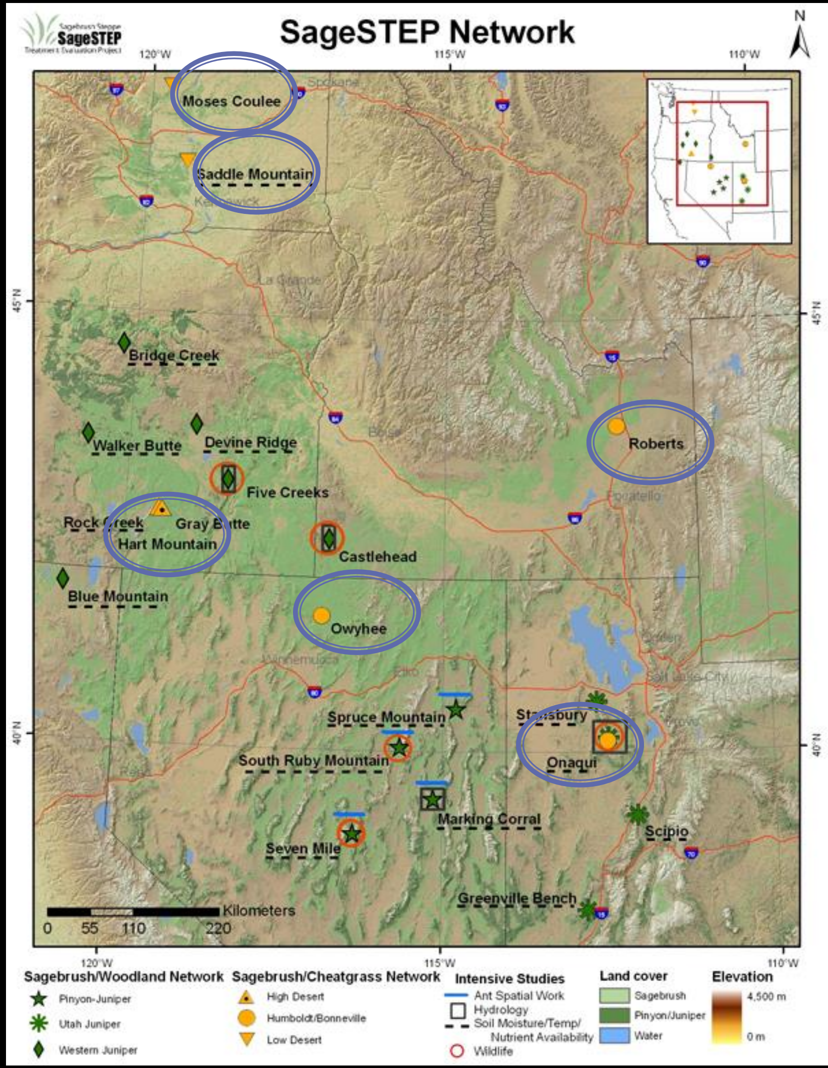
- Using daily germination count data obtained from Objective 1, we calculated the germination rate at **10% intervals from 10-90%** according to Rawlins et al. 2012
- Germination rate data was fit to **regression equations** to show the relationship between germination time and temperature
- Regression equations were applied to **historical field data** to predict the date of seed germination

Objective 2: Predicting Seed Germination Date

METHODS

Study Sites

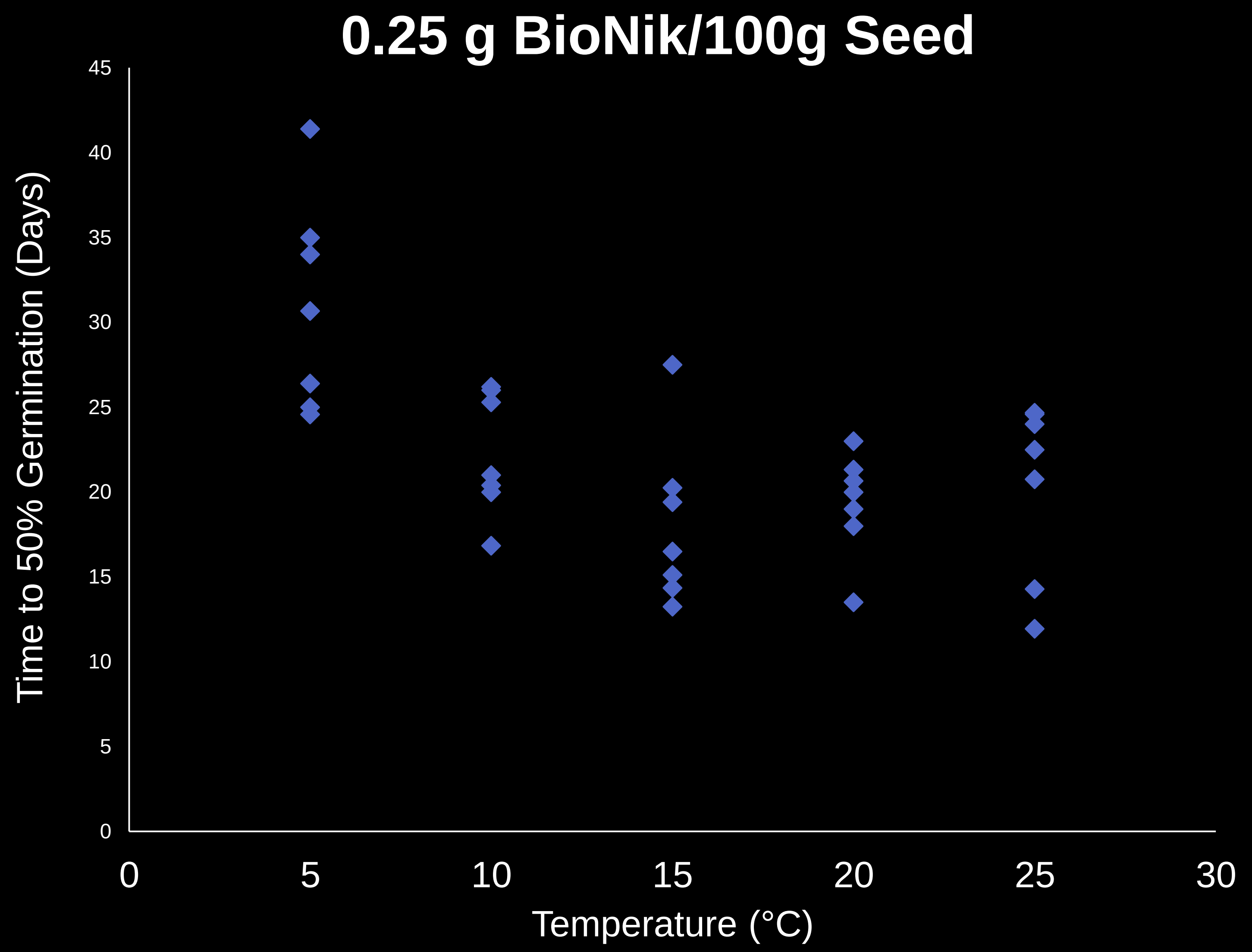
- Modeling was conducted on 6 Wyoming big sagebrush sites on four different years (2010-2014)
- We predicted the timing of seed germination using water potential (gypsum blocks) and soil temperature (thermocouples) data collected form the SageSTEP network



Objective 2: Predicting Seed Germination Date

METHODS

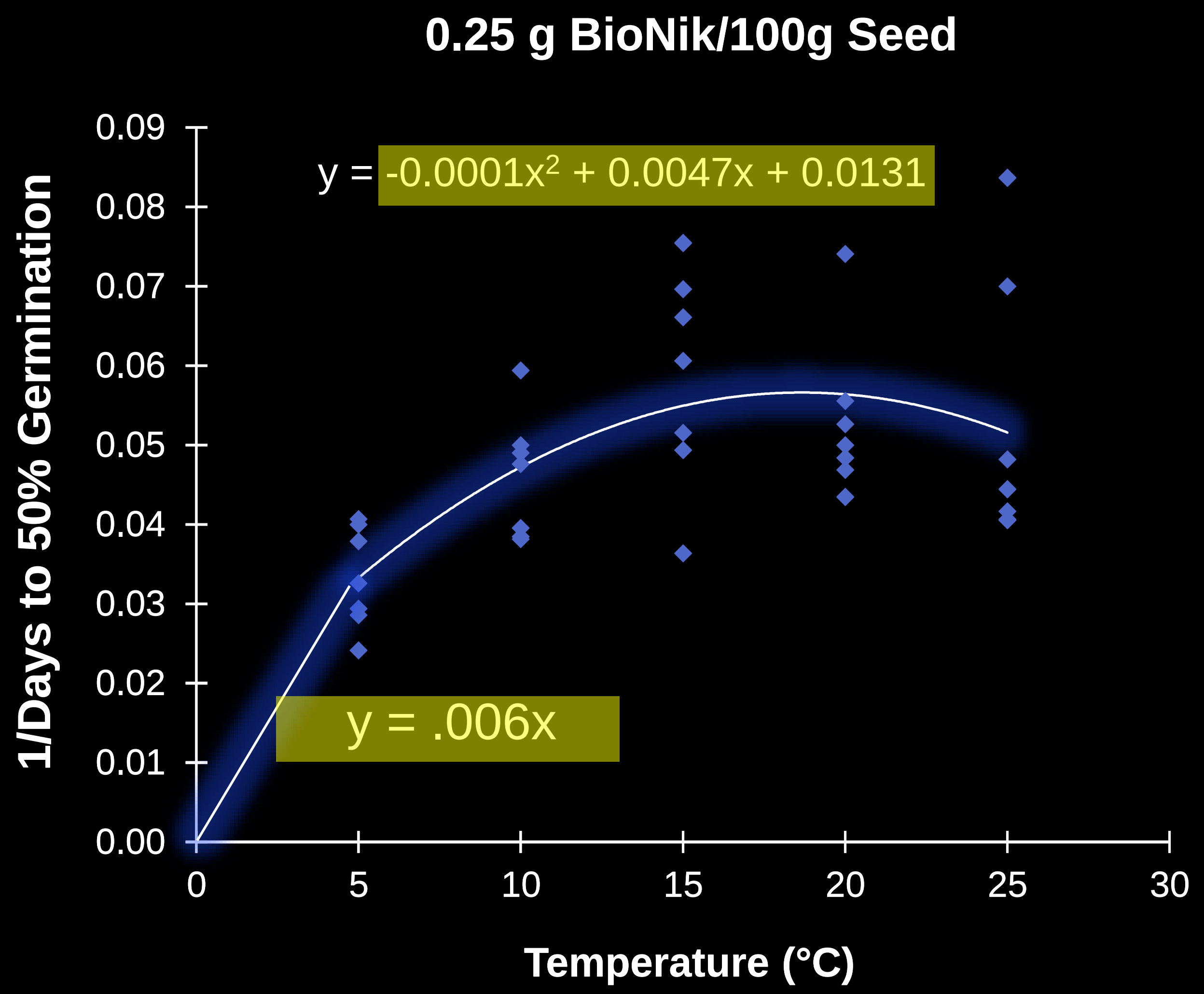
- Example



Objective 2: Predicting Seed Germination Date

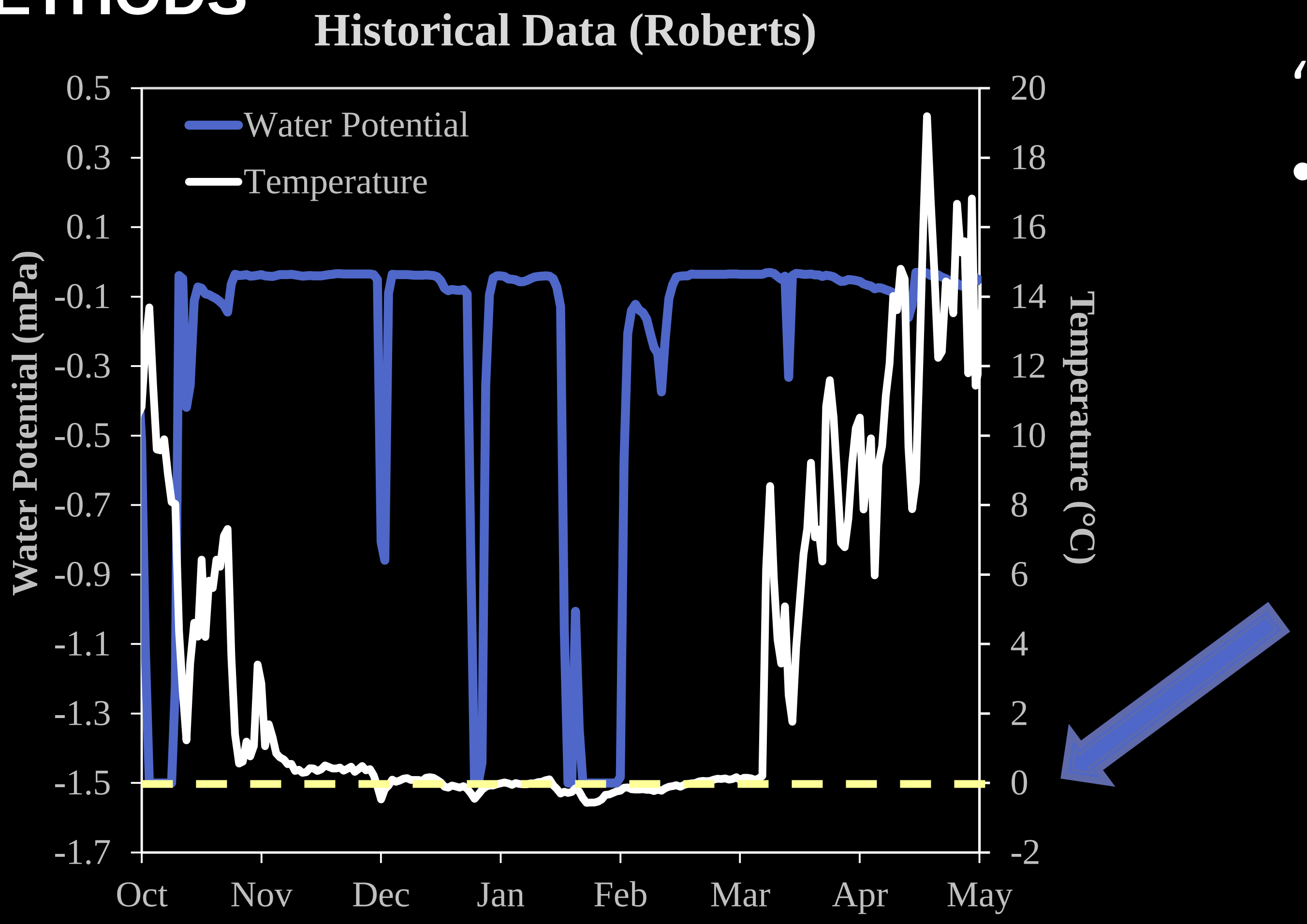
METHODS

- We take the inverse of the data
- Fit the data (polynomial)
- No data from 0 to 5 °C
- Linear extrapolation (Hardegree et al. 2013)



Objective 2: Predicting Seed Germination Date

METHODS



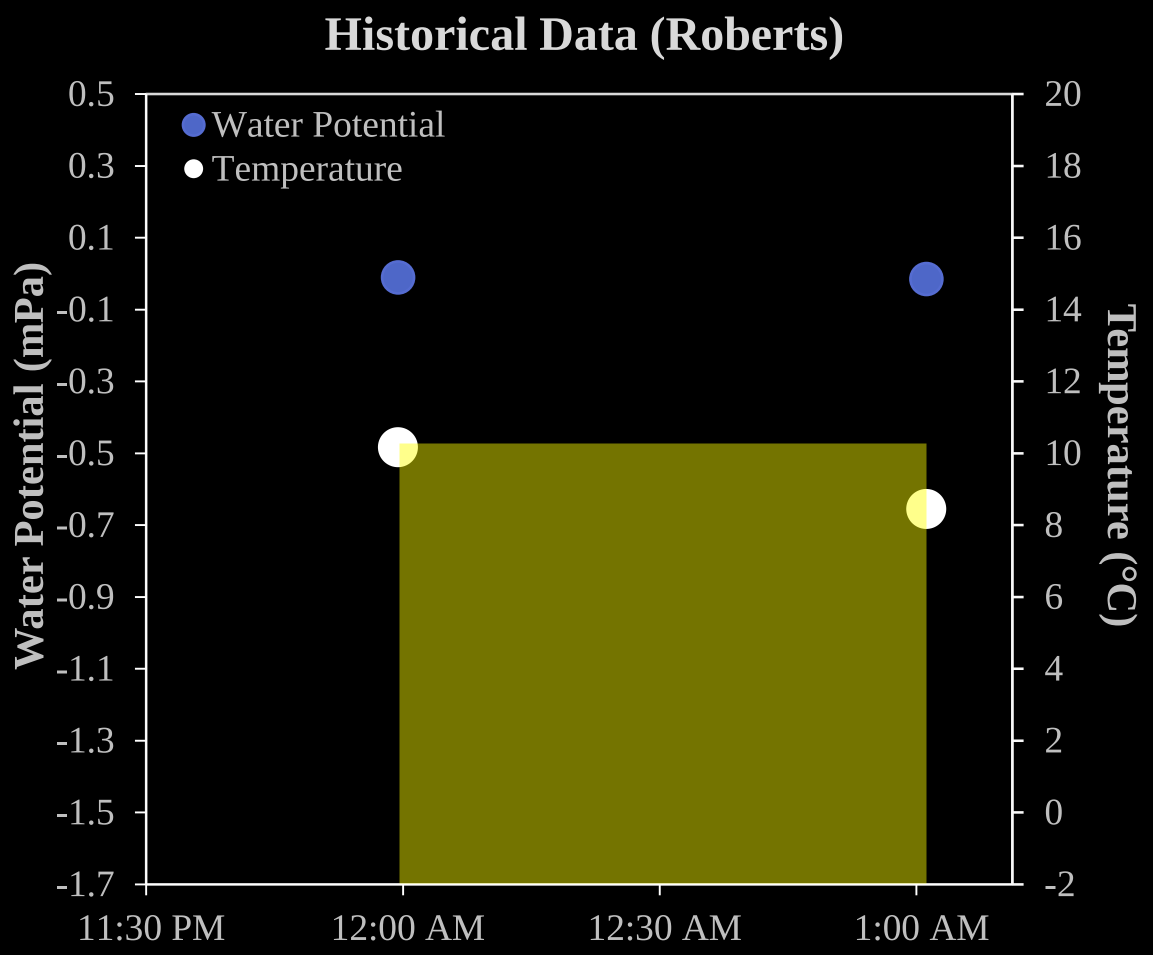
"On/Off" Switch

- Seeds start accumulating thermal time (i.e. progress towards germination when water potential is $\leq -1.5\text{MPa}$ (Rawlins et al. 2012) and soil temperature is > 0 °C

Objective 2: Predicting Seed Germination Date

METHODS

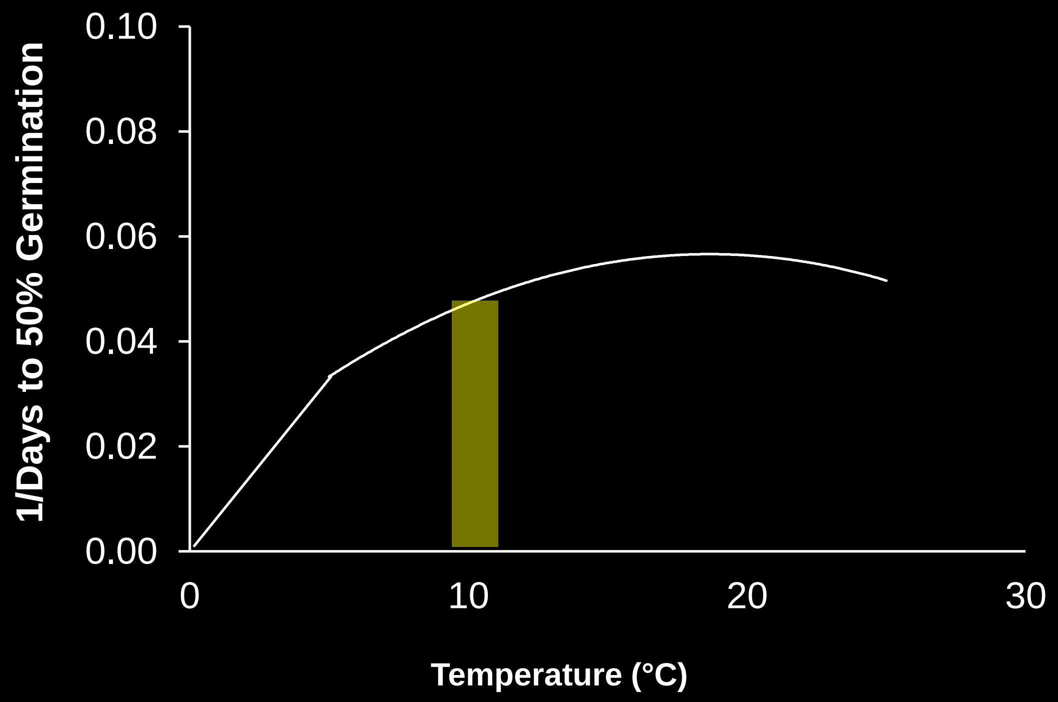
Time Spent at Temperature

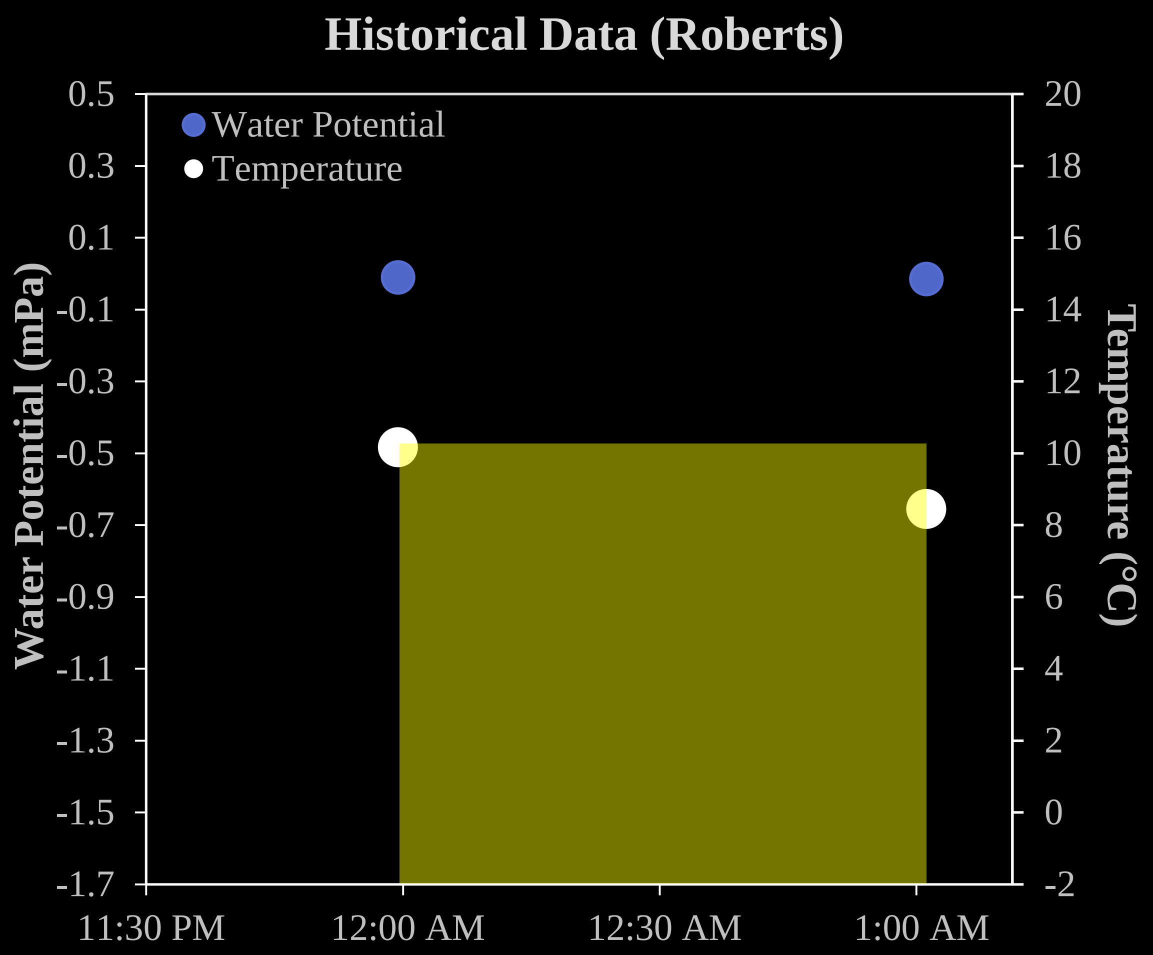


Objective 2: Predicting Seed Germination Date

METHODS

$$\frac{1\ hr \ * \frac{1 day}{24\ hr}}{\frac{1}{0.045\ 1/D50}} * 100 = 0.19\ \%$$





Objective 2: Predicting Seed Germination Date

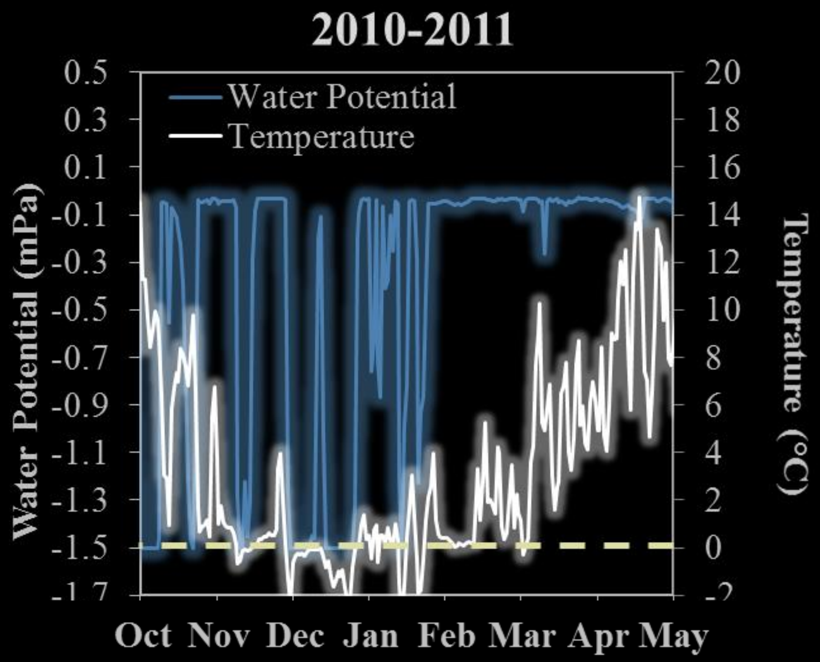
METHODS

$$\frac{Time\ Spent\ at\ Temperature}{Time\ to\ reach\ \%\ \ germination\ at\ Temperature}$$

- Progress towards germination is summed until reaching 100%
- Lots of data! Excel VBA programing is used to speed up process

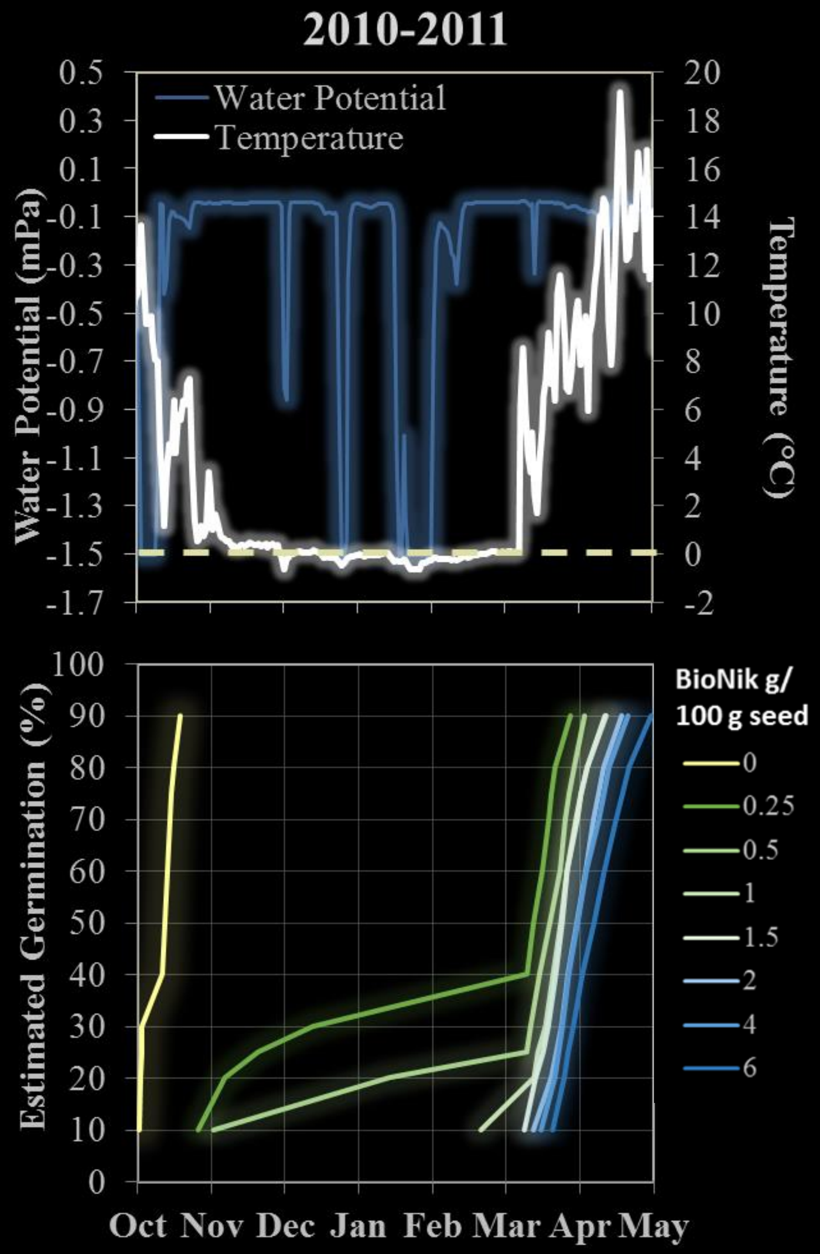
RESULTS

Heart Mountain

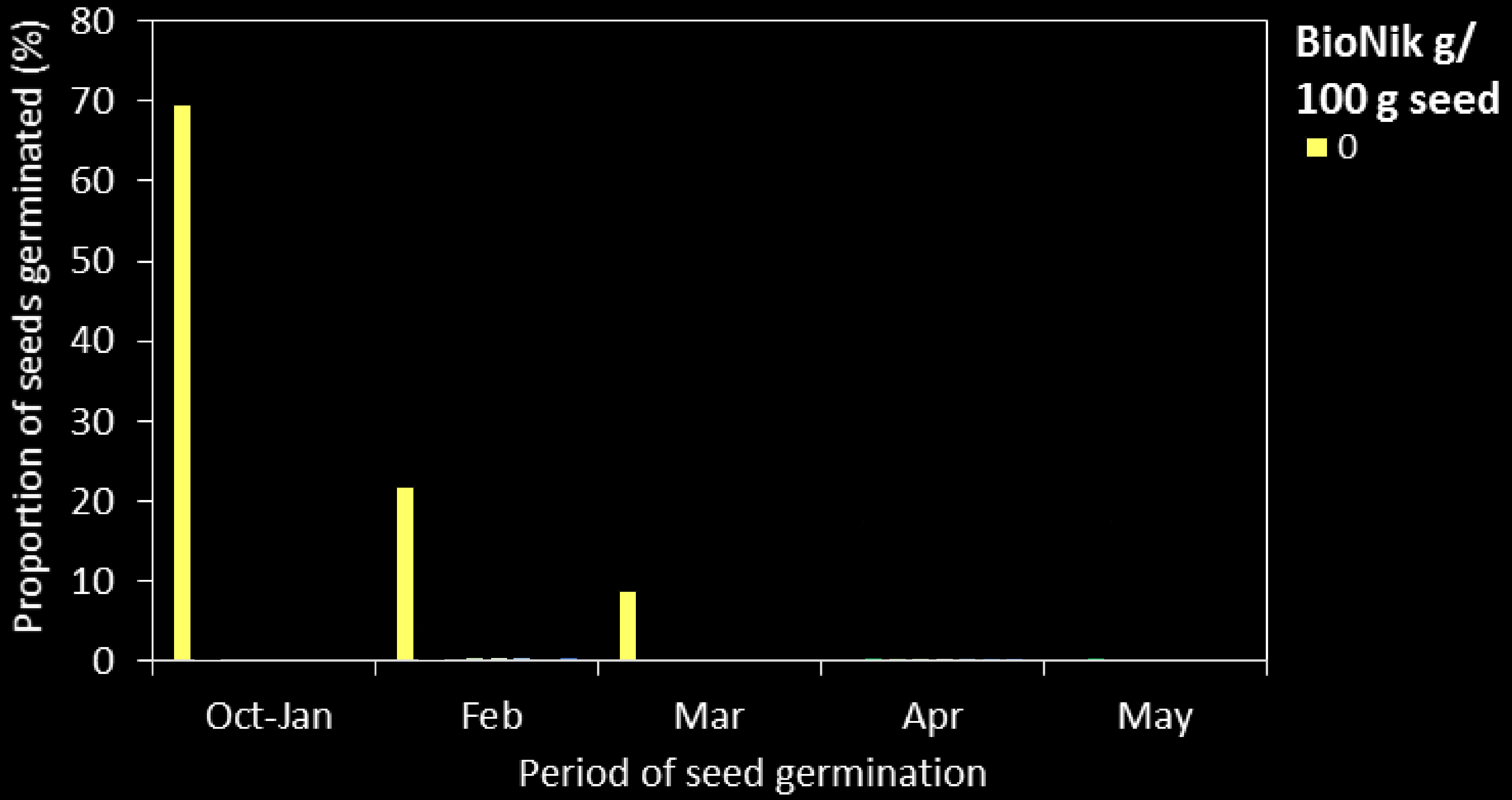


RESULTS

Roberts

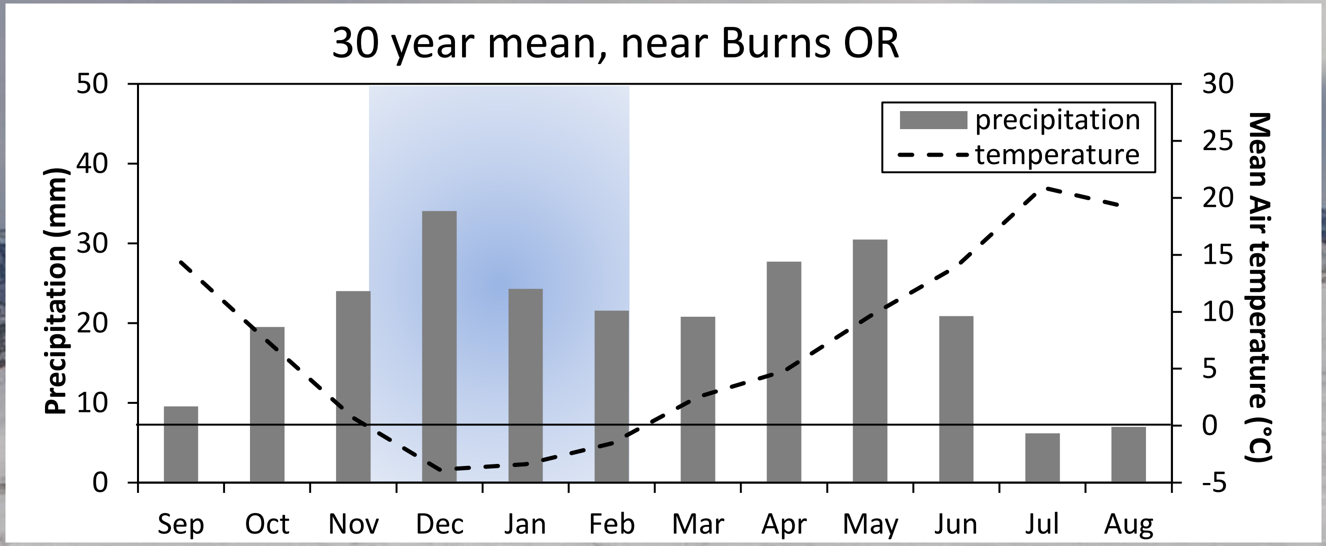


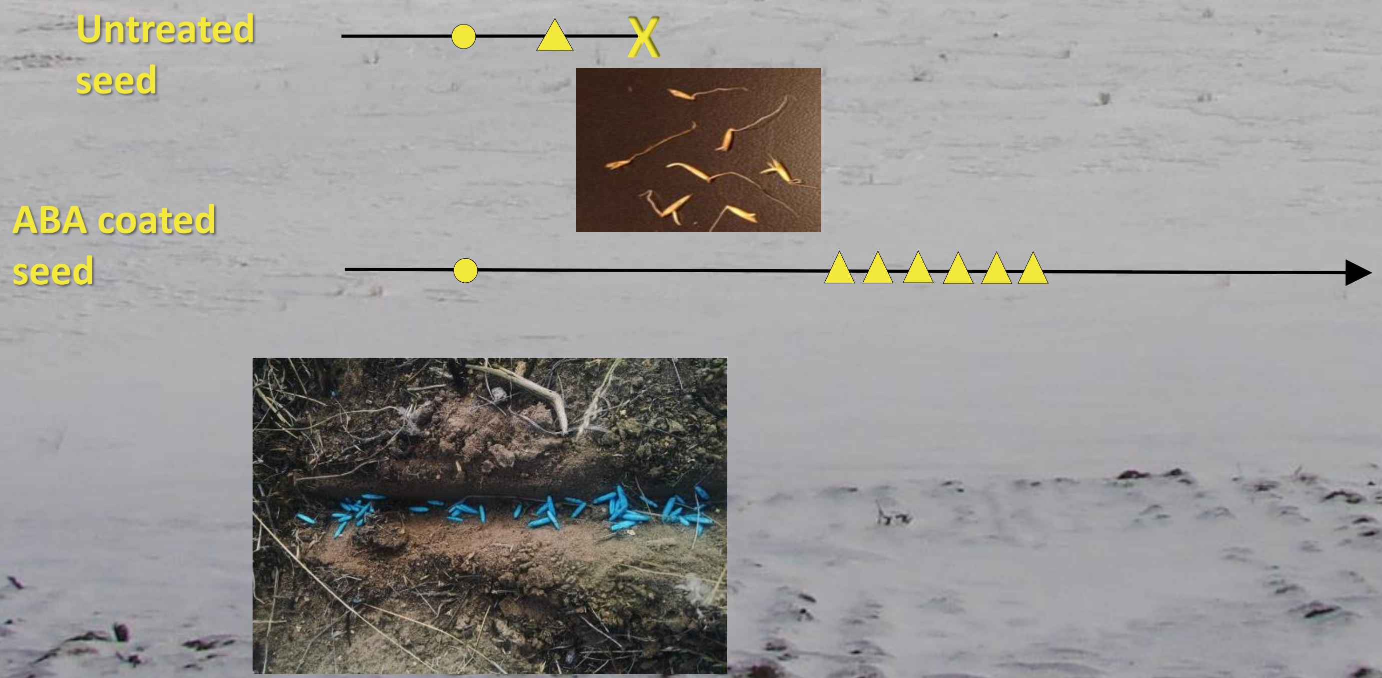
RESULTS



Proportion of seeds germinated (%)
80
70
60
50
40
30
20
10
0
Oct-Jan
Feb
Mar
Apr
May
Period of seed germination
BioNik g/
100 g seed
0

ABA Seed Coating to Delay Seed Germination



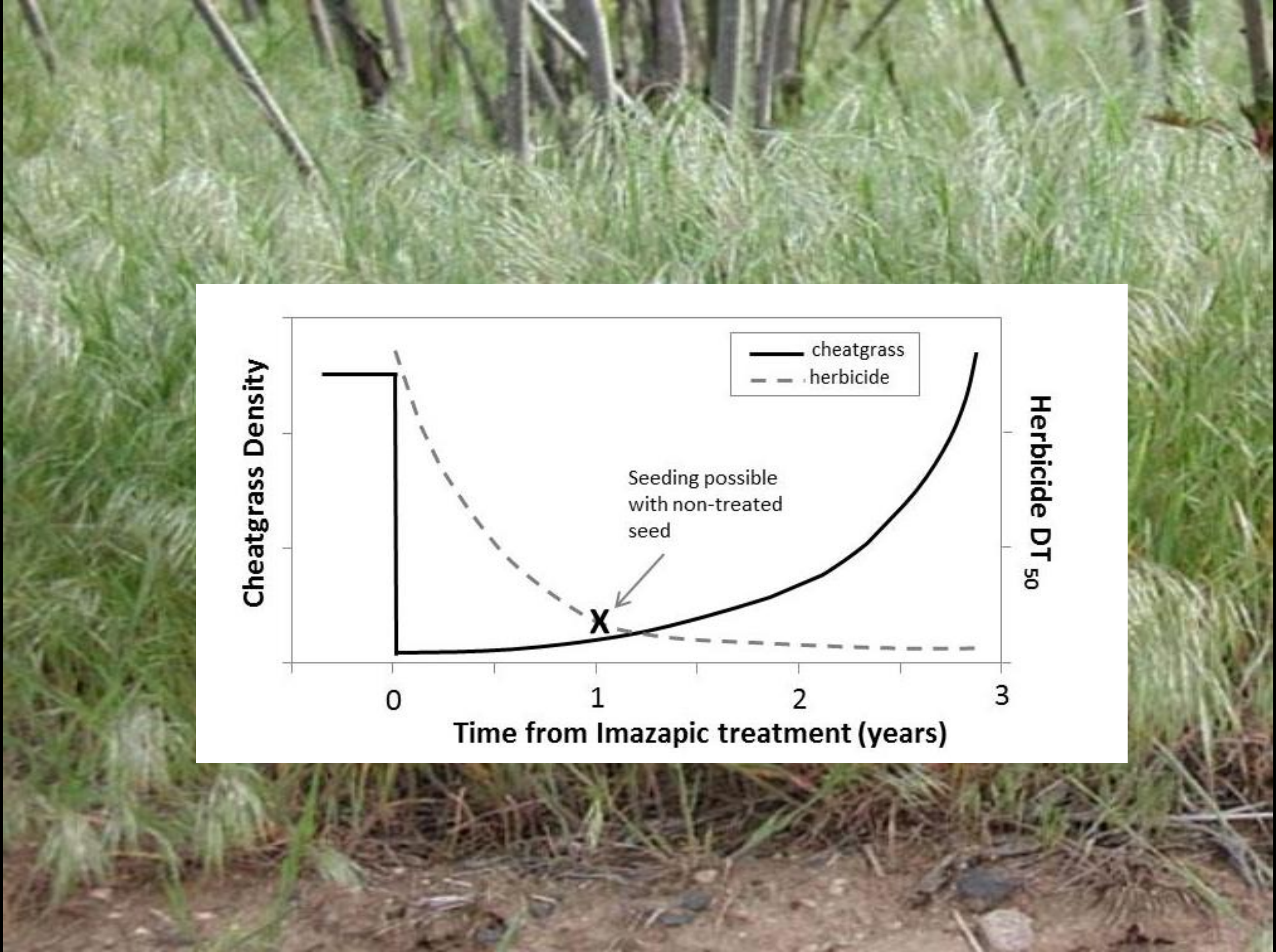


Future Research

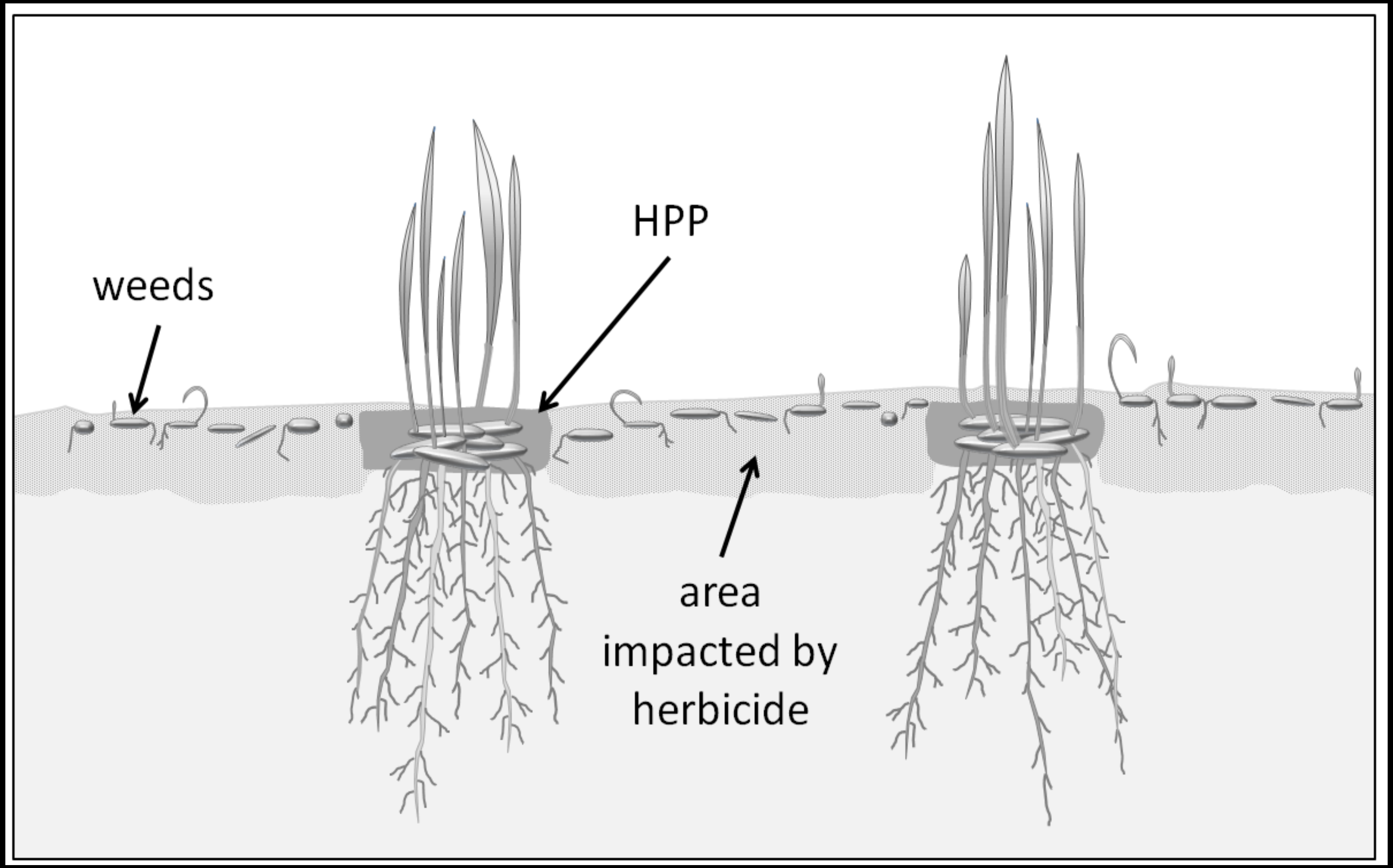
- Field test thermal accumulation models
- Quantify how ABA treated seed influence plant establishment
- Determine if mixes of ABA treated seed with different seed germination timing scenarios can decrease the risk of reseeding failures by having cohorts of seed germinating at different time intervals
- Conduct a cost-benefit analysis on the seed-coating treatments

Annual Weed Competition

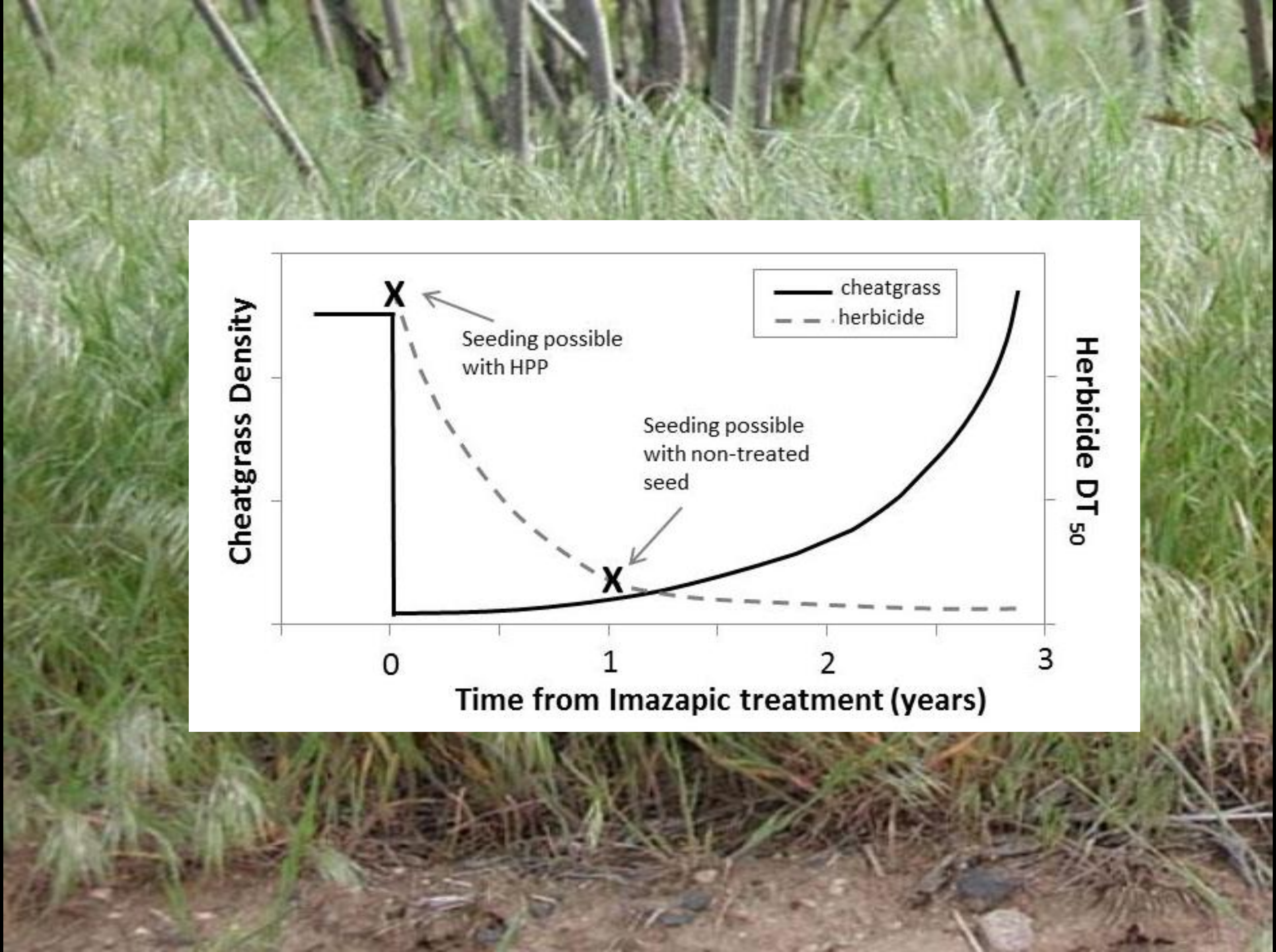
- **At the seedling stage, most perennial sagebrush associated species cannot effectively compete with exotic annual grasses, due to the annuals having:**
  - ✓ higher plant and seed bank densities
  - ✓ faster germination
  - ✓ greater germination potential
  - ✓ higher growth rates
- **Annual grasses must be removed or greatly reduced prior to reseeding native perennial species (Monson et al. 2004).**


Cheatgrass Density
Herbicide DT 50
cheatgrass
herbicide
Seeding possible with non-treated seed
X
0
1
2
3
Time from Imazapic treatment (years)

Herbicide Protection Pod

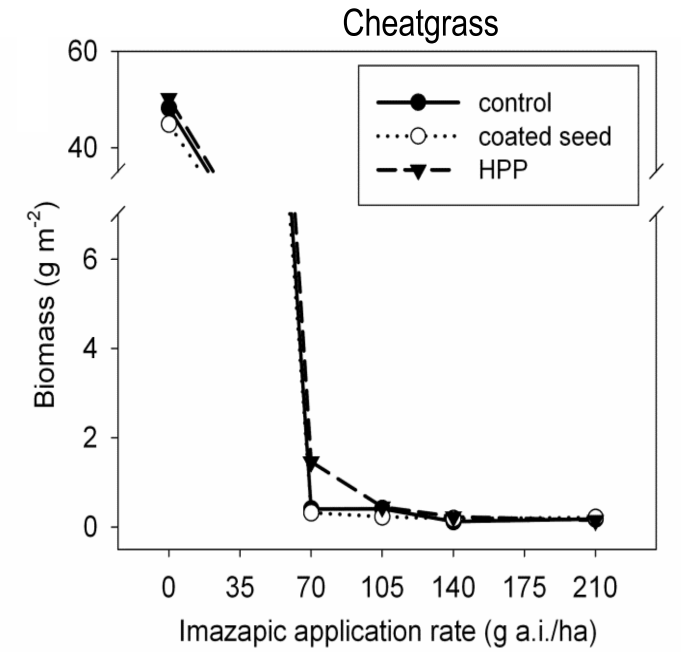


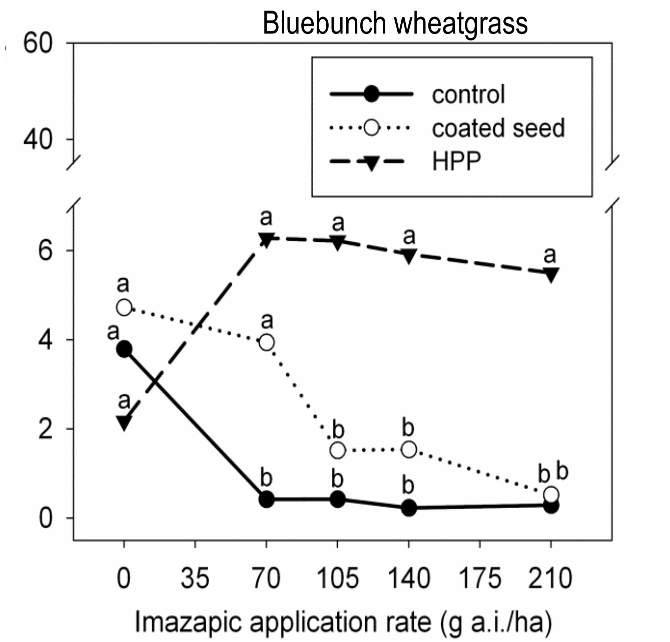
Madsen et al., Rangeland Ecology and Management, In Review

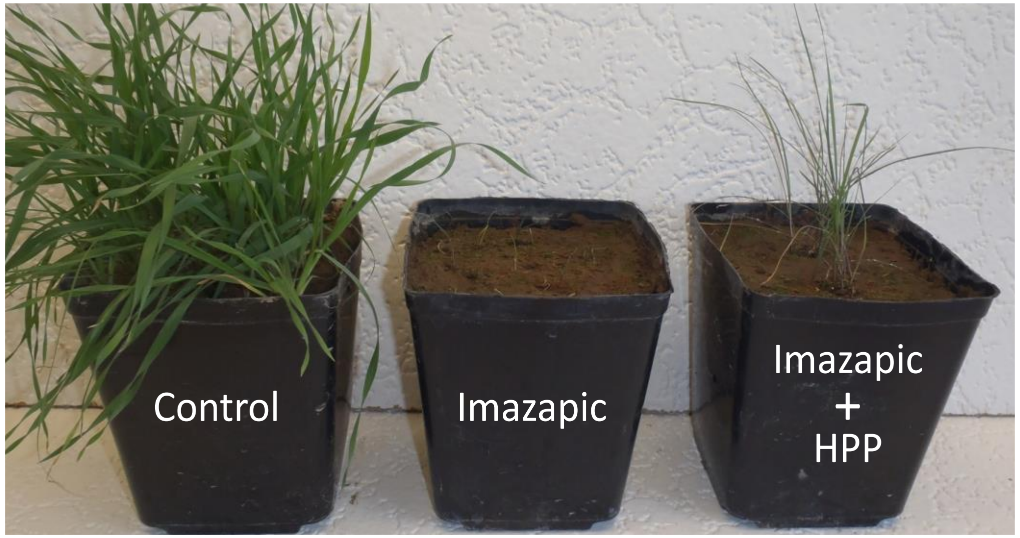


Cheatgrass Density
Herbicide DT 50
cheatgrass
herbicide
X
Seeding possible with HPP
X
Seeding possible with non-treated seed
0
1
2
3
Time from Imazapic treatment (years)

Laboratory Trial

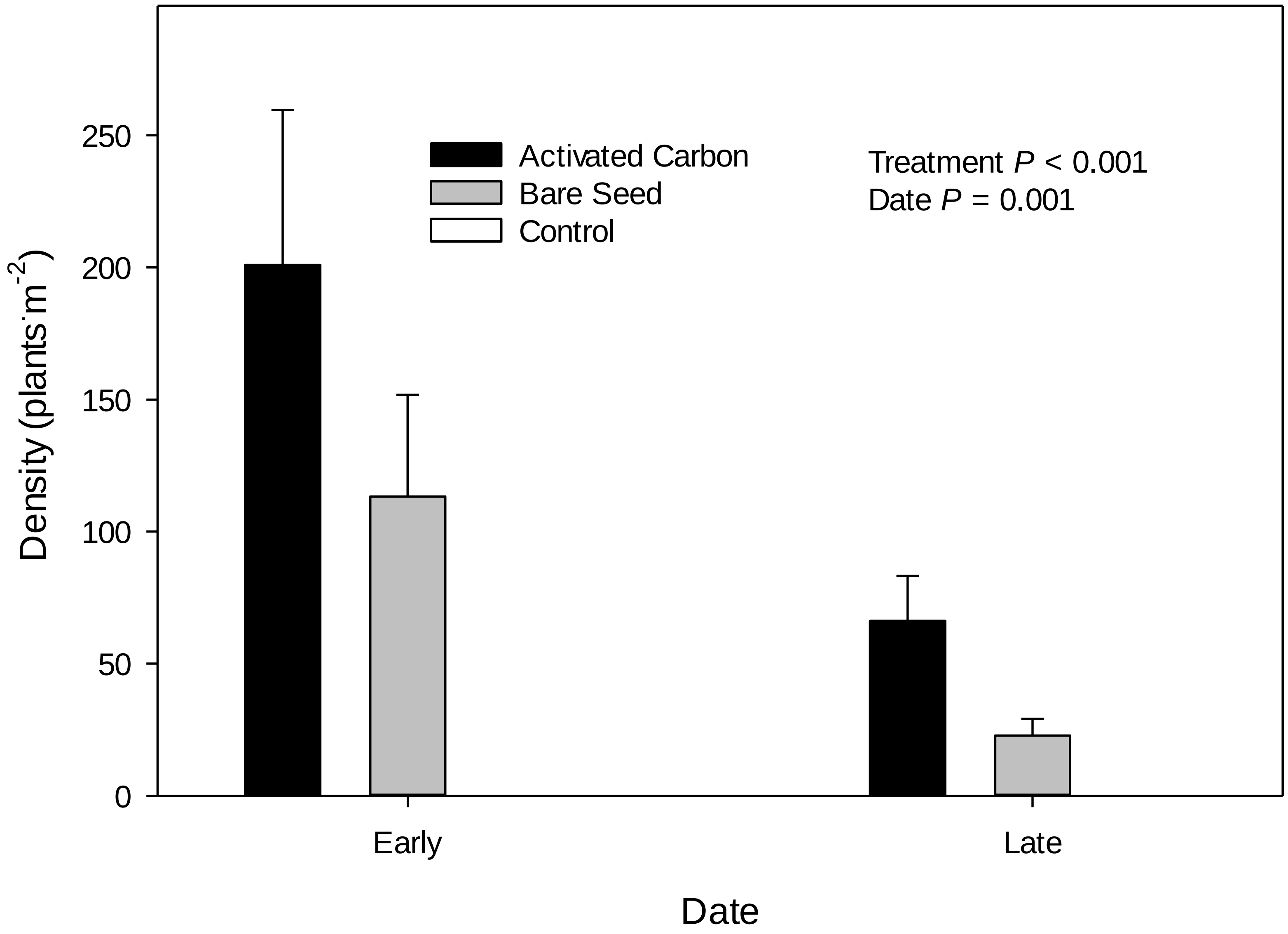




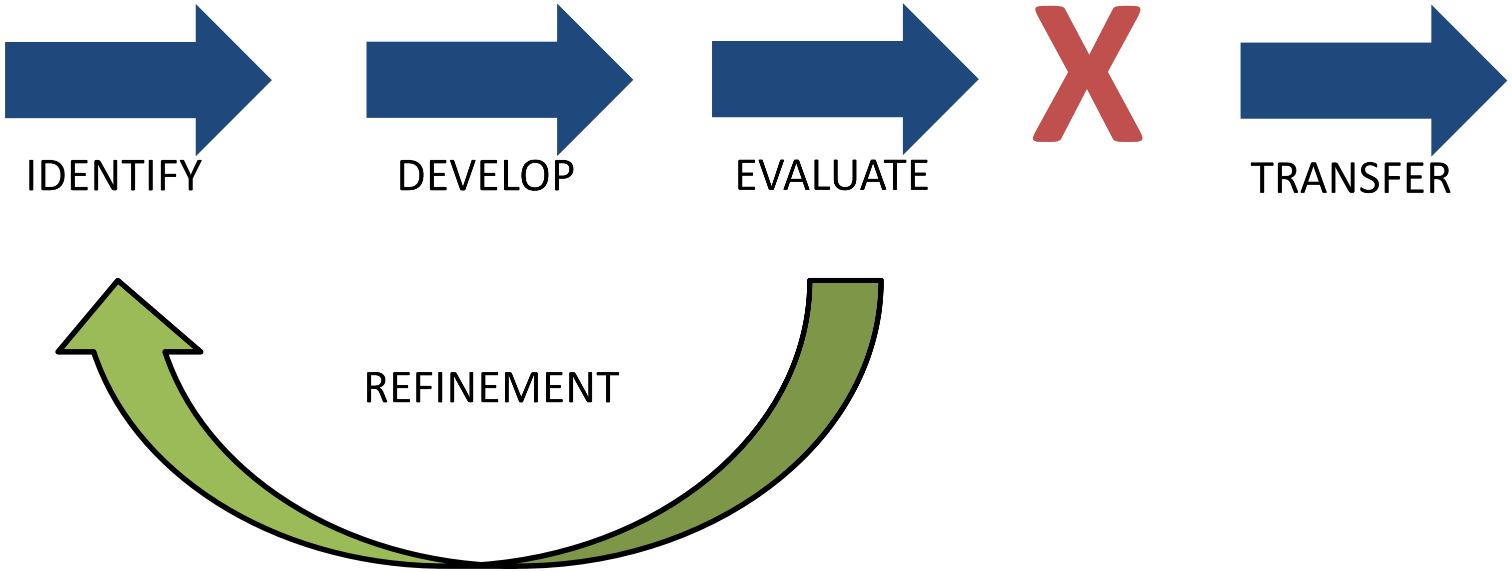


Field Trial

Davies et al. (IN PREPERATION)
Rangeland Ecology and Management



Future Research



- Straight line approach typically does not solve complex problems
- We need to appreciate the refinement process that comes with iteration and build it into our planning process
- Modeling may accelerate the RD process

Conclusions

- Continued research is needed to develop seed enhancement technologies that overcome specific barrier to plant establishment and in conducting research to combine proven technologies to address a range of limitations
- There is a potential for seed enhancement technologies to yield direct and significant savings through improved seedling establishment rates
- Indirect savings may also be realized by maintaining functioning ecosystems through lowering wildfire suppression costs and maintaining landscapes that support both anthropogenic activities and a diversity of wildlife habitats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Temporal Variability in Microclimatic Conditions for Grass Germination and Emergence in the Sagebrush Steppe☆

Stuart P. Hardegree [a,*], Roger L. Sheley [b], Sara E. Duke [c], Jeremy J. James [d], Alex R. Boehm [e], Gerald N. Flerchinger [f]