Big Sagebrush (*Artemisia tridentata*) Ecophysiology: from native habitats to common gardens and beyond.

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Study 1

- Quantifying genetic variation in physiology and morphology in subspecies of big sagebrush (*Artemisia tridentata*) in a common garden setting.

Study 2

- Quantifying genetic variation in hydraulic functional traits during growing season in subspecies of big sagebrush (*Artemisia tridentata*) in a common garden setting.

Study 3

- Phenotypic variation of big sagebrush (*Artemisia tridentata*) in response to a soil-moisture gradient.

Study 4

- Quantifying phenotypic plasticity of big sagebrush (*Artemisia tridentata*) seedlings in a manipulative greenhouse setting.

Orchard common garden

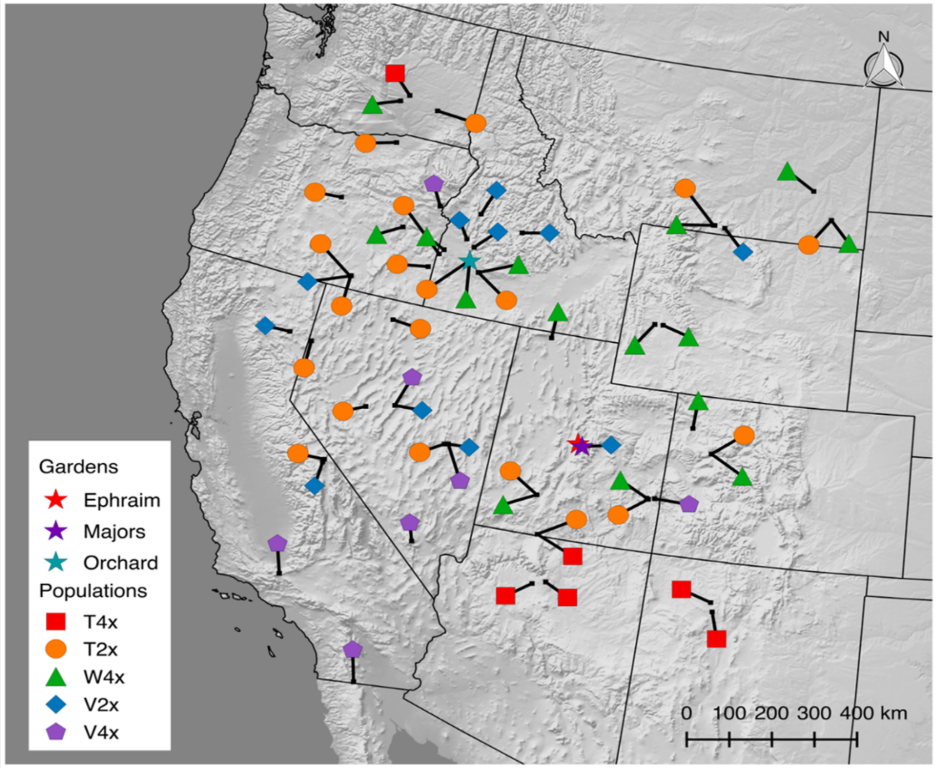


Figure 1. Map of big sagebrush (Artemisia tridentata) common gardens and seed source locations indicating their subspecies and cytotype. Common gardens were established in 2012 with 55 populations, 1-11 populations per state, and an average of 7.8 shrubs per population. (Chaney et al. 2016).

- Established: April 2010
- *A. t. wyomingensis* native environment
  - Warm intermountain steppe
  - Dry climate
- 3 subspecies
  - Diploid (2n)
  - Tetraploid (4n)
- 55 populations
- 11 states
- Wide ranges of climate

Study 1

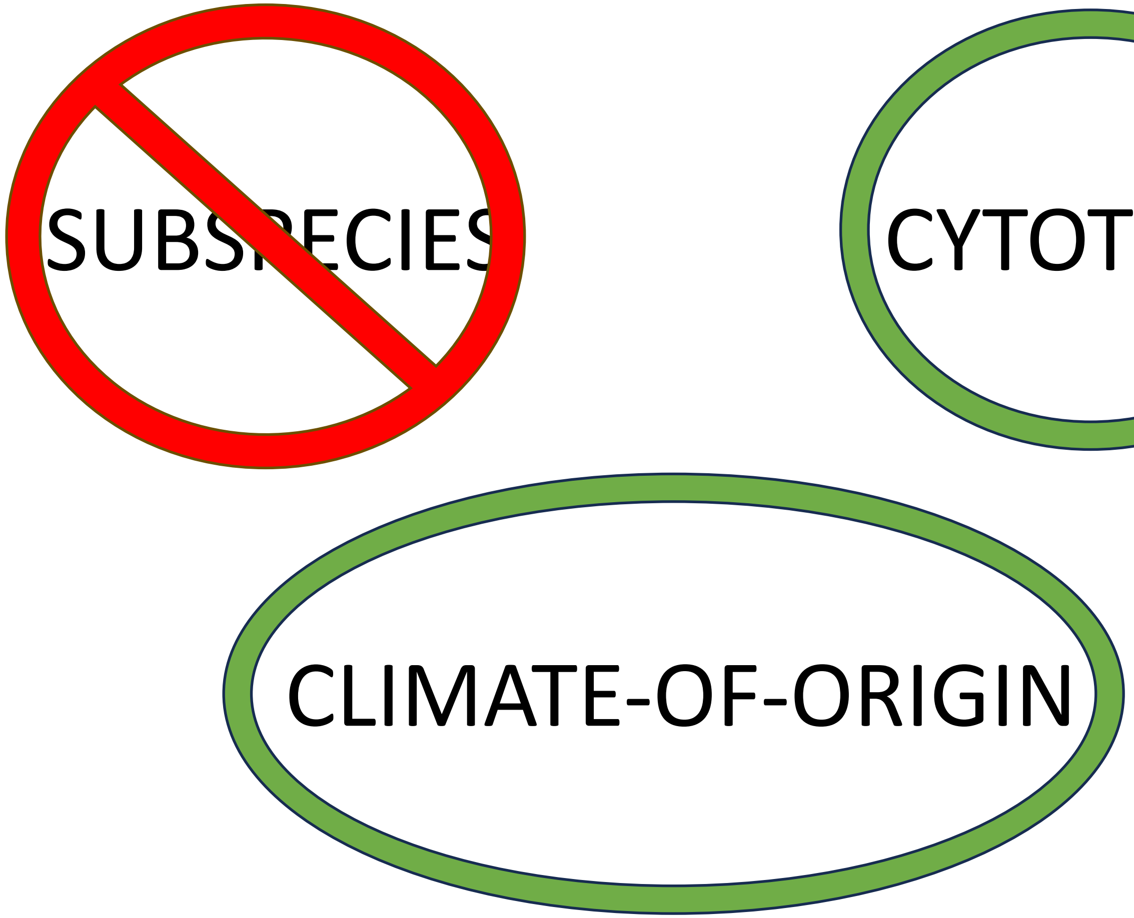
Quantifying genetic variation in physiology and morphology in subspecies of big sagebrush (*Artemisia tridentata*) in a common garden setting.

To what extent do subspecies, cytotype, and climate-of-origin contribute to phenotypic variation in big sagebrush (*Artemisia tridentata*)?

Question:

Study Design

- Summer 2019
  - 7/1, 7/11, & 7/25
- 90 shrubs
  - 51 diploid (2n) *A. t. tridentata*
  - 24 tetraploid (4n) *A. t. tridentata*
  - 15 tetraploid (4n) *A. t. wyomingensis*

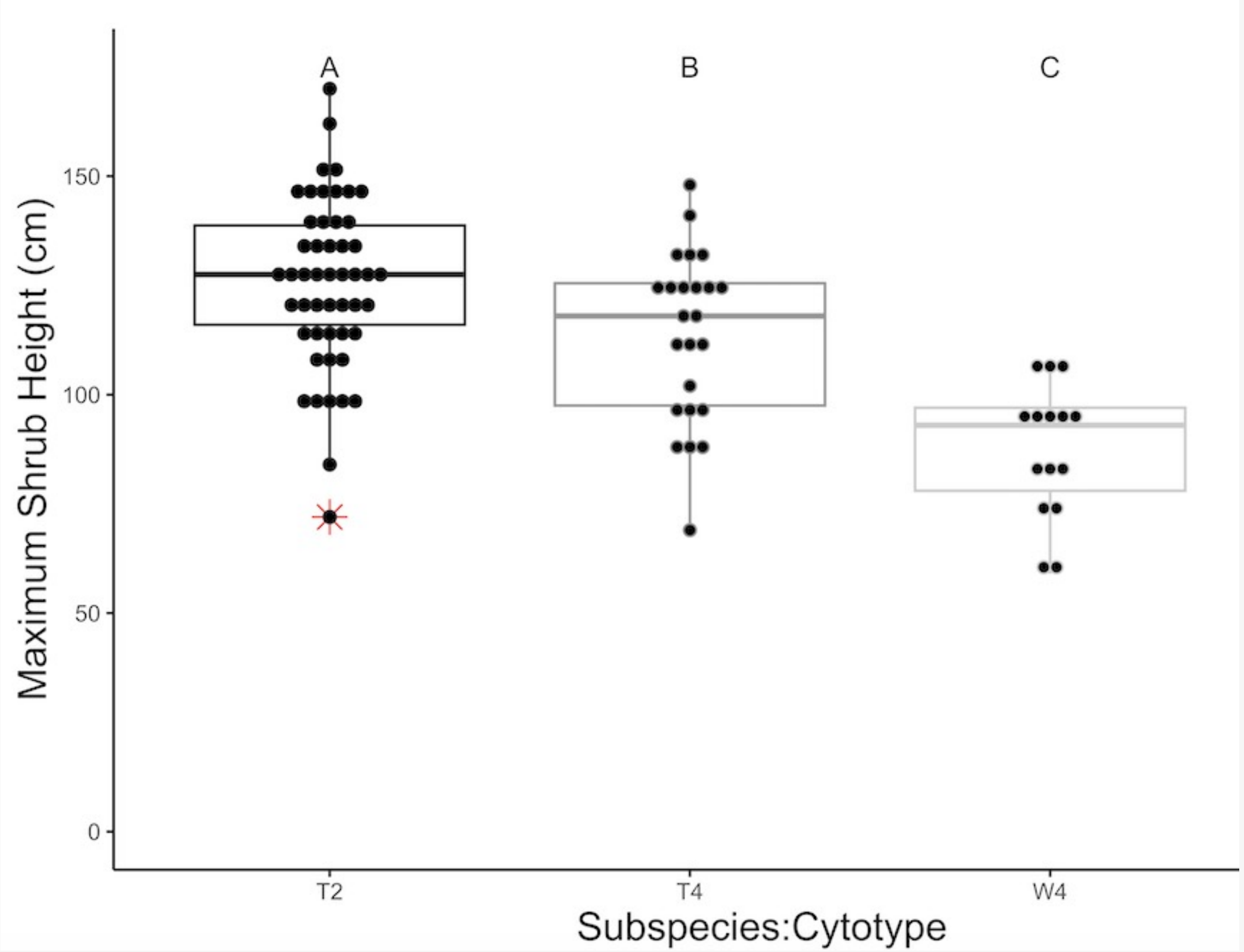


Based on recent findings (Chaney et al. (2016), Germino et al. (2019), and Lazarus et al., (2019)), I predicted:

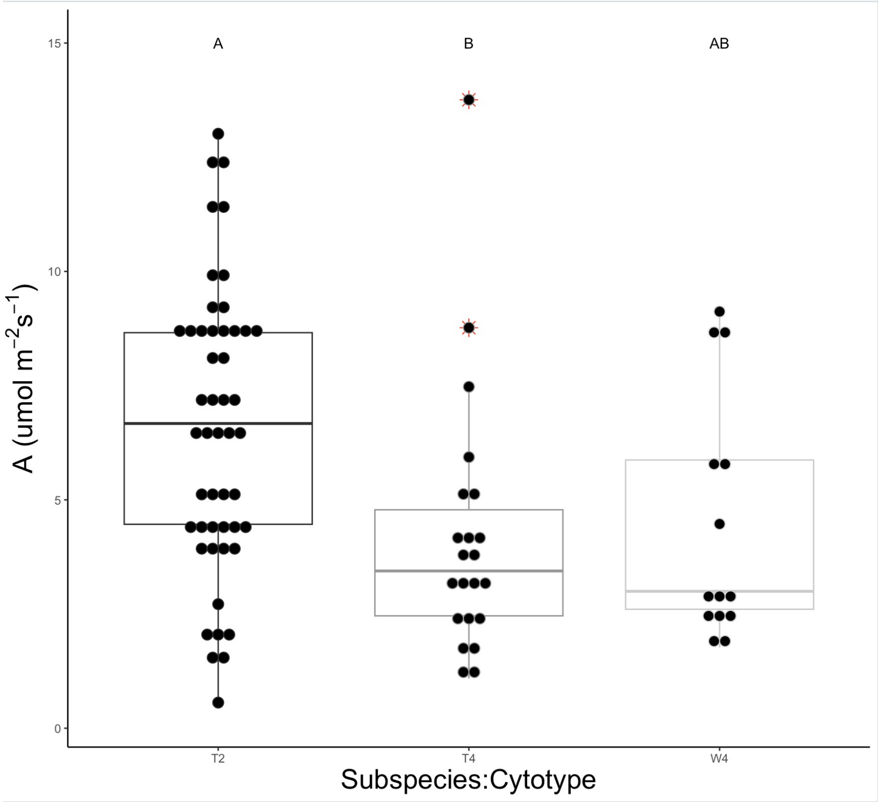
1) ***subspecies would have little to no influence on variation in these measured traits,*** *and instead*
2) ***climate-of-origin, and cytotype would be the main drivers for morphological and physiological variation in A. tridentata.***

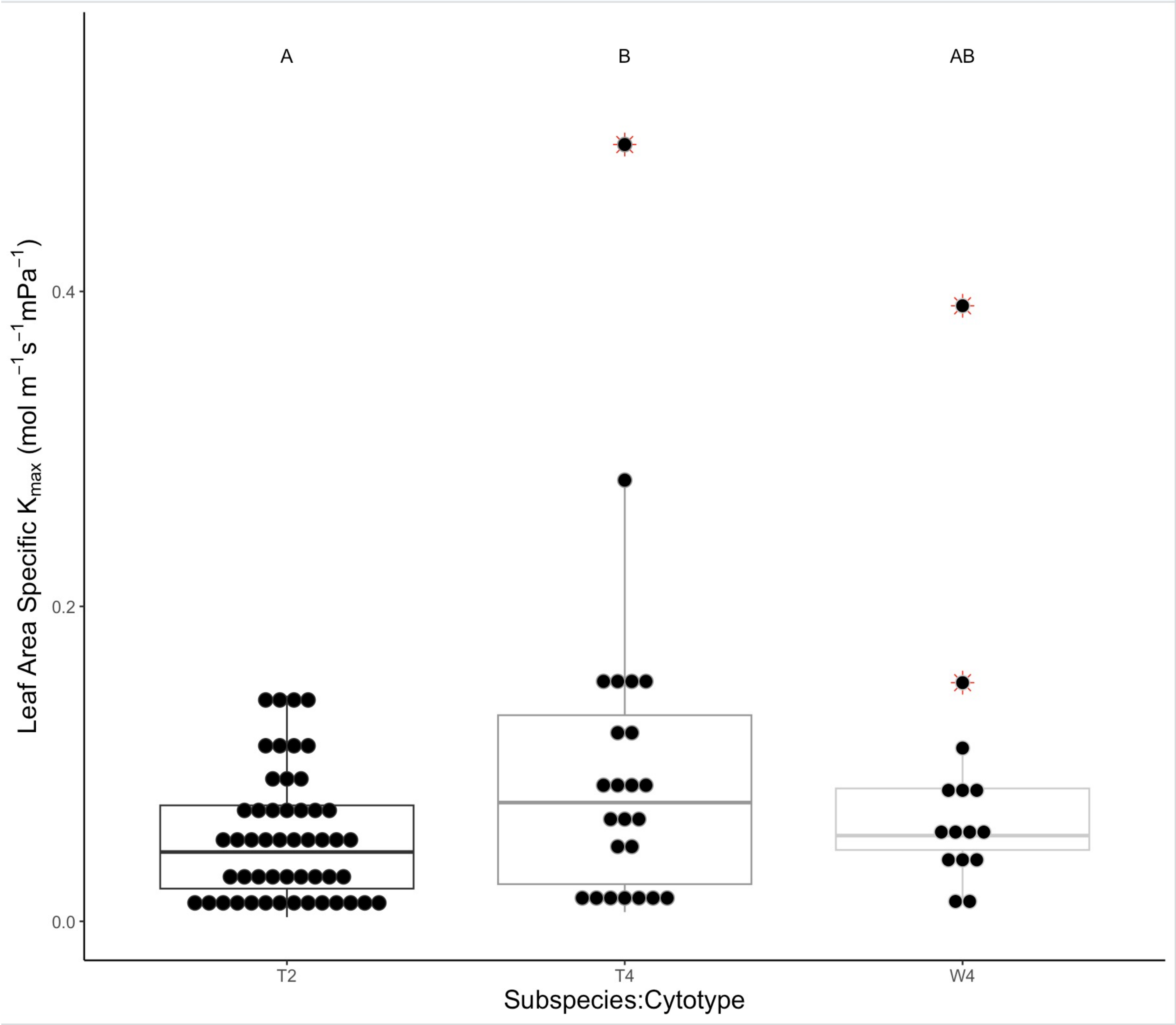
Analyses

- Generalized linear models
  - Subspecies:Cytotype
    - 2n *A. t. tridentata*
    - 4n *A. t. tridentata*
    - 4n *A. t. wyomingensis*
  - Precipitation & Temperature PC
  - Euclidean distance
- Posthoc pairwise tests
  - Tukey's HSD
    - Familywise type I error
- Non-metric multidimensional scaling ordination (NMDS)
  - Vector fitting of climatic variables



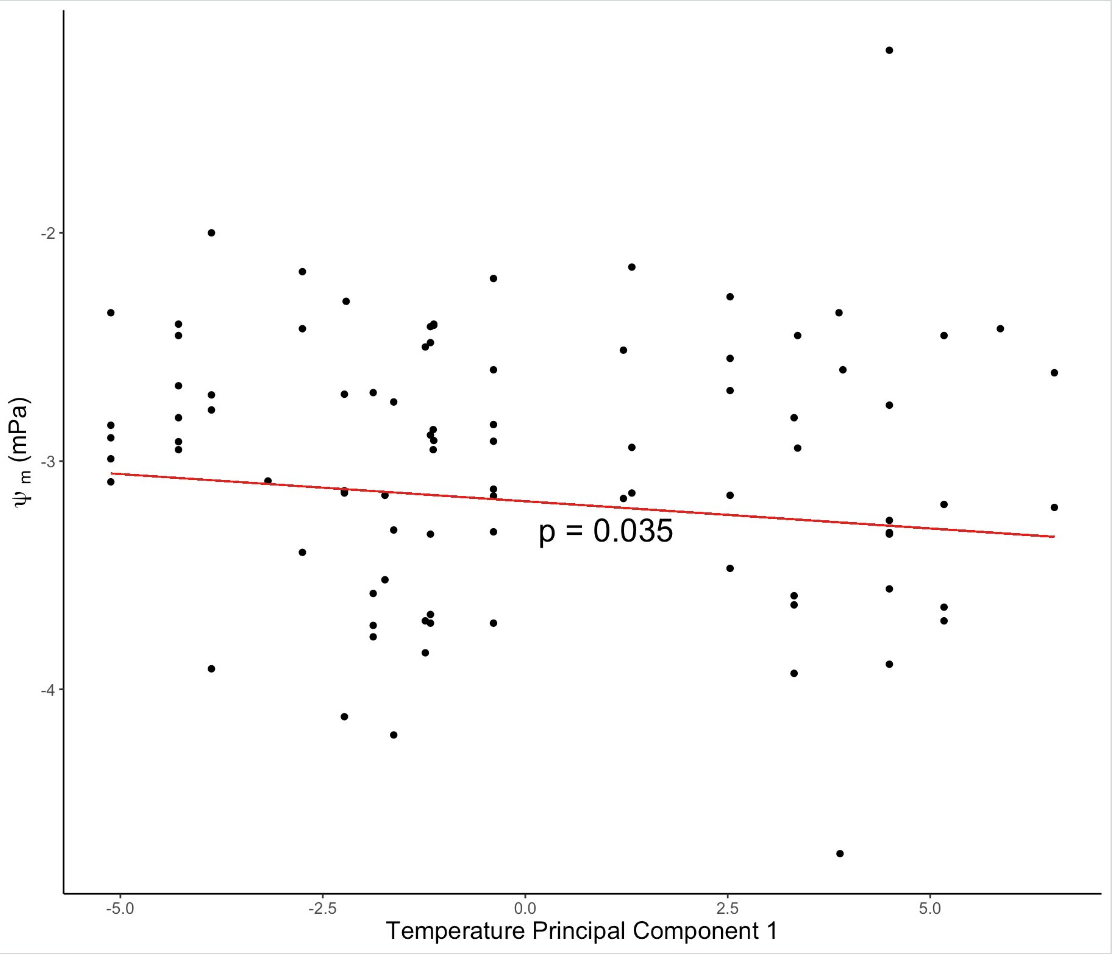
Big sagebrush subspecies only varied significantly from each other in maximum shrub height.

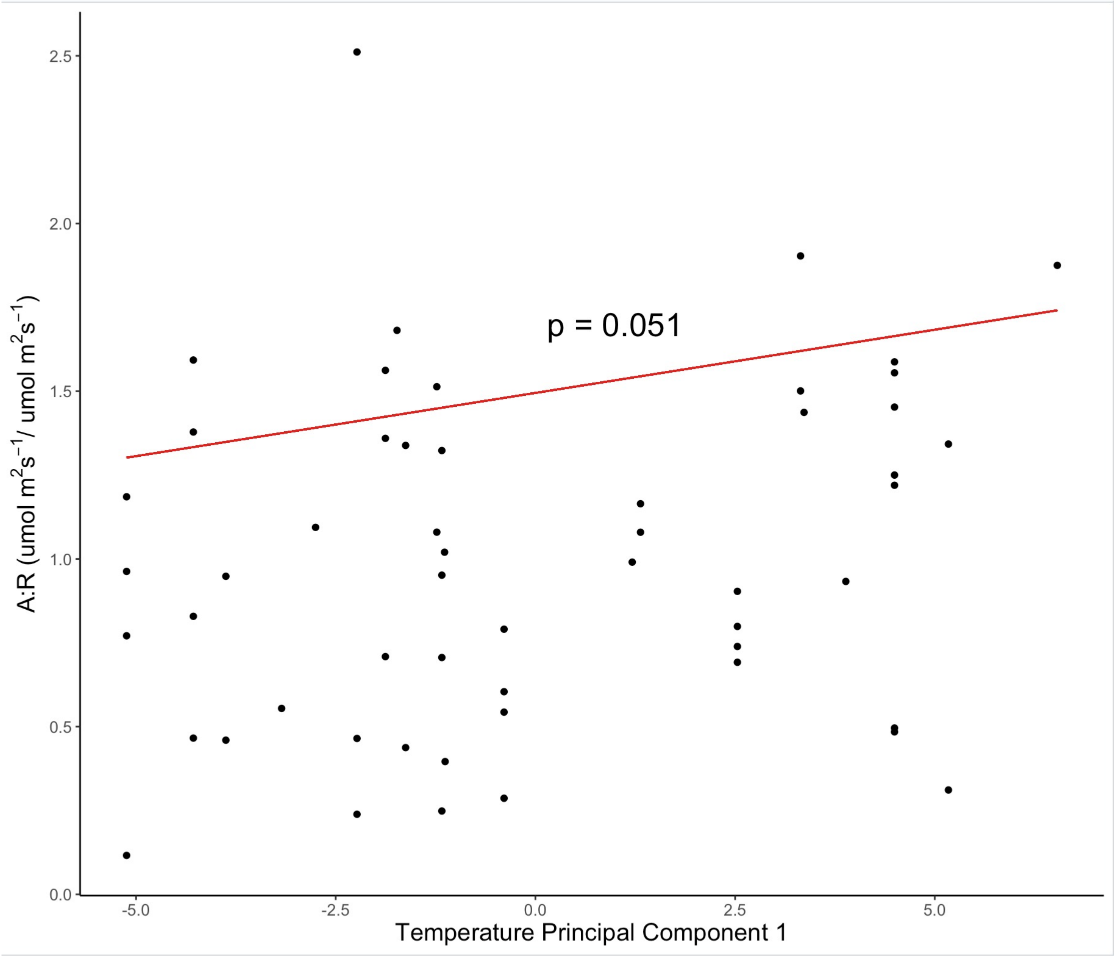




Significant variation between cytotypes only occurred between 2n and 4n *A. t. tridentata* in photosynthesis and leaf area specific branch maximum hydraulic conductivity.

Linear regression shows weak significant correlation between temperature principal component 1 and midday water potential (ψ_m) and photosynthesis to respiration ratio (A:R).

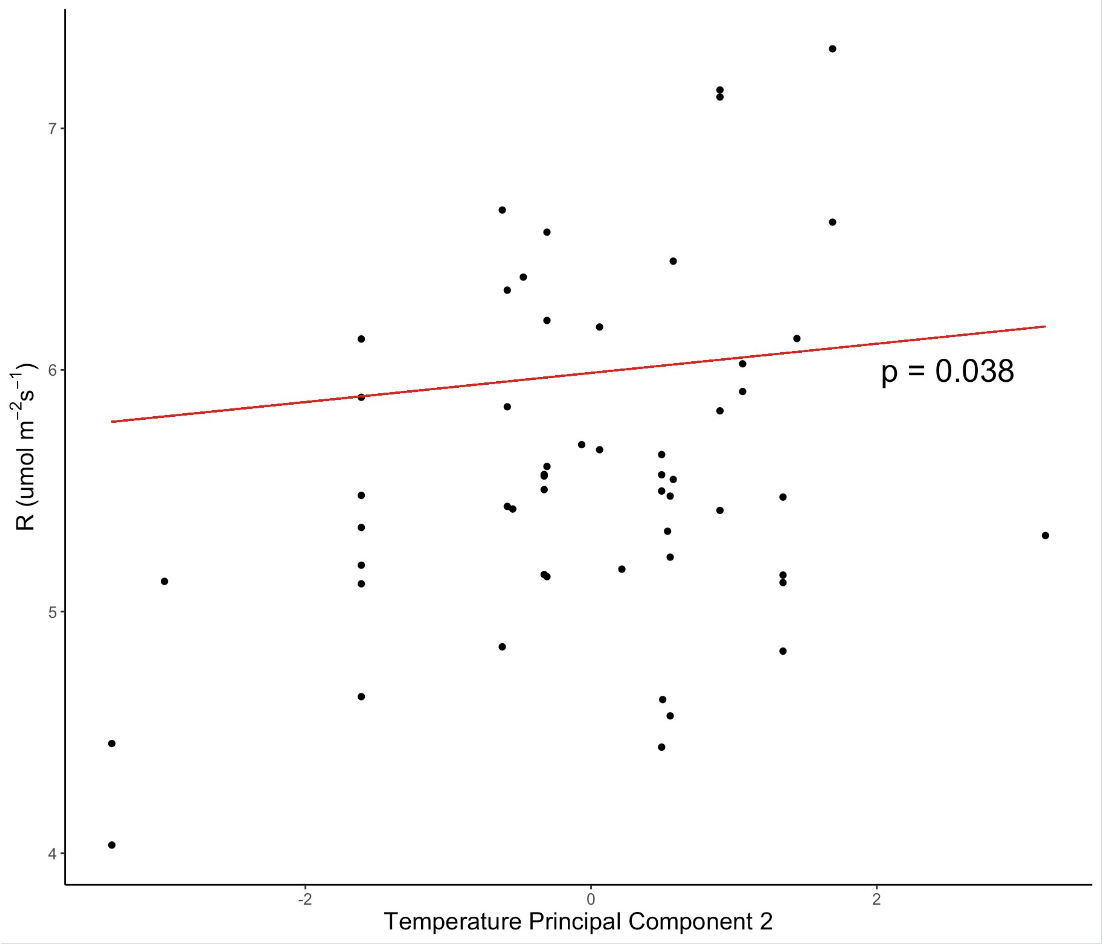


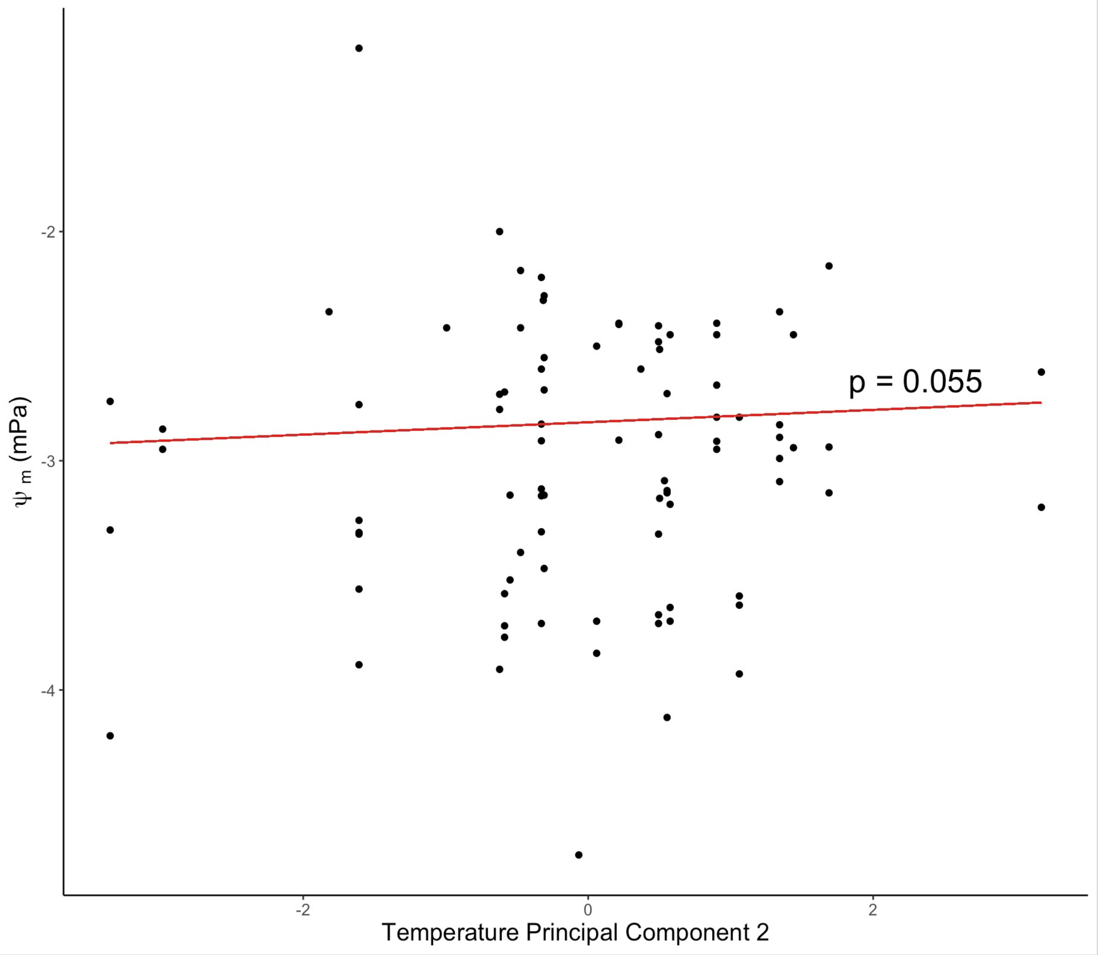


$R^2 = 0.169$

$R^2 = 0.028$

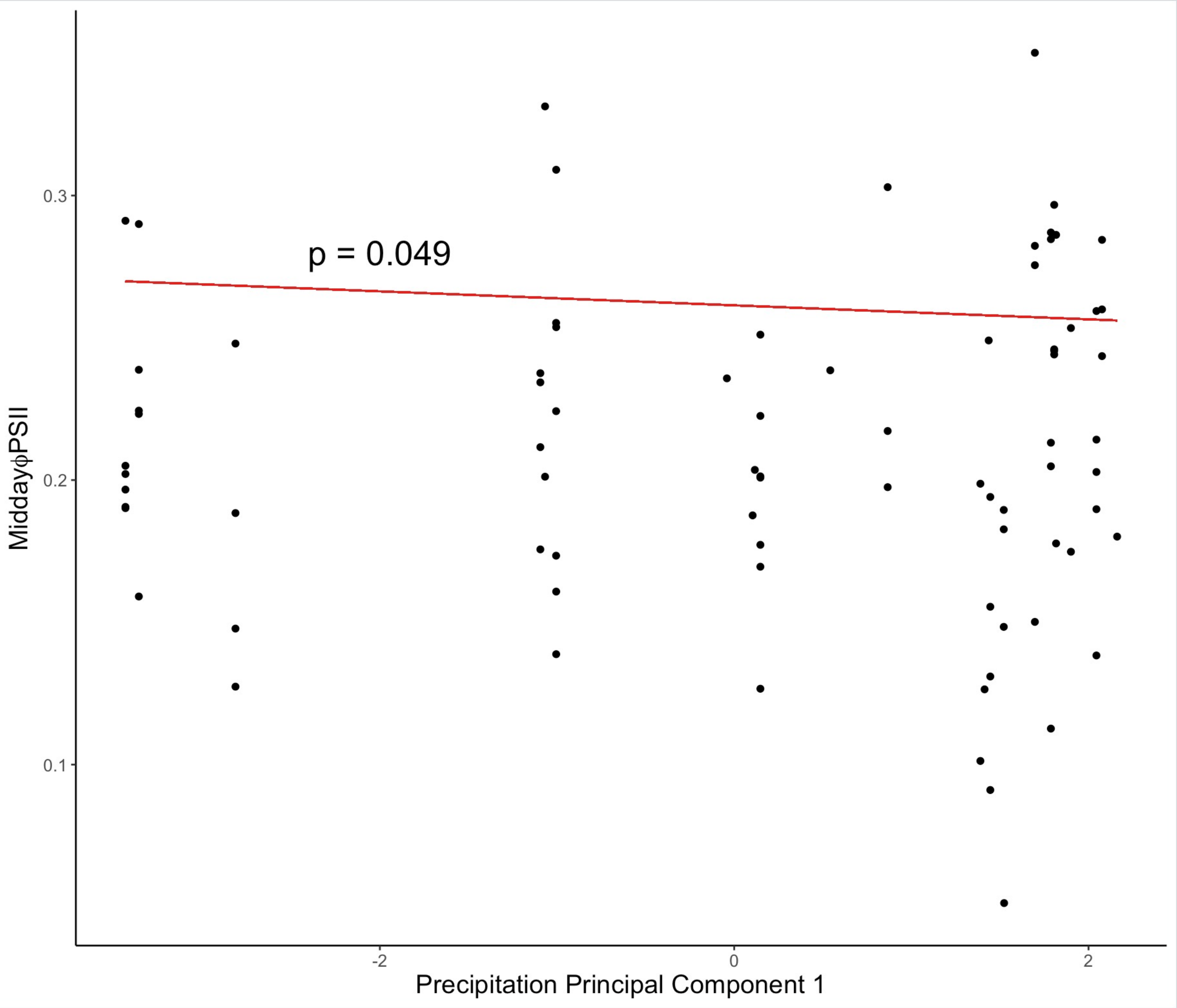
Linear regression shows weak significant correlation between temperature principal component 2 and respiration (R) and midday water potential (ψ_m).





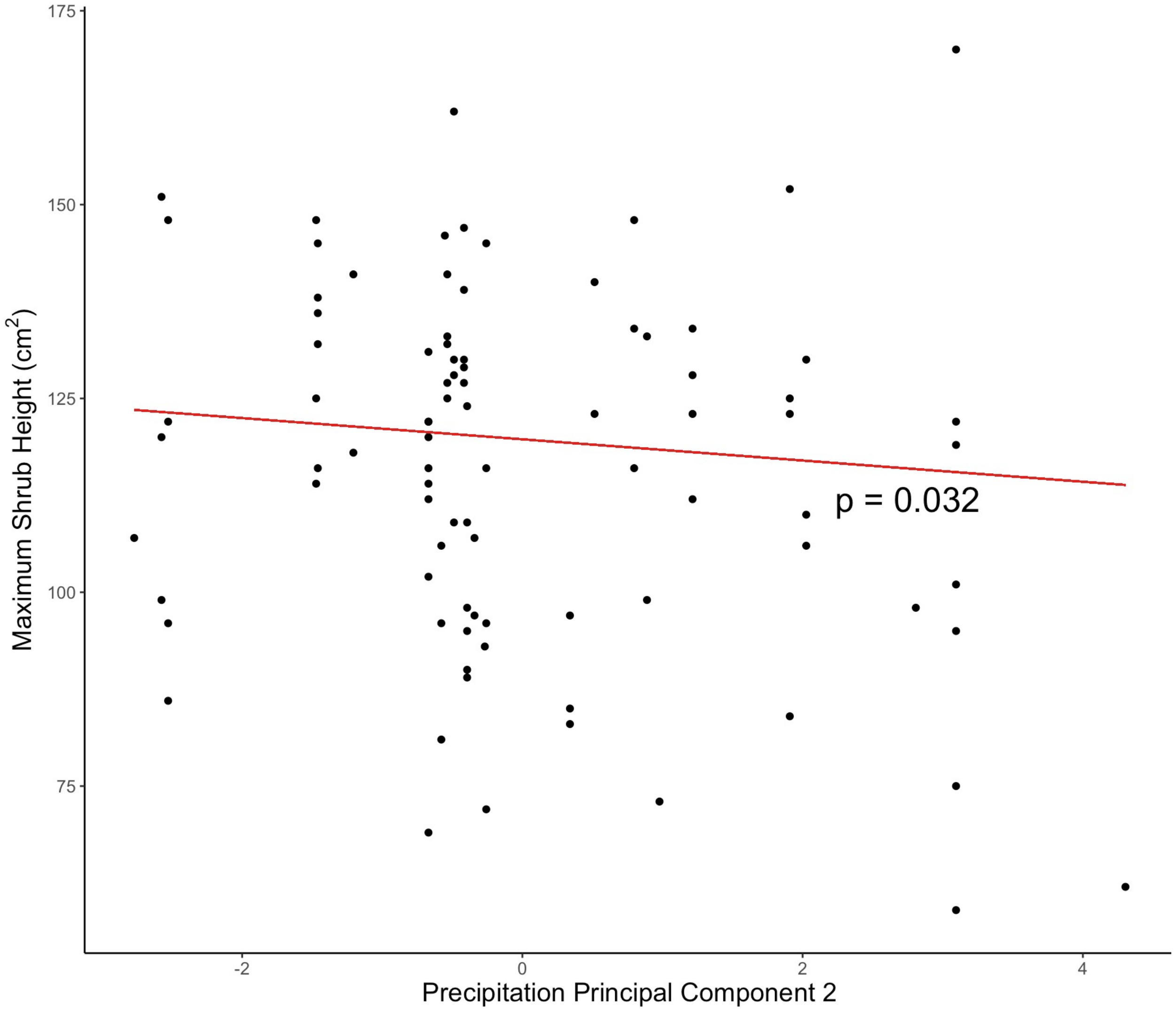
R^2 = 0.104

R^2 = 0.027

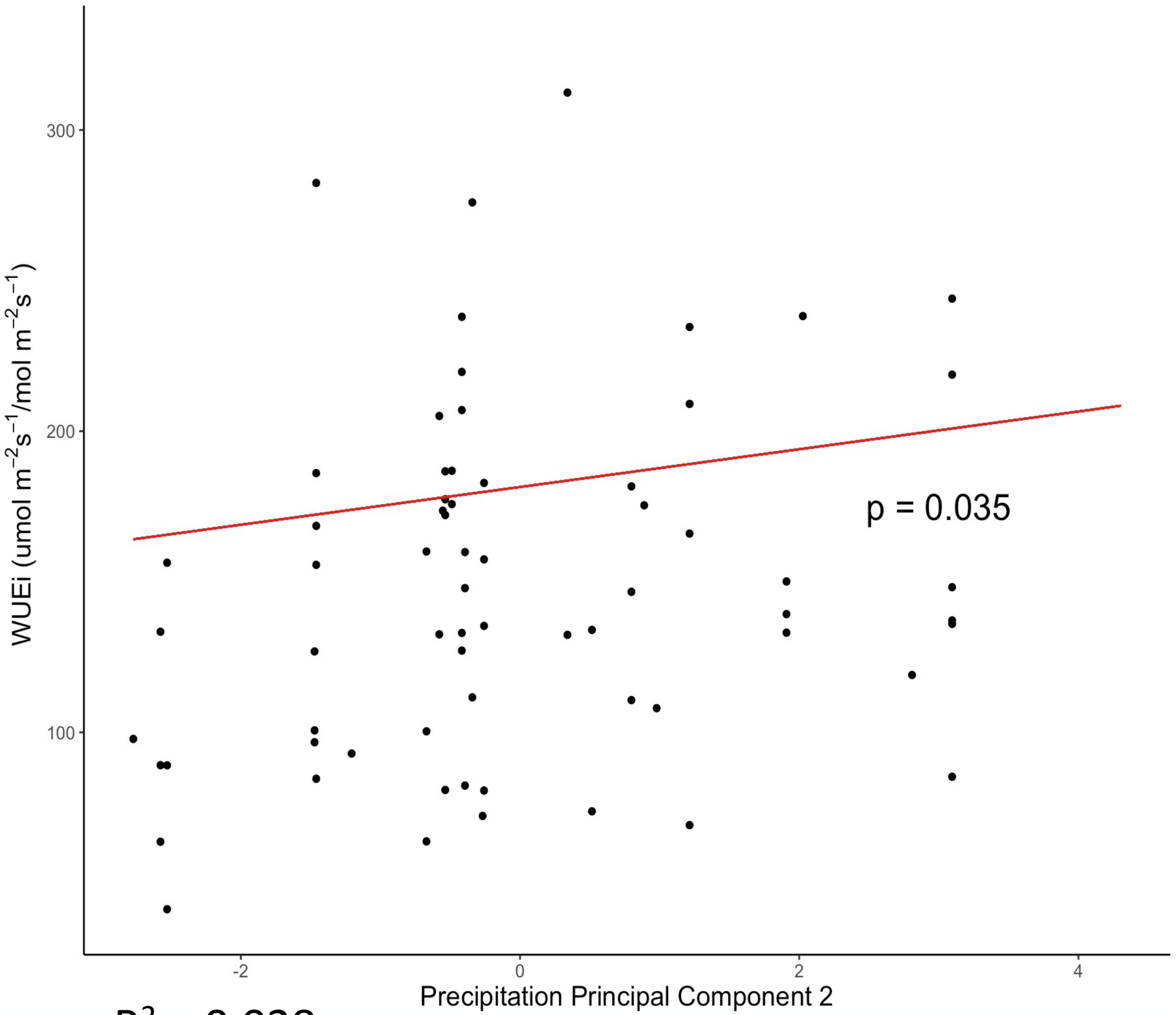


p = 0.049
MiddayφPSII
0.3
0.2
0.1
-2
0
2
Precipitation Principal Component 1

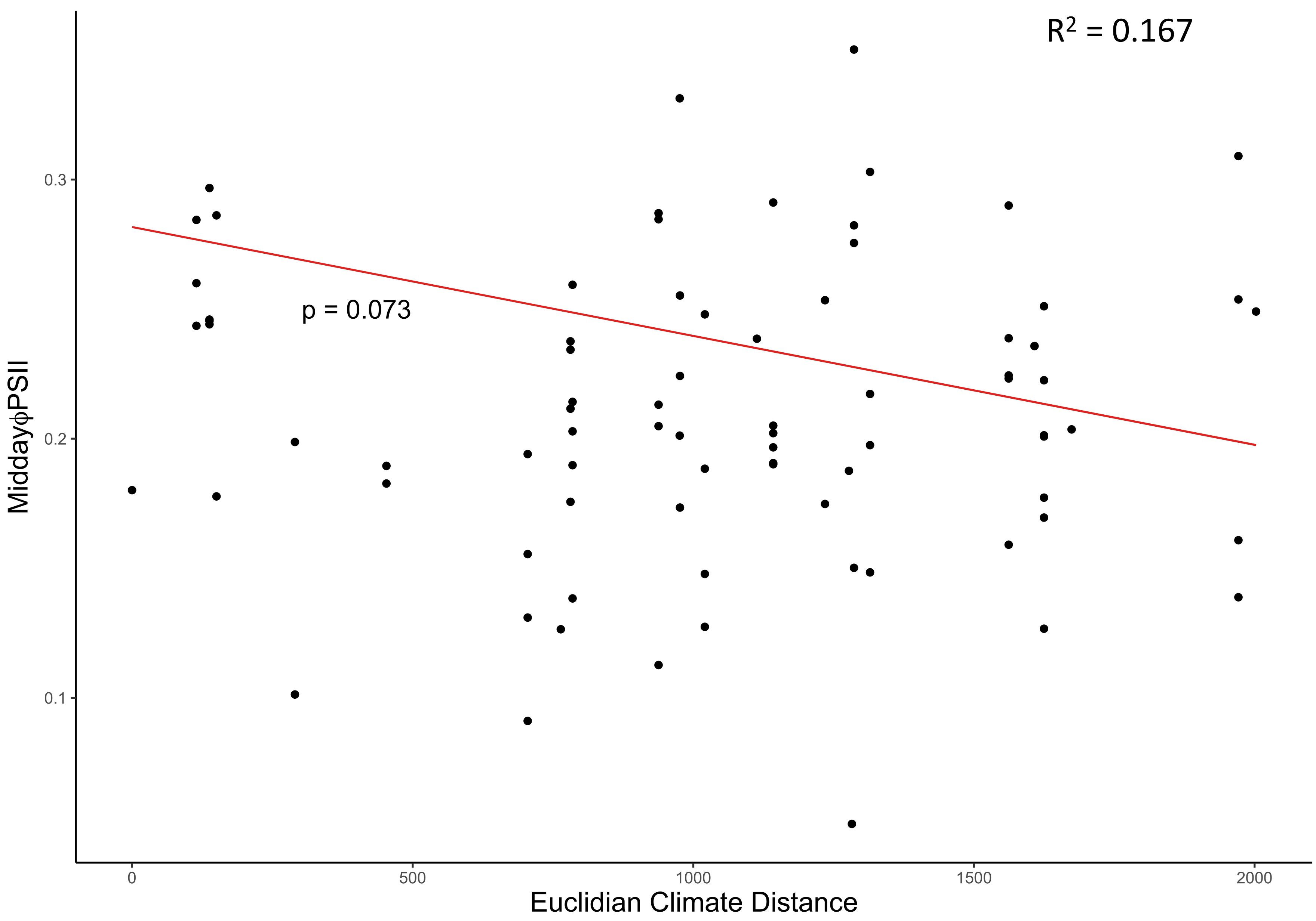
$R^2 = 0.167$



$R^2 = -0.024$

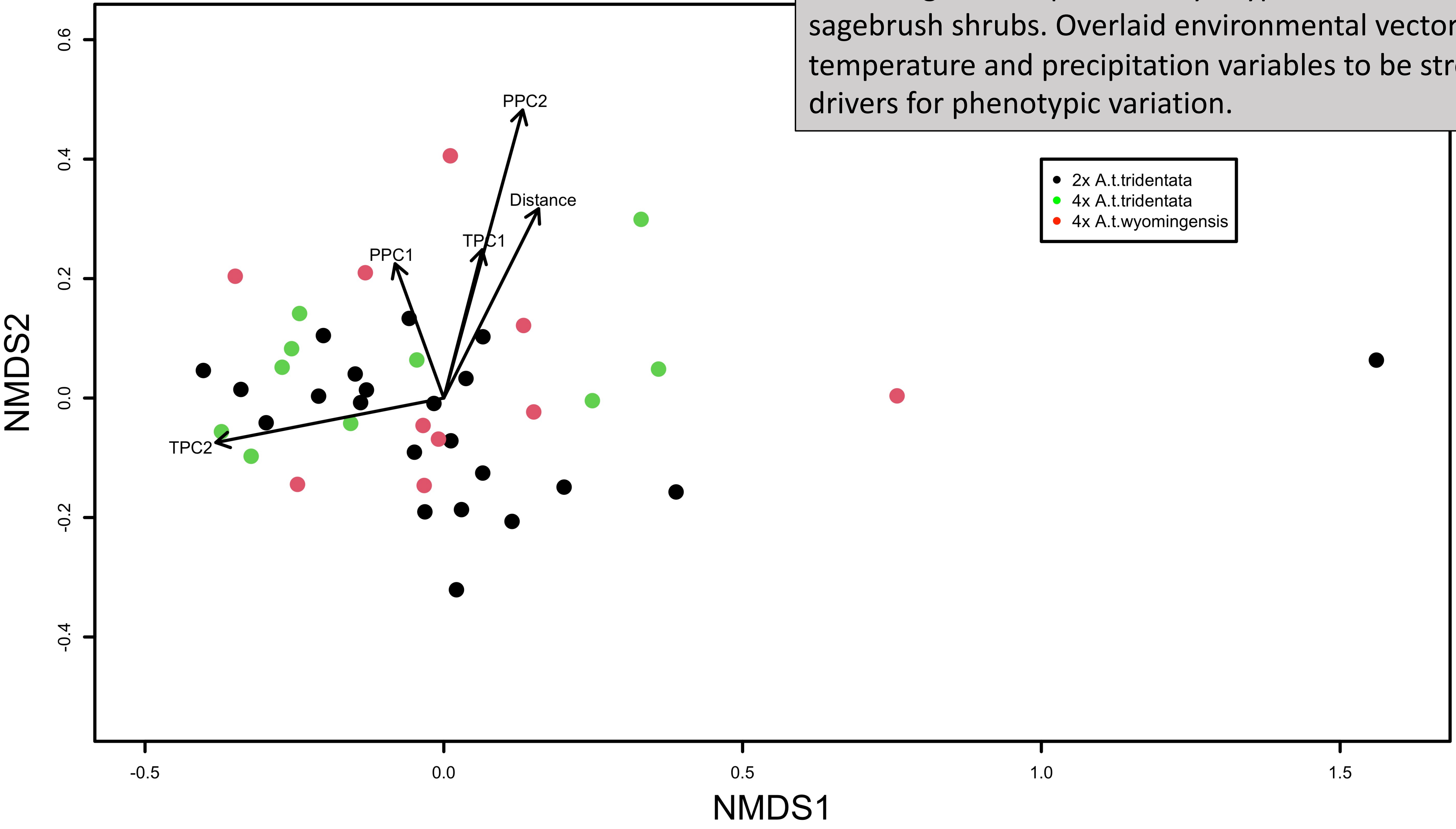


$R^2 = 0.028$



R² = 0.167
p = 0.073
0.3
0.2
0.1
MiddayφPSII
0
500
1000
1500
2000
Euclidian Climate Distance

Non-metric multidimensional scaling (NMDS) shows no clustering via subspecies or cytotype in measured big sagebrush shrubs. Overlaid environmental vectors showed temperature and precipitation variables to be strongest drivers for phenotypic variation.



Conclusion

This study found no strong evidence of morphological or physiological variation driven by subspecies, cytotype, nor climate-of-origin in mature big sagebrush when grown in a common garden.

Study 2

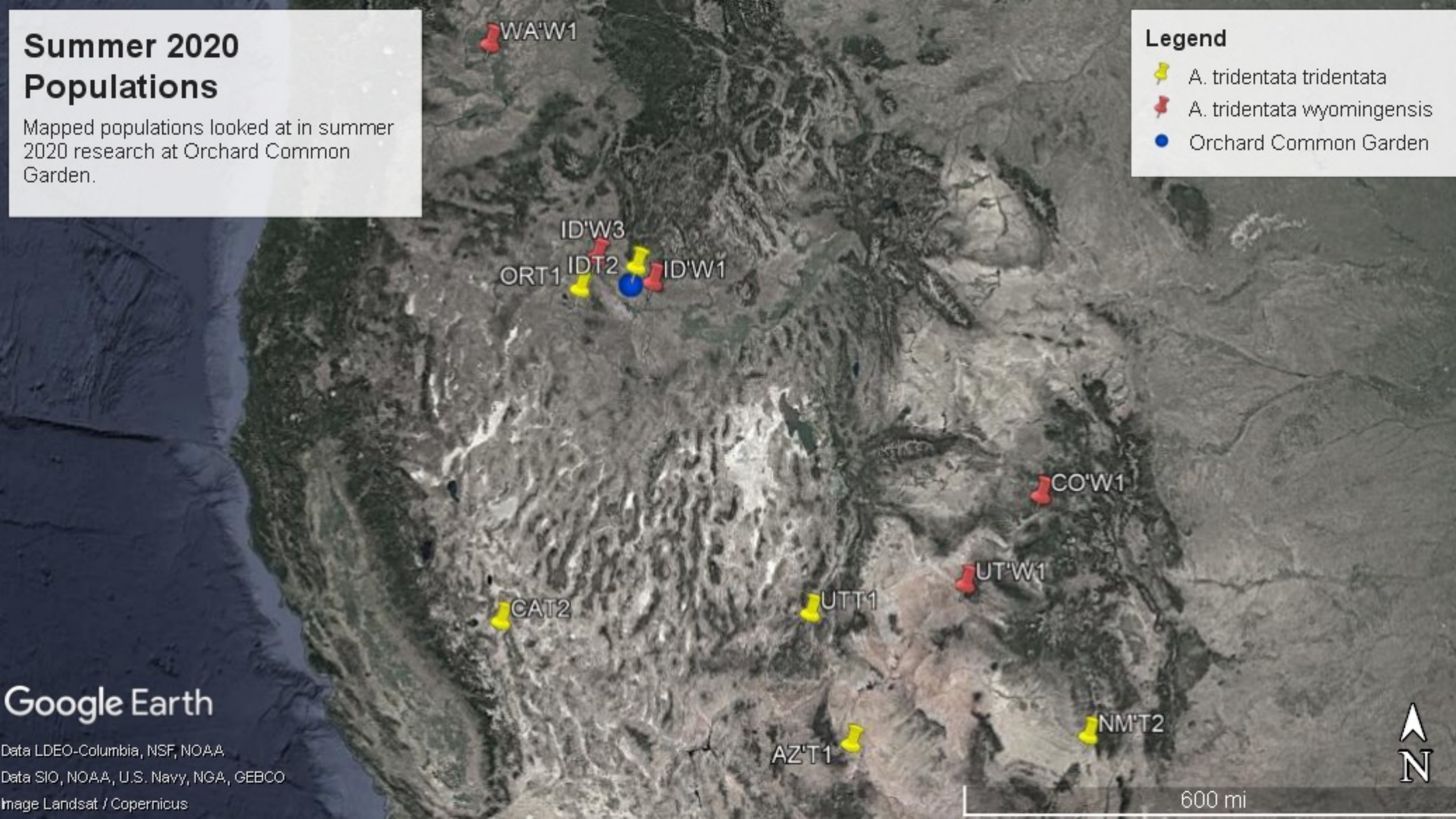
Quantifying genetic variation in hydraulic functional traits during growing season in subspecies of big sagebrush (*Artemisia tridentata*) in a common garden setting.

To what extent do subspecies, cytotype, and climate-of-origin contribute to variation in hydraulic functional traits during the growing season in big sagebrush (*Artemisia tridentata*)?

Question:

Summer 2020 Populations

Mapped populations looked at in summer 2020 research at Orchard Common Garden.



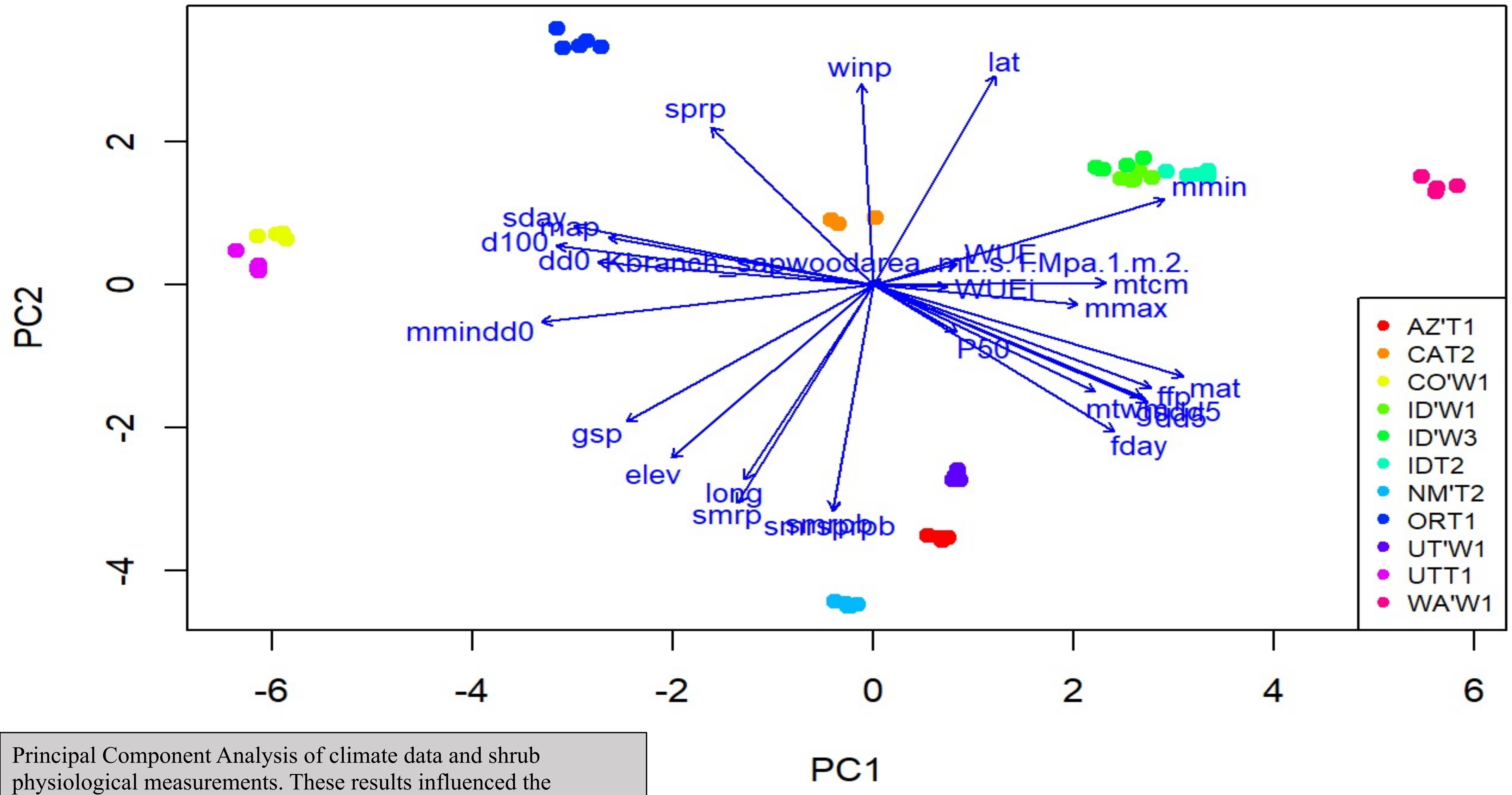
Methods

In the Orchard Common Garden, Boise, ID, measurements of **water use efficiency** (WUE, photosynthesis/transpiration) & **midday water potential** were obtained in May 2020.

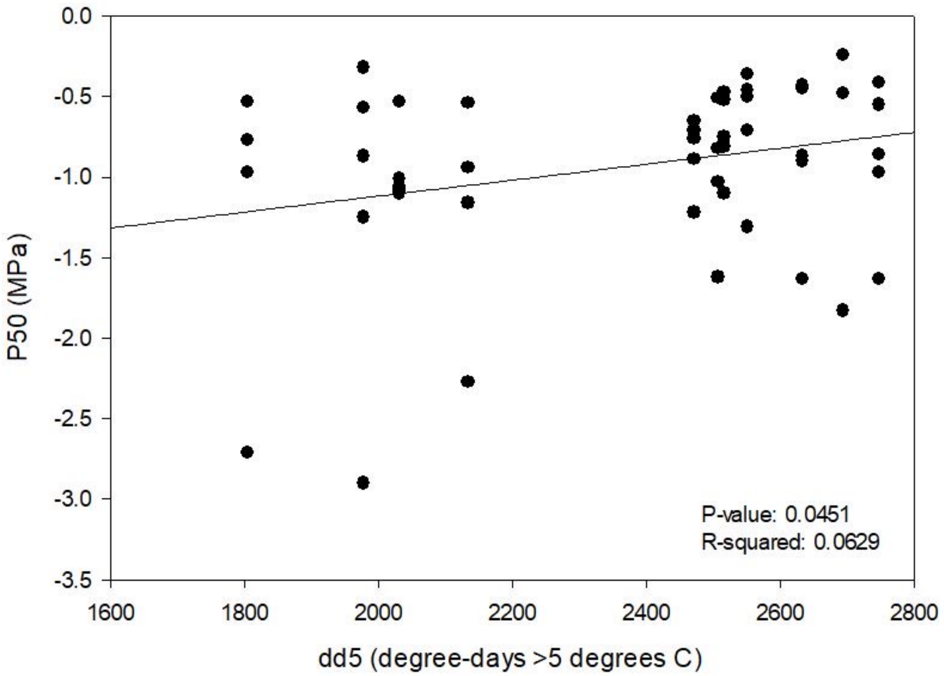
In the lab, **hydraulic vulnerability curves** were conducted using branch samples to quantify resistance to cavitation in the xylem.

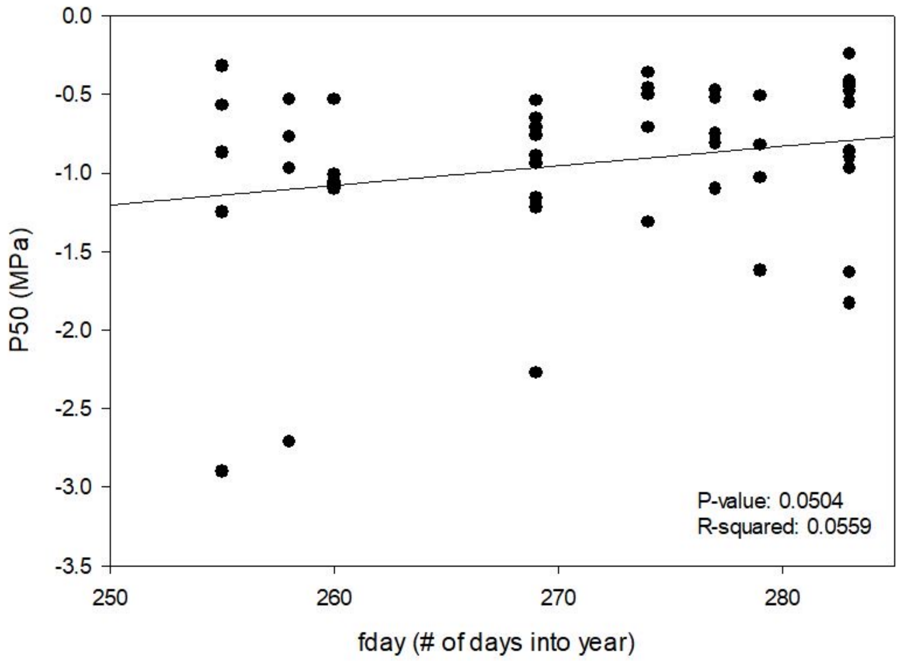
Principal Component Analysis was conducted to quantify multivariate relationships between environmental and geographical factors with plant hydraulic traits.

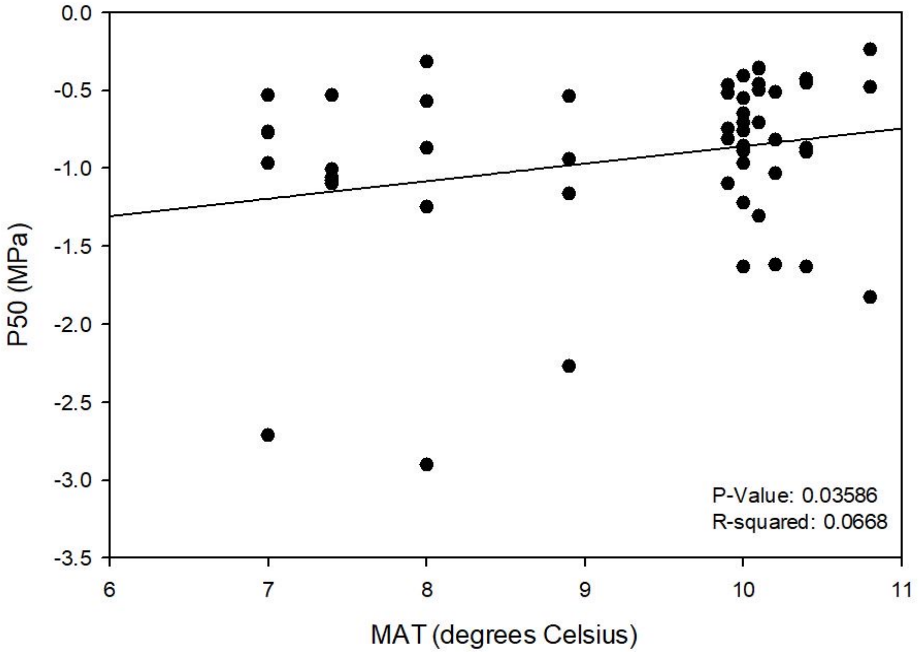
Based on the PCA results, **univariate linear regression analysis** was utilized to assess the relationships between topographic and climate variables with physiological measurements.

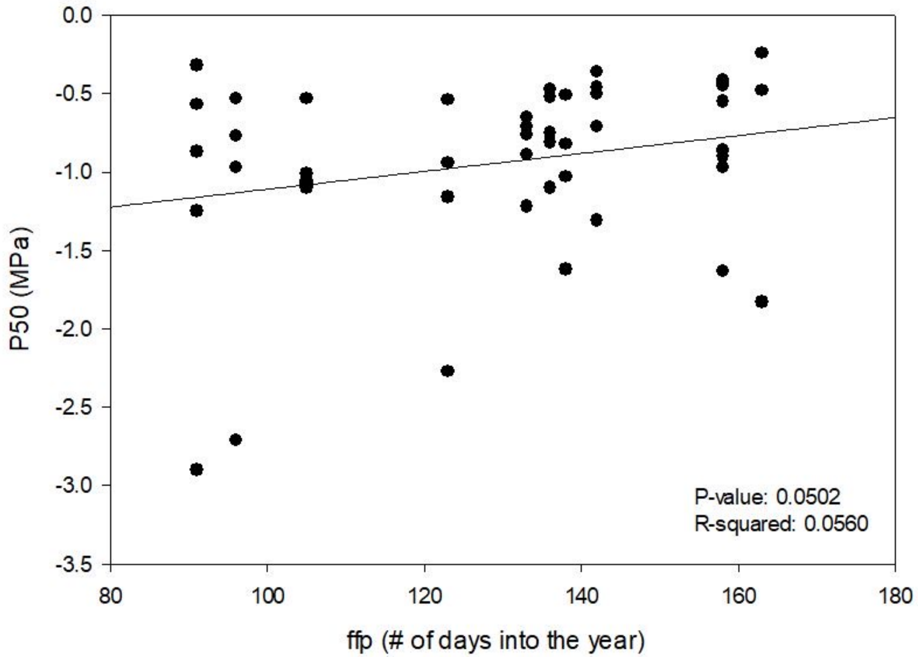


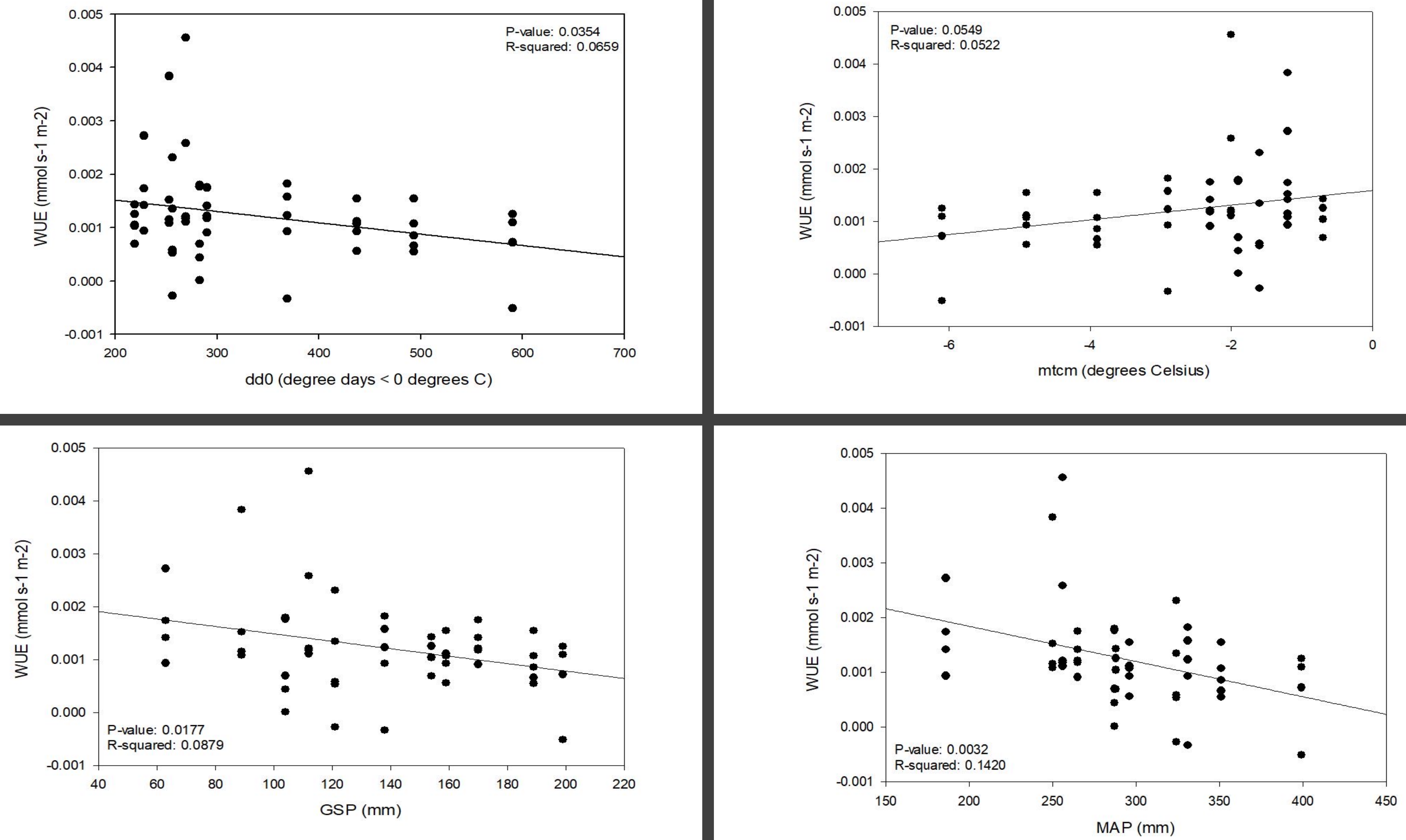
Principal Component Analysis of climate data and shrub physiological measurements. These results influenced the univariate linear regressions.


P50 (MPa)
dd5 (degree-days >5 degrees C)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
1600
1800
2000
2200
2400
2600
2800
P-value: 0.0451
R-squared: 0.0629

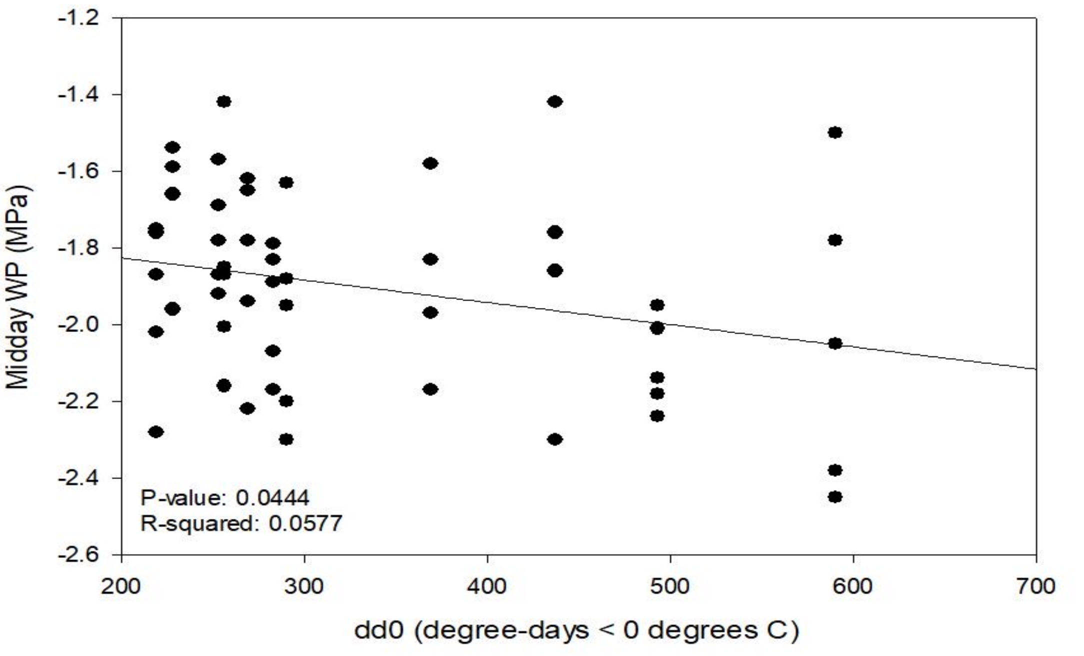

P50 (MPa)
fday (# of days into year)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
250
260
270
280
P-value: 0.0504
R-squared: 0.0559

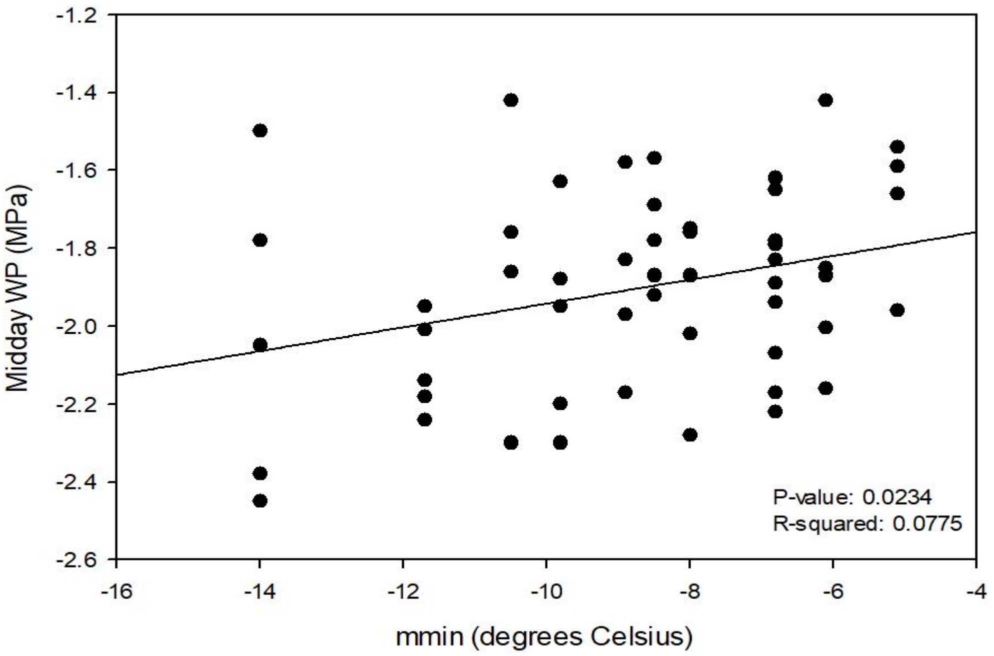

P50 (MPa)
MAT (degrees Celsius)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
6
7
8
9
10
11
P-Value: 0.03586
R-squared: 0.0668

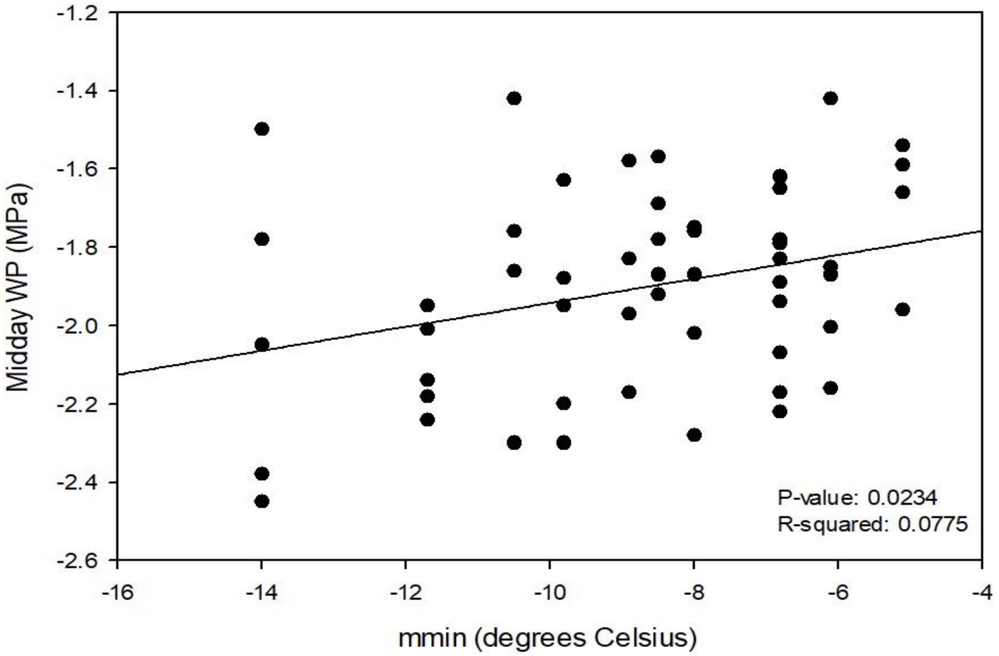

P50 (MPa)
ffp (# of days into the year)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
80
100
120
140
160
180
P-value: 0.0502
R-squared: 0.0560

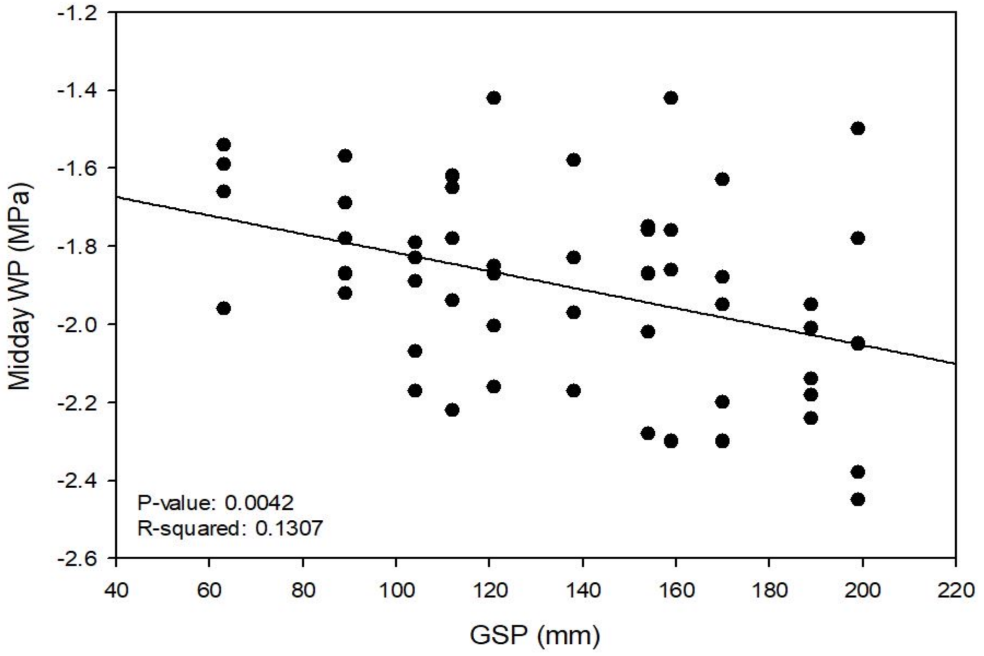


P-value: 0.0354
R-squared: 0.0659
WUE (mmol s-1 m-2)
dd0 (degree days < 0 degrees C)
P-value: 0.0549
R-squared: 0.0522
WUE (mmol s-1 m-2)
mtcm (degrees Celsius)
P-value: 0.0177
R-squared: 0.0879
WUE (mmol s-1 m-2)
GSP (mm)
P-value: 0.0032
R-squared: 0.1420
WUE (mmol s-1 m-2)
MAP (mm)


Midday WP (MPa)
dd0 (degree-days < 0 degrees C)
P-value: 0.0444
R-squared: 0.0577


Midday WP (MPa)
mmin (degrees Celsius)
P-value: 0.0234
R-squared: 0.0775


Midday WP (MPa)
mmin (degrees Celsius)
P-value: 0.0234
R-squared: 0.0775


Midday WP (MPa)
GSP (mm)
P-value: 0.0042
R-squared: 0.1307

Main Findings

Principal Component Analysis:

- Climate variables relating to temperature and frost events (mat, mtwm, ffp, fday, etc.) appear to be grouped together with a slight positive relationship to P50.
- Climate variables relating to temperature, precipitation, and frost events (map, sday, d100, dd0) appear to be grouped together with a negative relationship to WUE and midday water potential. While WUE and midday water potential appear to have a positive relationship with mtcm, mmax, and mmin.

P50 (amount of pressure in the xylem that causes 50% loss of hydraulic conductivity due to cavitation):

- P50 values were associated with thermal metrics, rather than precipitation metrics.
- In general, shrubs from colder environments (longer winters) had more negative P50 values.
- **Stress resistance in the branch xylem may be more targeted to freezing resistance, rather than drought resistance, and this may be genetically-related.**

WUE (Photosynthesis / Transpiration):

- Shrubs from environments with warmer annual temperatures and warmer winters had greater WUE.
- Shrubs from environments with less precipitation had greater WUE.
- **WUE has both thermal and moisture drivers, and variation in this may be genetically-related.**

Midday Water Potential:

- Shrubs from environments with colder, longer winters had more negative midday water potentials.
- Shrubs from environments with greater precipitation had more negative water potentials.
- **Midday water potential has both thermal and moisture drivers, and variation in this may be genetically-related.**

Conclusion

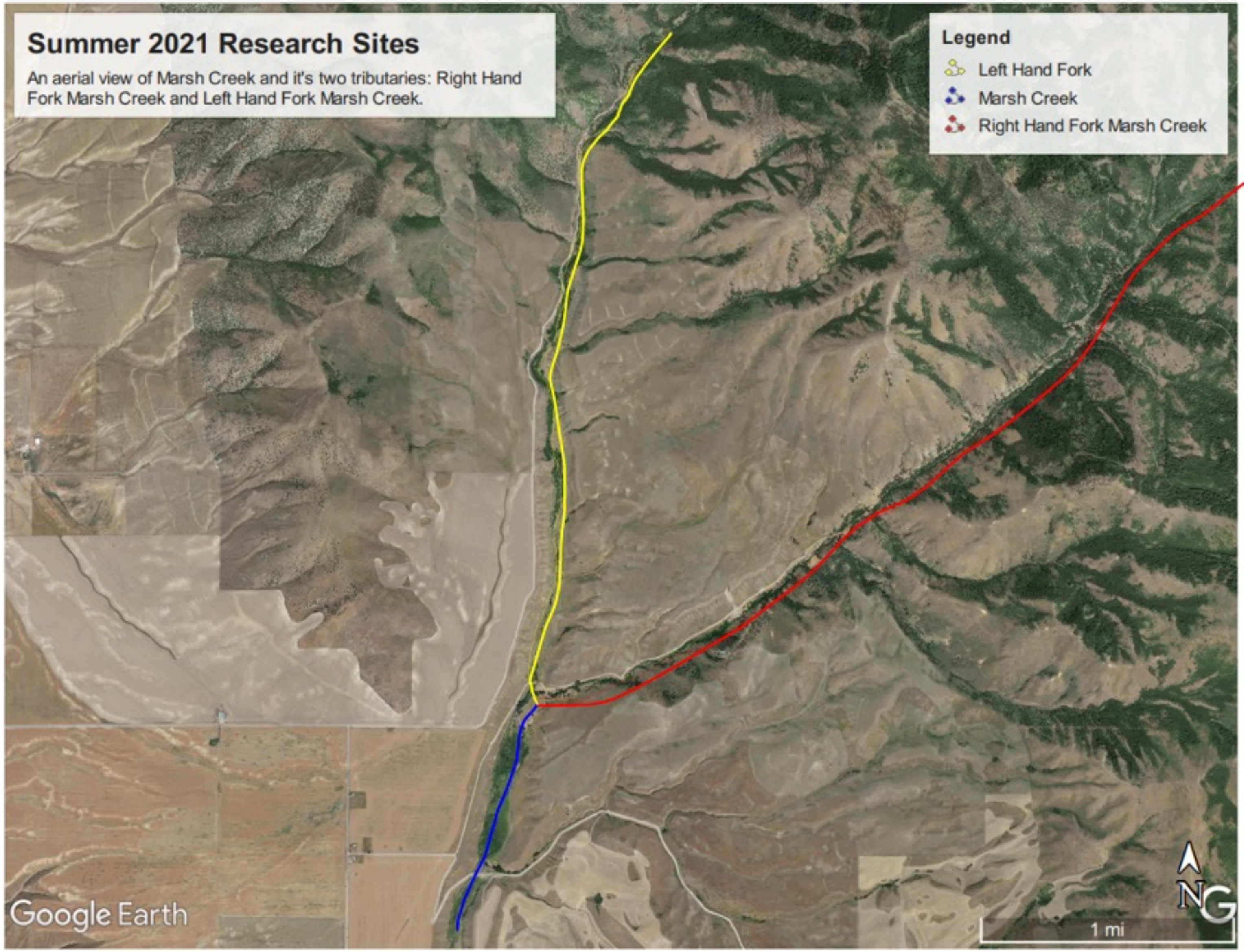
Interestingly, phenotypic plasticity and adaptive capacity in this widespread shrub that inhabits water-limited environments may be more associated with thermal constraints compared to moisture constraints.

Study 3

Phenotypic variation of big sagebrush (*Artemisia tridentata*) in response to a soil-moisture gradient.

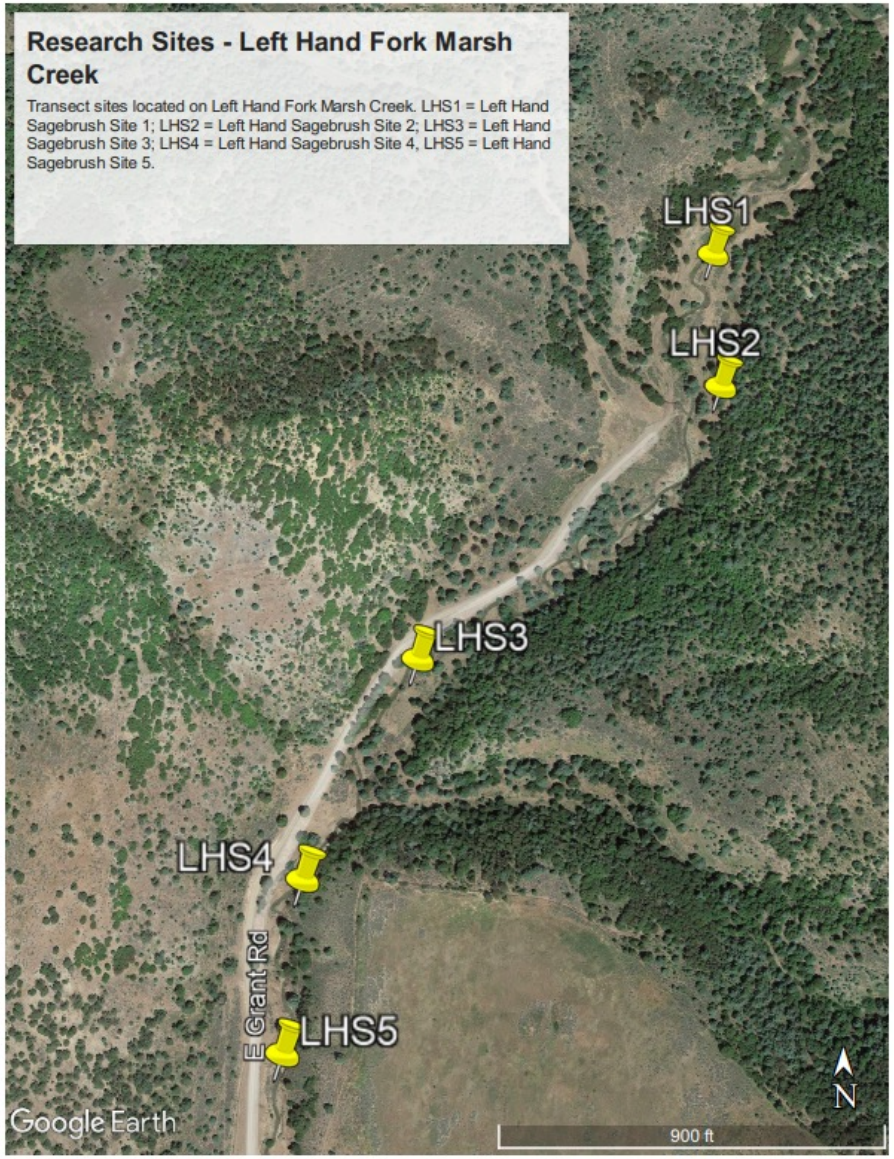
To what extent does phenotypic expression vary in a single population of big sagebrush along a sharp soil-moisture gradient?

Question:



Summer 2021 Research Sites
An aerial view of Marsh Creek and it's two tributaries: Right Hand Fork Marsh Creek and Left Hand Fork Marsh Creek.
Legend
Left Hand Fork
Marsh Creek
Right Hand Fork Marsh Creek
Google Earth
N
1 mi


Research Sites - Right Hand Fork Marsh Creek
Transect sites located on Right Hand Fork Marsh Creek. RHS1 = Right Hand Sagebrush Site 1; RHS2 = Right Hand Sagebrush Site 2.
Right Hand Fork Marsh C
RHS2
RHS1
Google Earth
N
200 ft


Research Sites - Left Hand Fork Marsh Creek
Transect sites located on Left Hand Fork Marsh Creek. LHS1 = Left Hand Sagebrush Site 1; LHS2 = Left Hand Sagebrush Site 2; LHS3 = Left Hand Sagebrush Site 3; LHS4 = Left Hand Sagebrush Site 4, LHS5 = Left Hand Sagebrush Site 5.
LHS1
LHS2
LHS3
LHS4
LHS5
E Grant Rd
Google Earth
N
900 ft



Methods

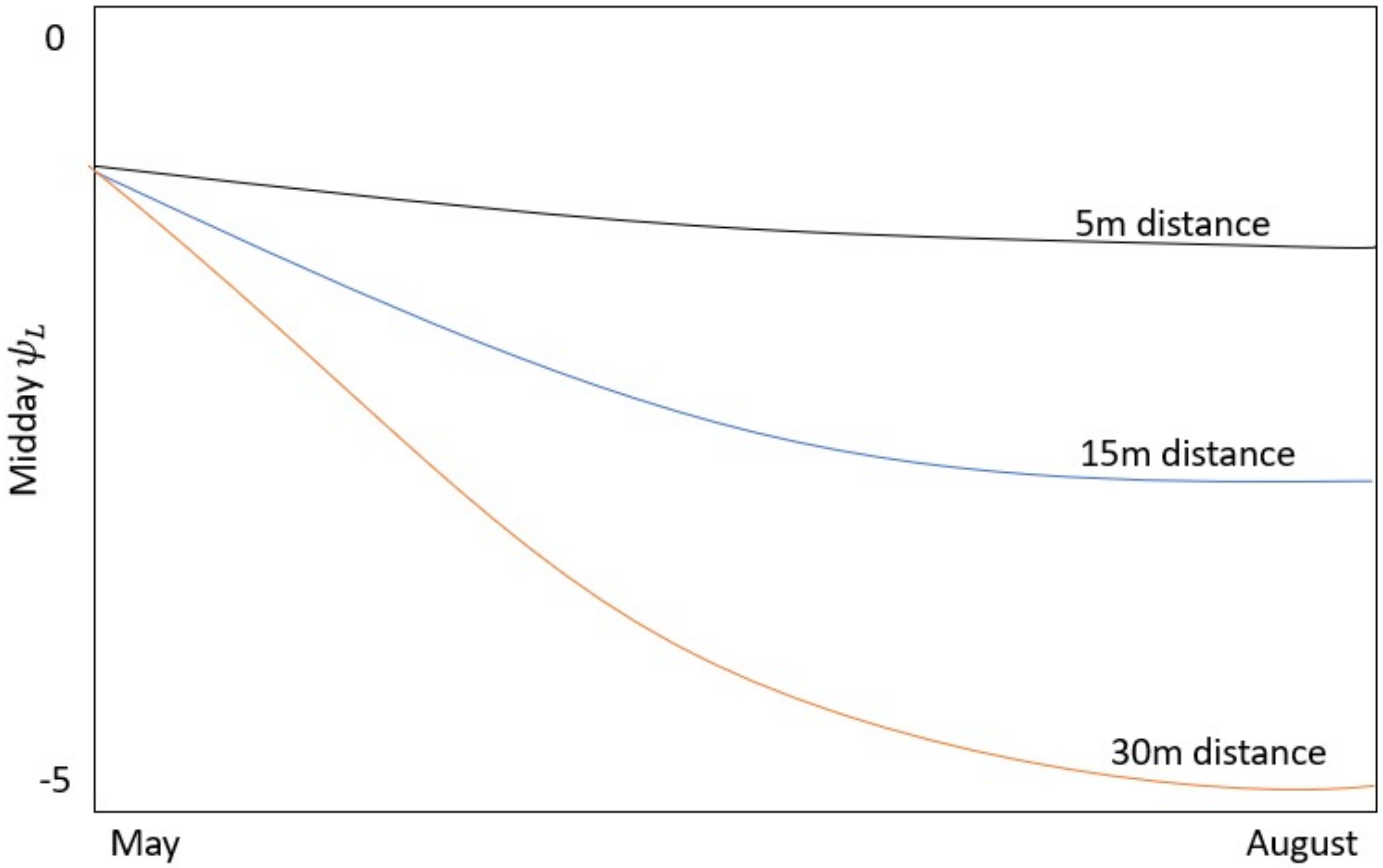
Hypoxic soil stress response variables

- Respiration
- Stomatal conductance
- Leaf water potentials
- Photosynthesis
- Shrub size/growth rate
- Water use efficiency

Drought stress response variables

- Water use efficiency
- Hydraulic conductivity
- Leaf water potentials
- Stomatal conductance
- Transpiration
- Photosynthesis

Expected Results



Study 4

Quantifying phenotypic plasticity of big sagebrush (*Artemisia tridentata*) seedlings in a manipulative greenhouse setting.

To what extent does phenotypic plasticity vary in response to drought and episodic freezing conditions?

Question:

Experimental Design

Seed collection

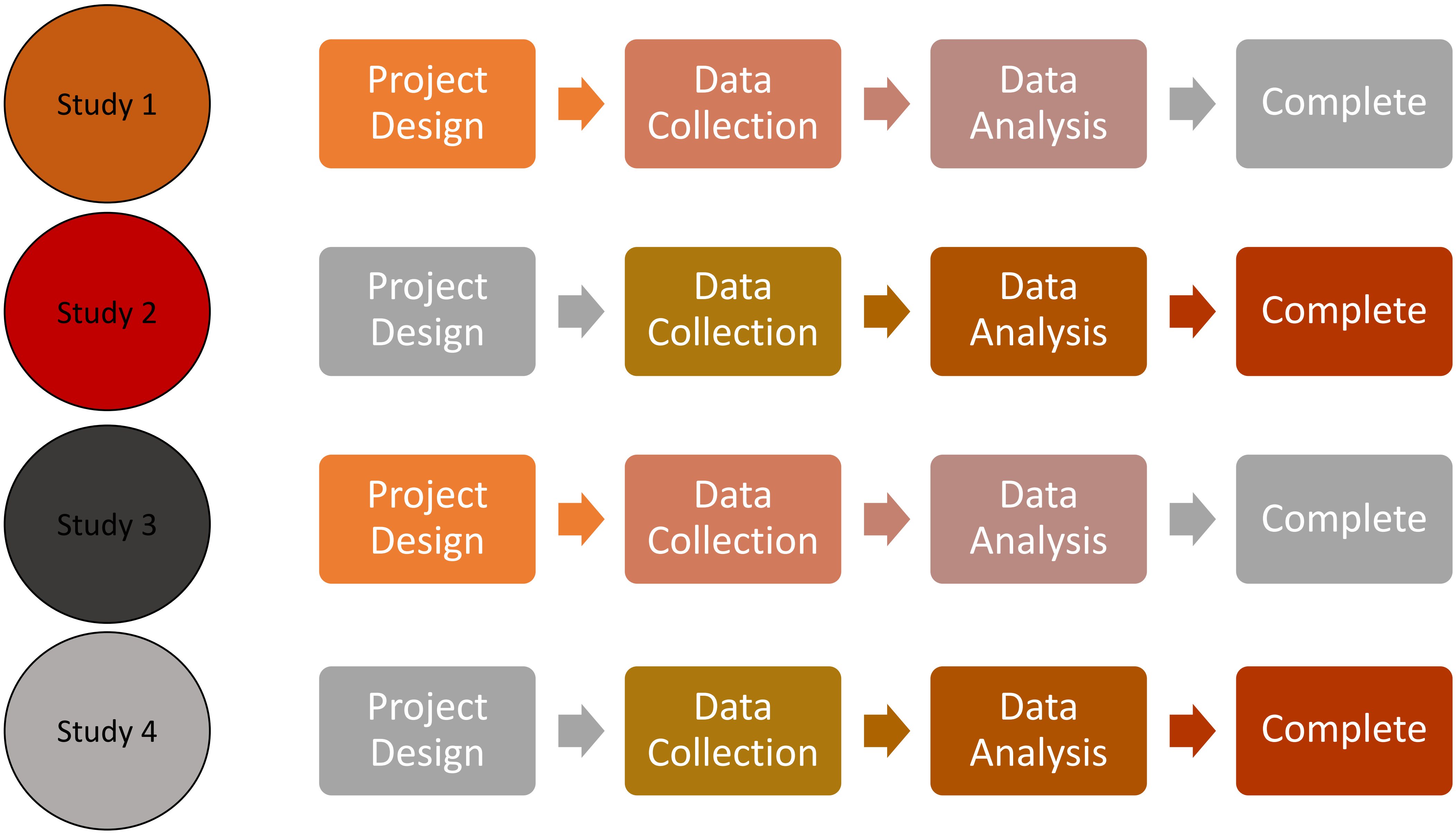
- 4 populations of big sagebrush
  - *A. t. tridentata* from hot and dry climate
  - *A. t. tridentata* from wet and cold climate
  - *A. t. wyomingensis* from hot and dry climate
  - *A. t. wyomingensis* from wet and cold climate
- Seeds collected from 10 shrubs per population

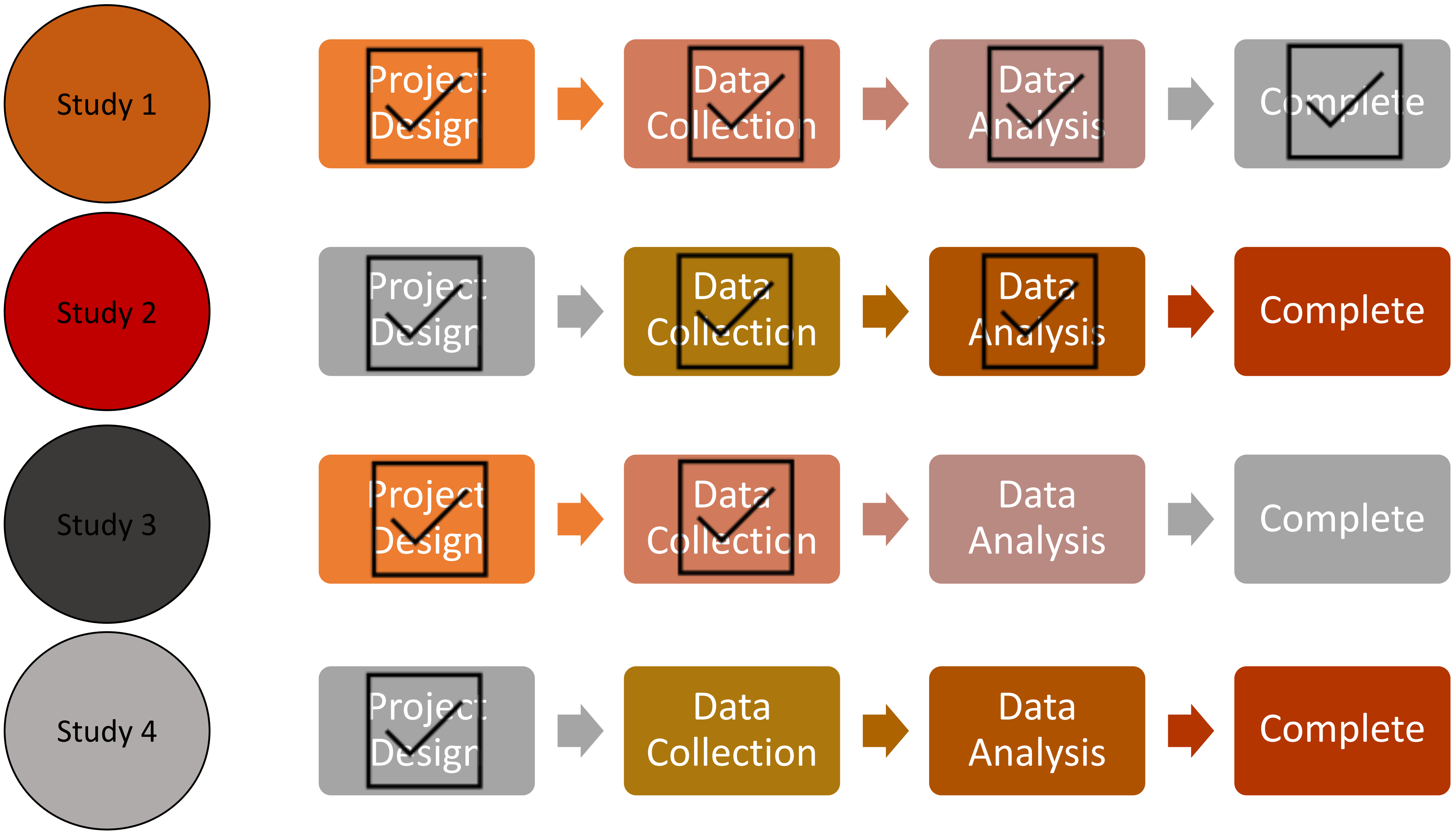
Seeds threshed and cold stratified for a month

Seed germination and root establishment

Experimental conditions placement

- Drought Conditions x 2 Episodic Freezing Events
- Drought Conditions x No Episodic Freezing
- Non-drought Conditions x 2 Episodic Freezing Events
- Non-drought Conditions x No Episodic Freezing


Study 1
Project Design
Data Collection
Data Analysis
Complete
Study 2
Project Design
Data Collection
Data Analysis
Complete
Study 3
Project Design
Data Collection
Data Analysis
Complete
Study 4
Project Design
Data Collection
Data Analysis
Complete


Study 1
Project Design
Data Collection
Data Analysis
Complete
Study 2
Project Design
Data Collection
Data Analysis
Complete
Study 3
Project Design
Data Collection
Data Analysis
Complete
Study 4
Project Design
Data Collection
Data Analysis
Complete

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  - Adler Patch
  - Tierin Osterfeld
  - Harrison Seitz
  - Christopher Forshee
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  - Larice Walker (mother)
  - Martin Walker (Step-dad)
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GEM3 Genes by Environment Modeling · Mechanisms · Mapping

Idaho State University

Questions?