

# Genetic phenomena in American ginseng of management concern: tests for local adaptation

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# Overview

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- 1) Local Adaptation
  - a) Brief review
  - b) Evidence in ginseng?
- 2) Reciprocal Transplant
- 3) Breeding Study
- 4) Preliminary Indications



# Local Adaptation

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Genetic differentiation between populations as a result of natural selection



# Local Adaptation



*Delphinium nelsonii*, Waser & Price 1994



*Potentilla glandulosa*, Clausen, Keck & Heisey 1948



*Prunella vulgaris*, Winn and Evans 1991



*Amphicarpaea bracteata*, Parker 1992



*Lotus scoparius*, Monatlvo & Ellstrand 2001



*Chamaecharis fasciculata*, Fenster & Galloway 2000



*Impatiens pallida*, Schemske 1984



*Phlox drummondii*, Schmidt & Levin 1985



*Polemonium viscosum*, Galen et al. 1991



*Ranunculus repens*, Lovett-Doust 1981



*Salicornia europaea*, Davy & Smith 1988



*Dryas octopetala*, McGraw & Antonovics 1983



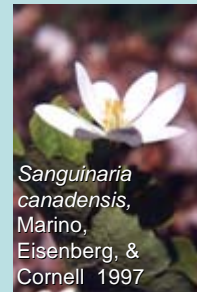
*Plantago lanceolata*, van Tienderen & van der Toorn 1991



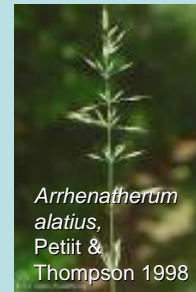
*Lupinus arboreus*, Kittelson & Marron 2001



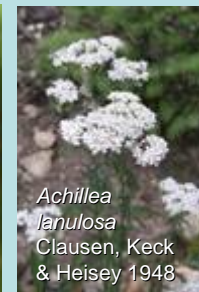
*Gilia capitata*, Nagy & Rice 1997



*Sanguinaria canadensis*, Marino, Eisenberg, & Cornell 1997



*Arrhenatherum alatum*, Petit & Thompson 1998



*Achillea lanulosa*, Clausen, Keck & Heisey 1948



# Local Adaptation

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## Sources and Influences:

- Environmental variation
  - Variation in selection
  - Can occur over small scales
- Gene flow
  - Pollen movement
  - Breeding system



# Case Study

- Waser and Price 1994
- Breeding study
  - Hand pollination at different crossing distances
    - *1m 3m 10m 30m*
- Intermediate offspring had highest fitness
  - Inbreeding depression
  - Outbreeding depression







# Case Study II

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- Montalvo and Ellstrand 2000
- “Home site advantage” hypothesis
- Seedlings from 12 sites
  - Mesic common garden
  - Xeric common garden
- Non-local genotypes =  
↓survival & ↓fitness



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Evidence for  
local adaptation  
in ginseng?





# Preliminary Evidence

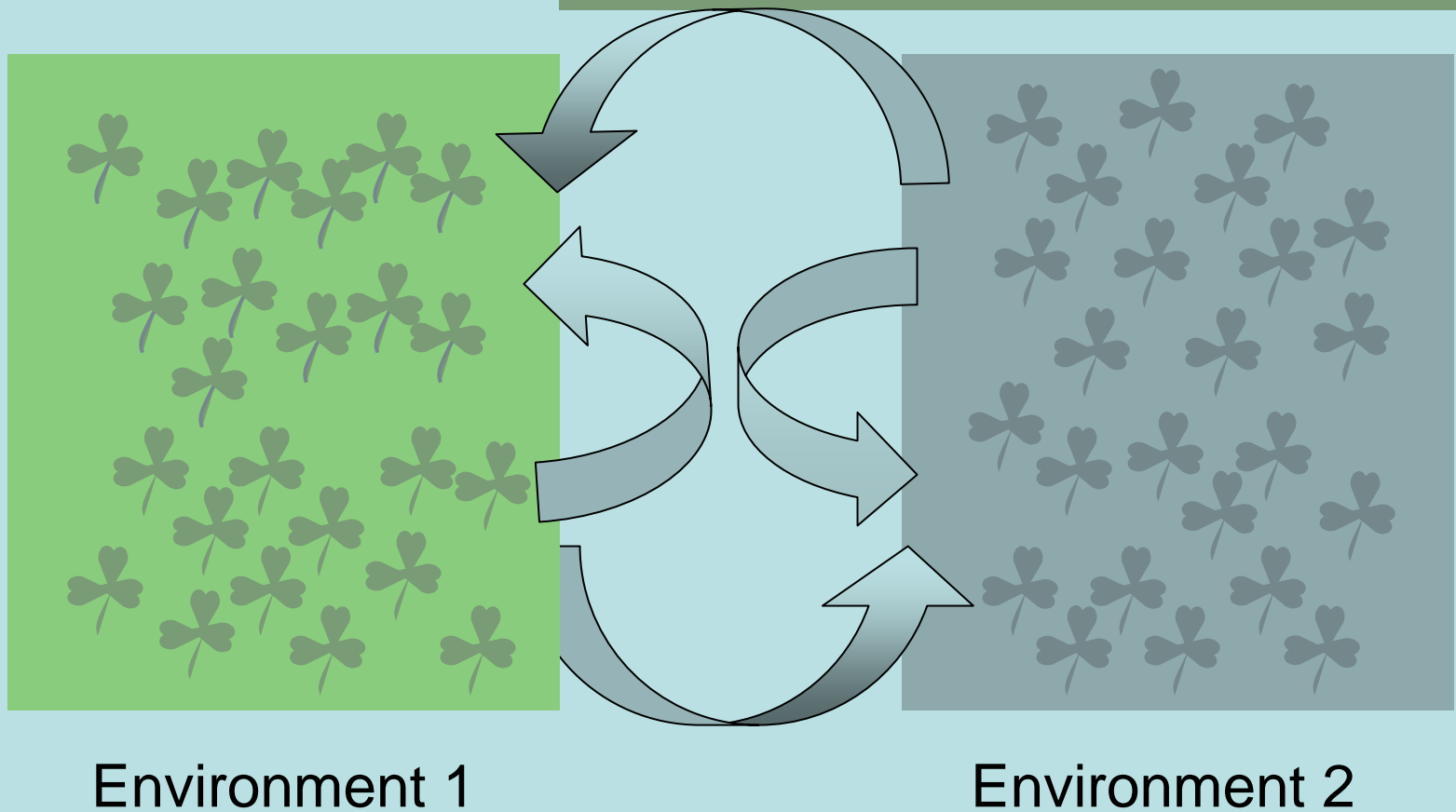
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- **Breeding system**
  - self-pollination
- **Neutral allozyme loci**
  - Between population differentiation  
Cruse-Sanders and Hamrick 2004
- **Common garden**
  - 8 populations in NY
  - Ginsenosides relate to age differently between populations  
Mudge et al. 2004

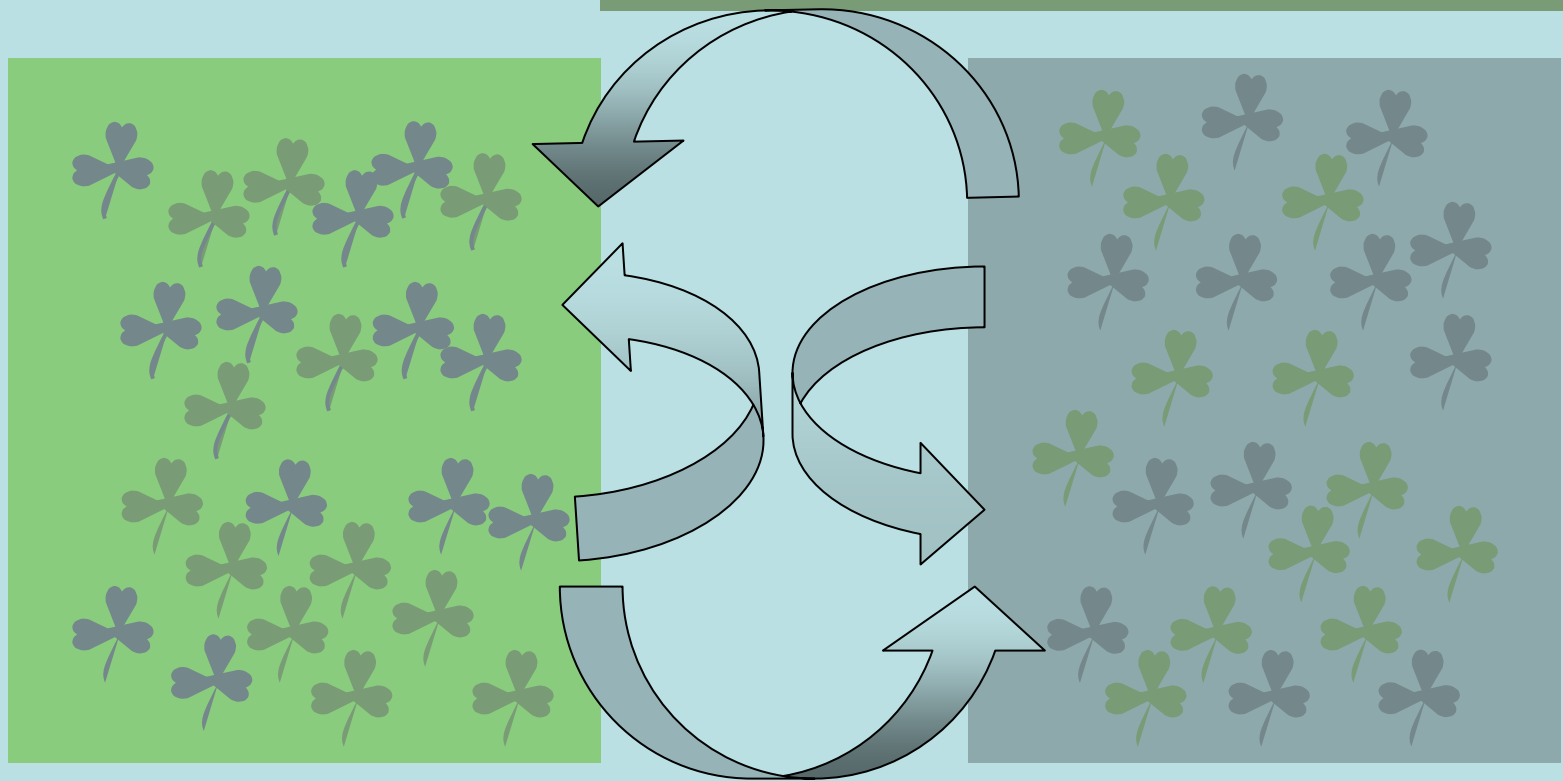


# Reciprocal Transplant





# Reciprocal Transplant

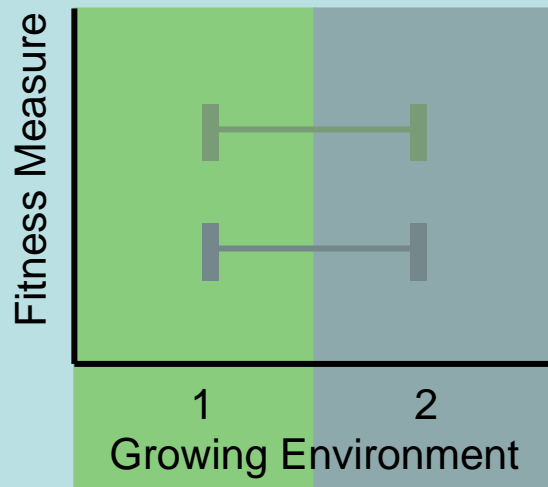


Environment 1

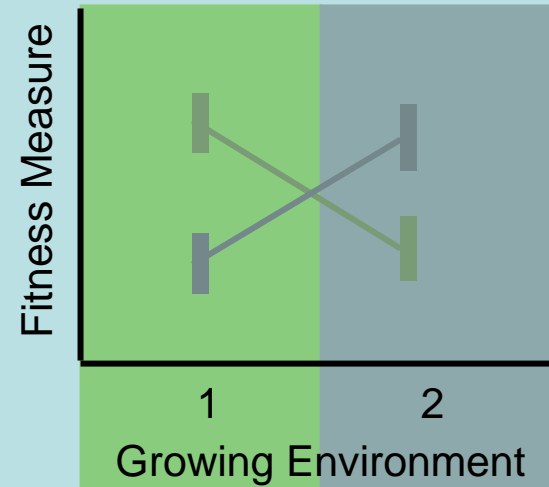
Environment 2



# Possible Results



No evidence of local adaptation



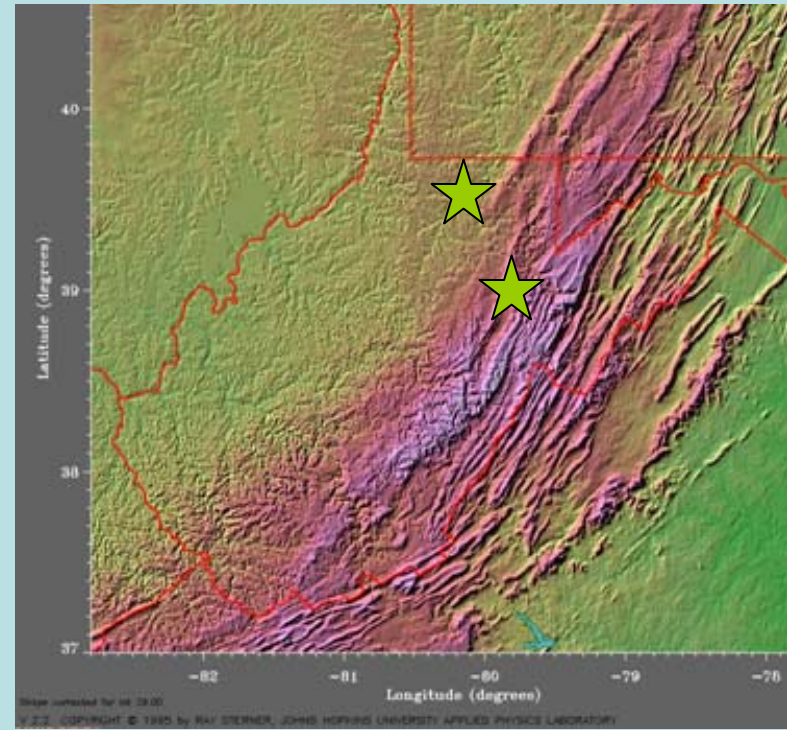
Evidence of local adaptation



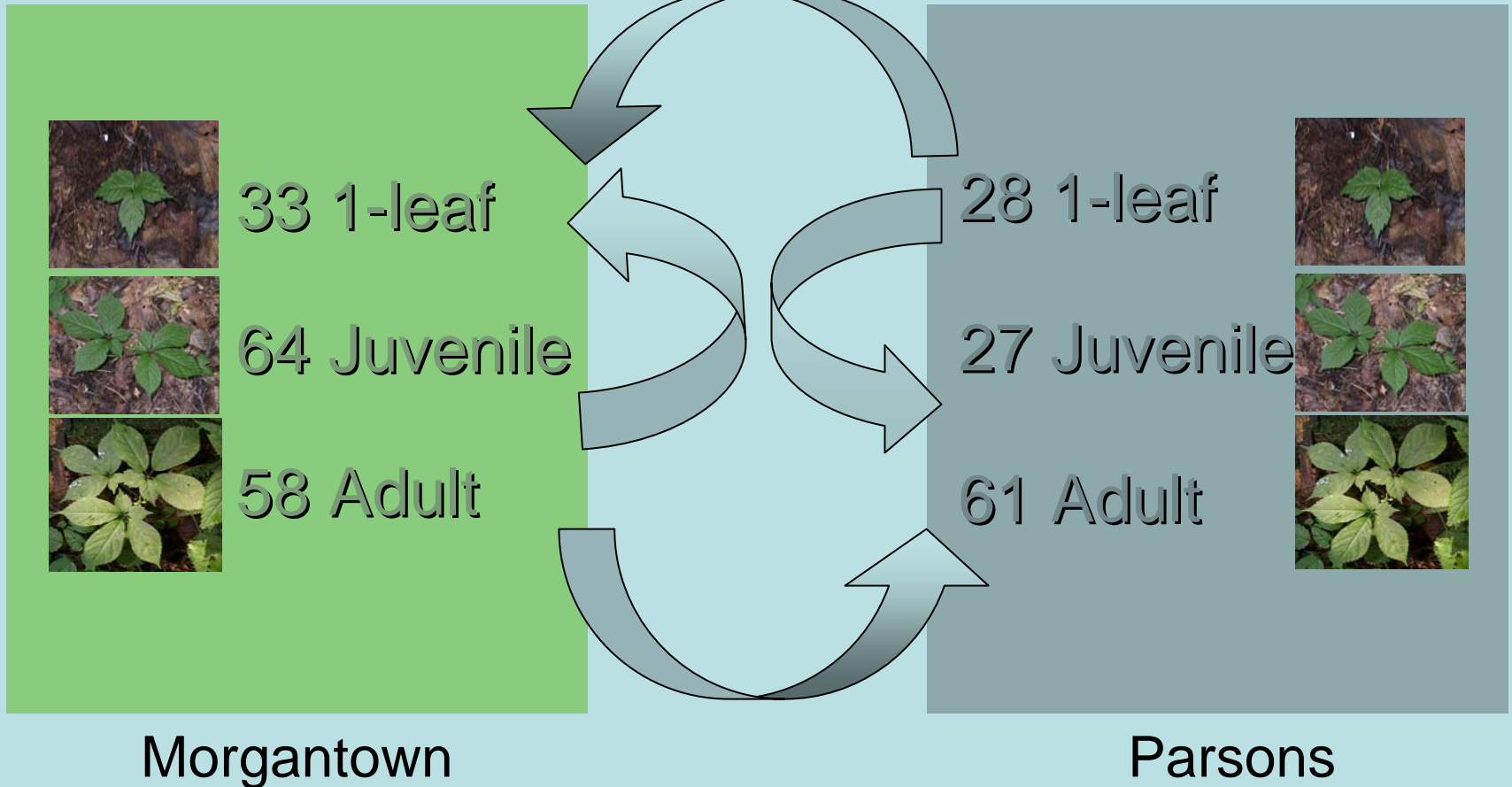
# Reciprocal Transplant

## 2 populations

- Morgantown, WV
  - Elevation 960 ft
  - Mean temp 52°F
  - Mean annual rainfall 41"
- Parsons, WV
  - Elevation 1,800 ft
  - Mean temp 48°F
  - Mean annual rainfall 58"



June 2005



33 1-leaf



64 Juvenile



58 Adult

Morgantown



28 1-leaf



27 Juvenile



61 Adult

Parsons





# June 2005

14 1-leaf  
13 Juvenile  
31 Adult  

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17 1-leaf  
32 Juvenile  
29 Adult

Morgantown

16 1-leaf  
32 Juvenile  
29 Adult  

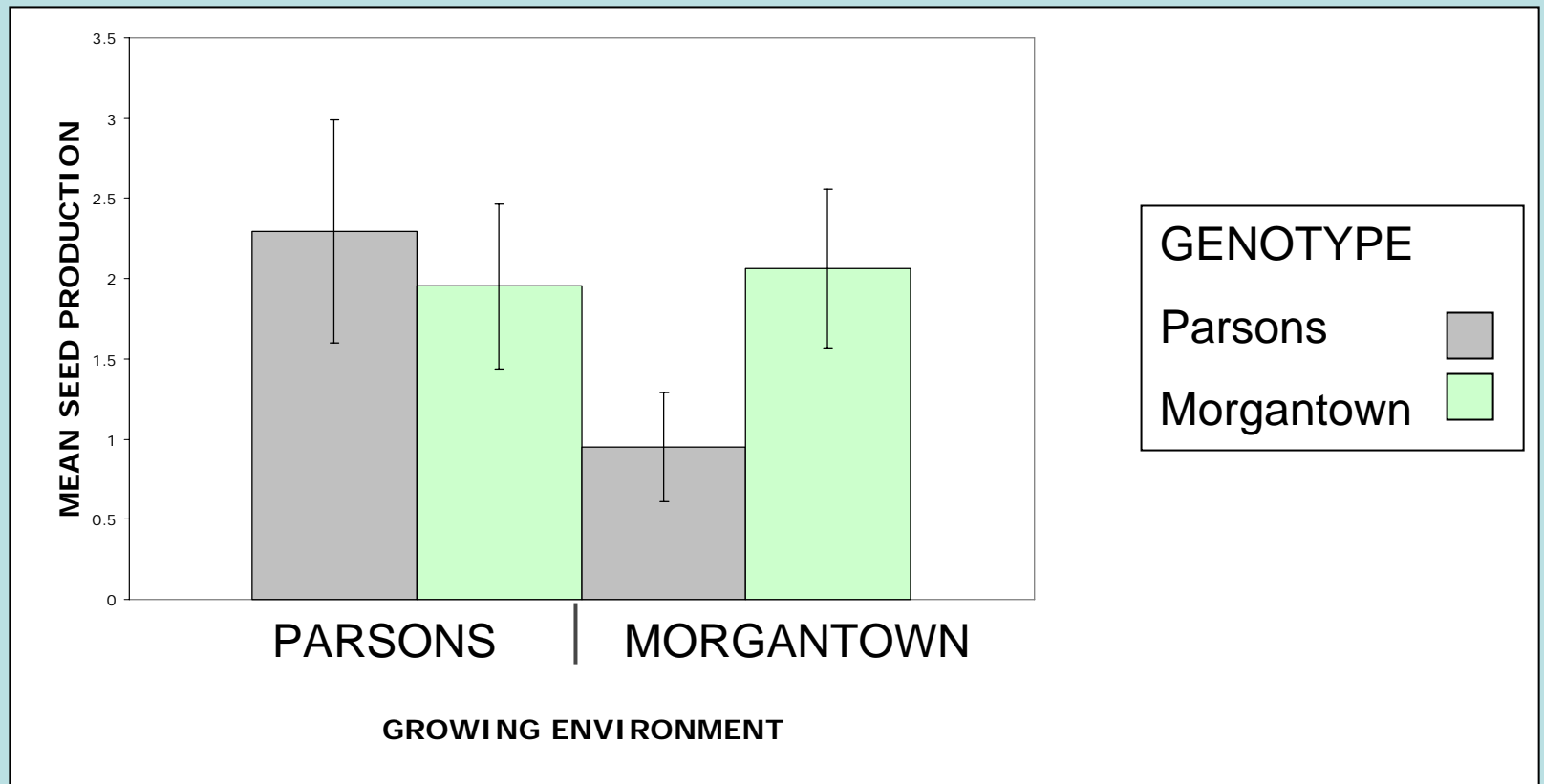
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14 1-leaf  
14 Juvenile  
30 Adult

Parsons



# Initial Results



Genotype X Environment:  $F = 3.1322$ ,  $p = 0.0787$



# Future Work

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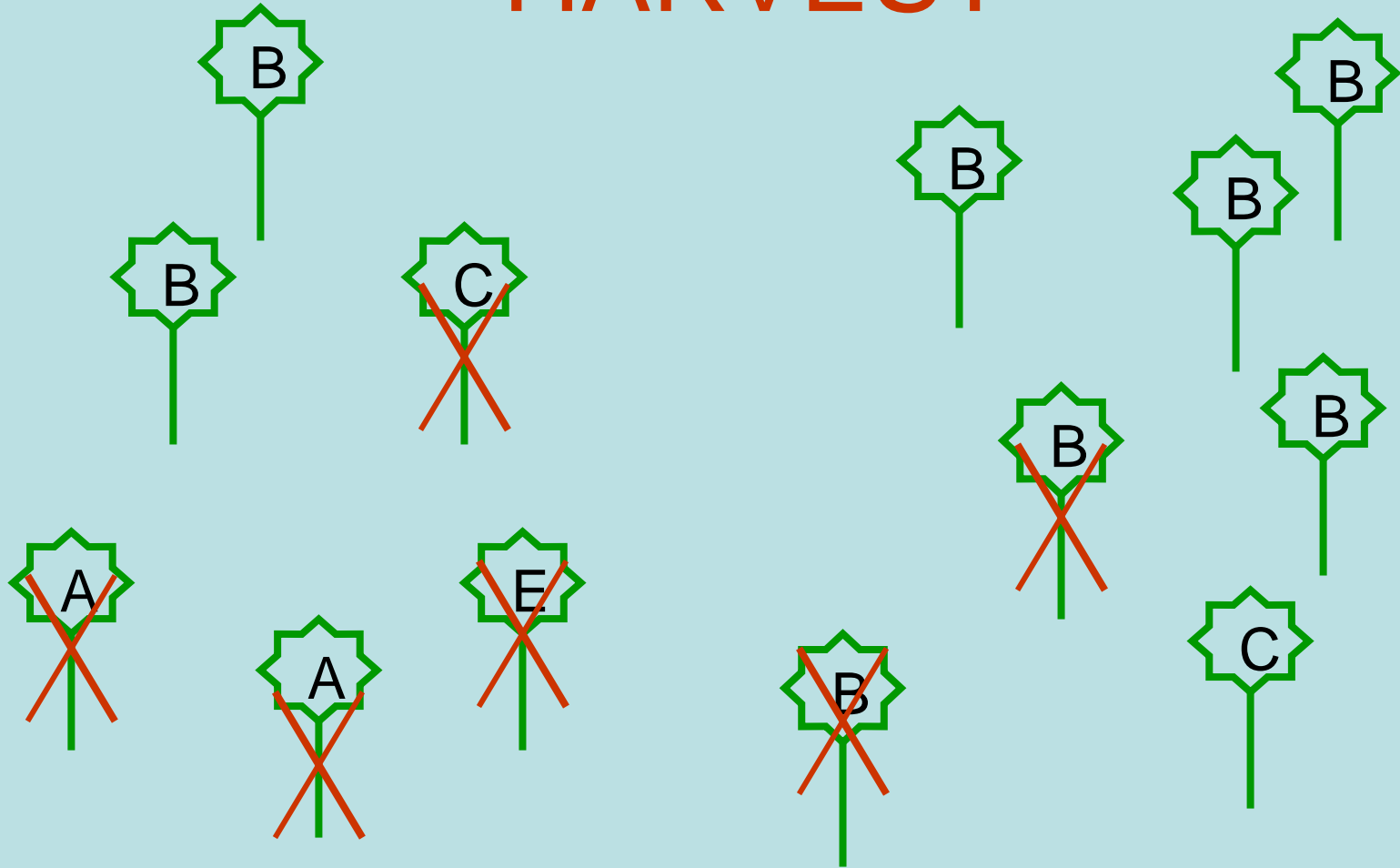
- Track survival, growth and reproduction through 2006
- Physiological measurements
  - Chlorophyll content-SPAD
  - Chlorophyll fluorescence
- Pass on research to increase years of data

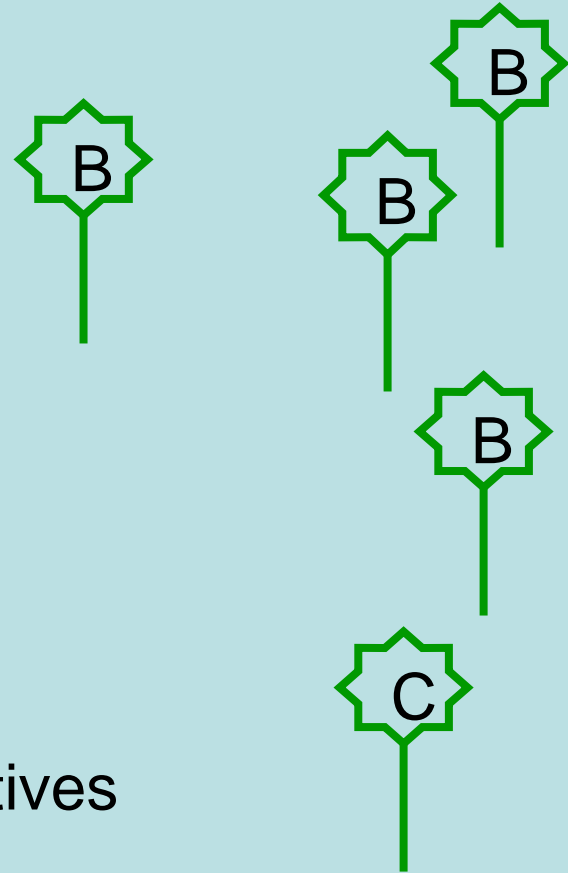
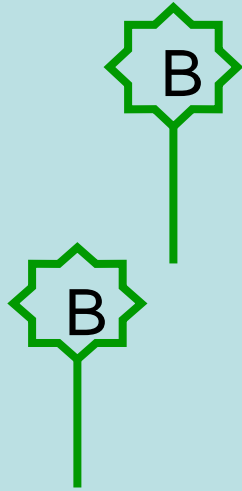


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Evidence for  
local adaptation  
in ginseng?

# HARVEST





Smaller population size

Reduced genetic diversity

Increased mating between relatives

**→ INBREEDING**



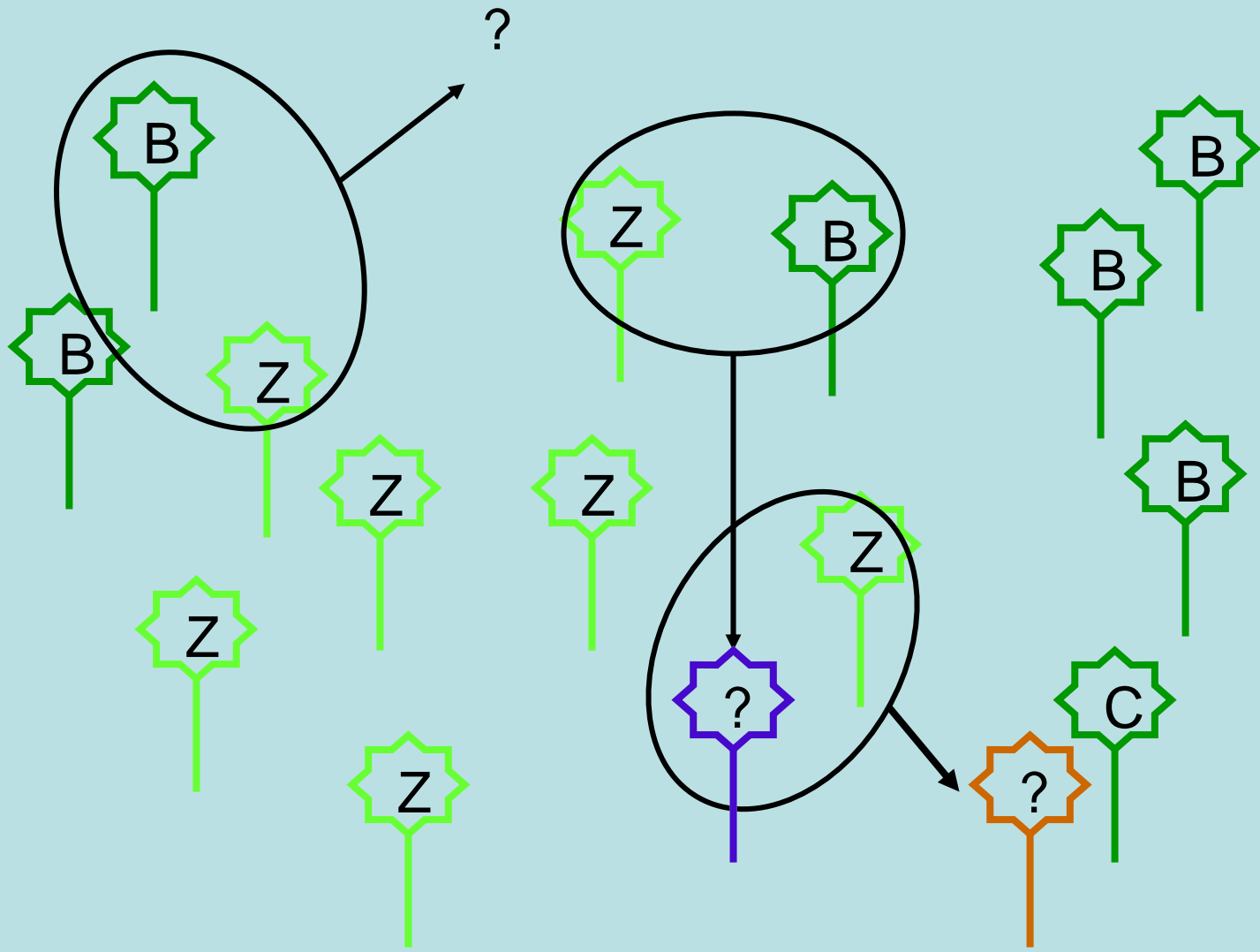


# Inbreeding Depression

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- **Reduced performance due to:**
  - Lowered heterozygosity
  - Expression of deleterious recessives
- **In plants:**
  - Early life-cycle vulnerable
  - Likely in species without histories of inbreeding
- **In American ginseng:**
  - Historically larger population sizes



Outbreeding



# Outbreeding Depression

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- **Reduced performance due to:**
  - Introduction of novel genes
  - Break up of locally adapted gene complexes
- **In plants:**
  - Concern for population restoration
  - Likely in locally-adapted, selfing species
- **In American ginseng:**
  - Harvester and management practices



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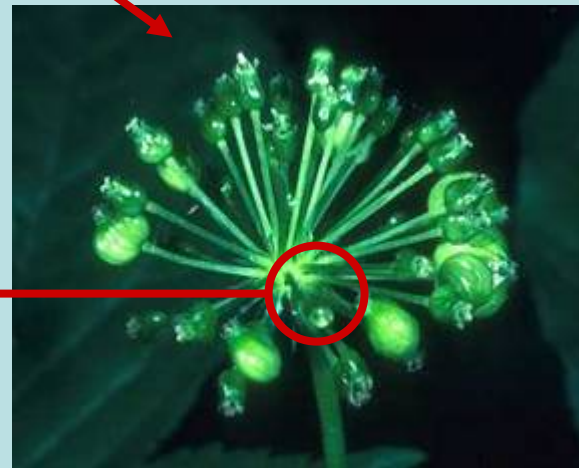
Do inbreeding and outbreeding play any roles in the germination, growth and survival of seedlings?



# Floral Anatomy



Inflorescence



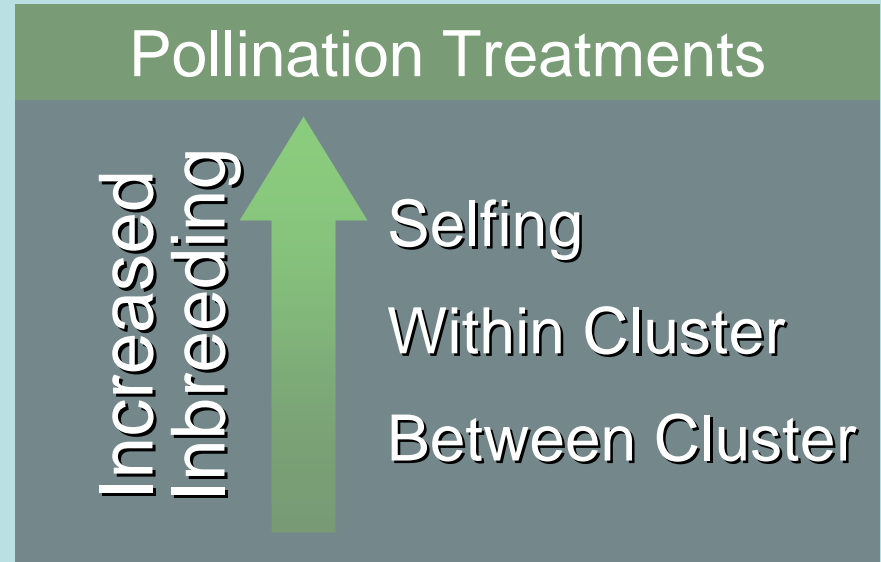
*Aralia nudicaulis*.  
Flower (mag.).

Flower



# Methods-Inbreeding

- Summer 2003
- Three wild populations
  - 63 Maternal plants
  - 309 Flowers
  - 8 Control plants
- Natural pollinators excluded



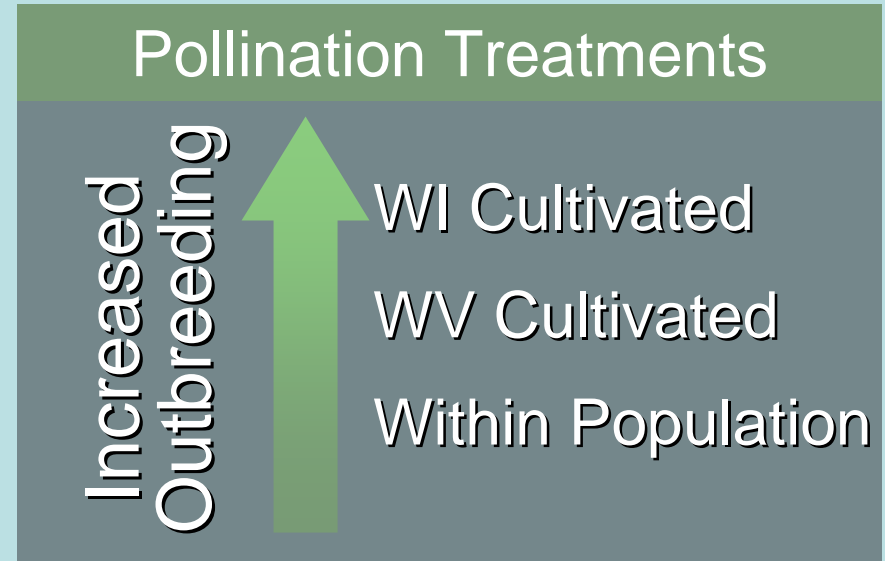
Based on Cruse-Sanders and Hamrick 2004





# Methods-Outbreeding

- Two wild populations
  - 69 Maternal plants
  - 443 Flowers
  - 11 control plants
- Cultivated pollen donors
  - West Virginia
  - Wisconsin





# Morphological Differences

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Wisconsin  
Cultivated



West Virginia  
Cultivated

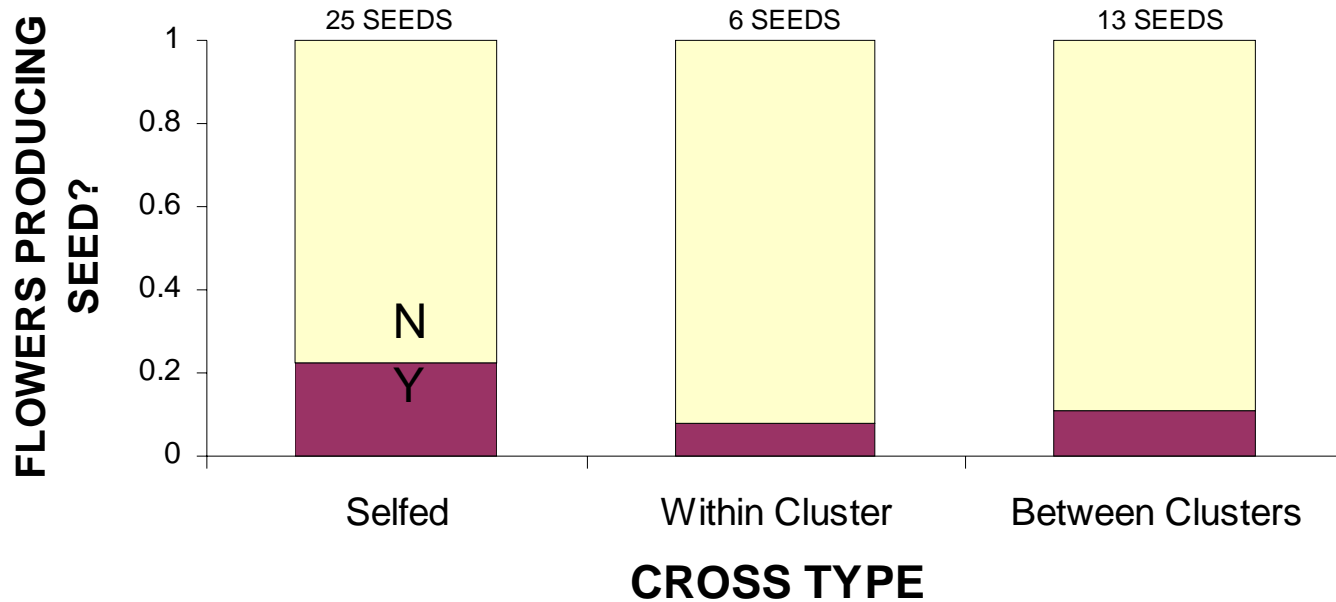


West Virginia  
Wild



# Seed Production

## Inbreeding

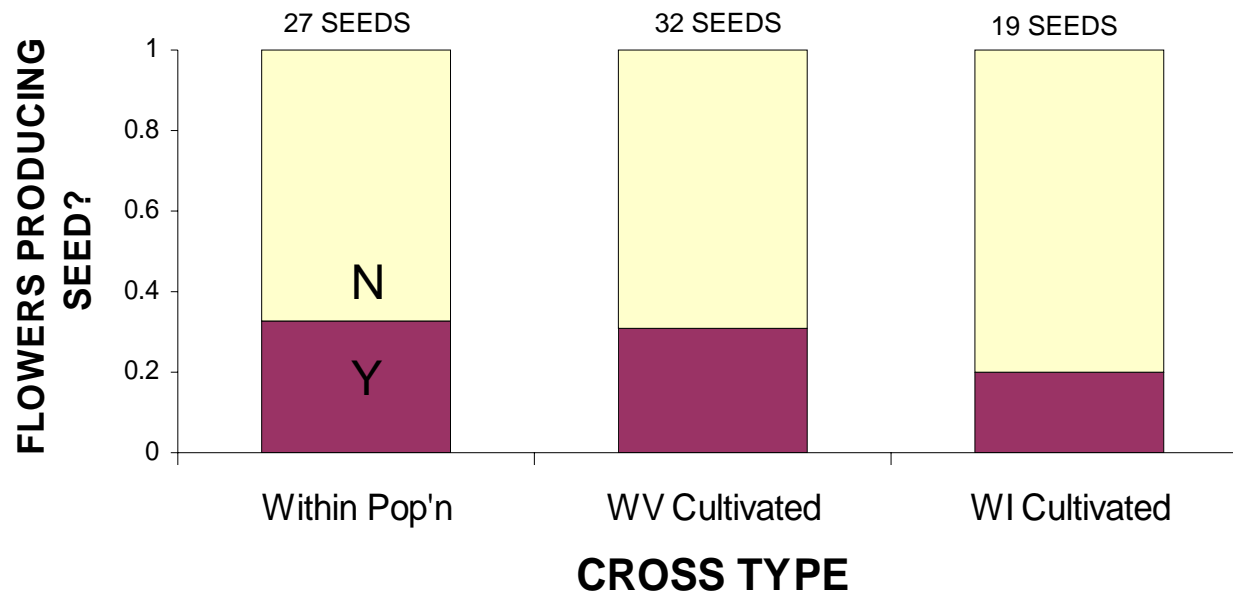


$$\chi^2=9.682 \quad p=0.0079 \quad \text{Control} = 0.031$$



# Seed Production

## Outbreeding



$\chi^2=4.830$   $p=0.0894$  Control = 0.049



# Germination

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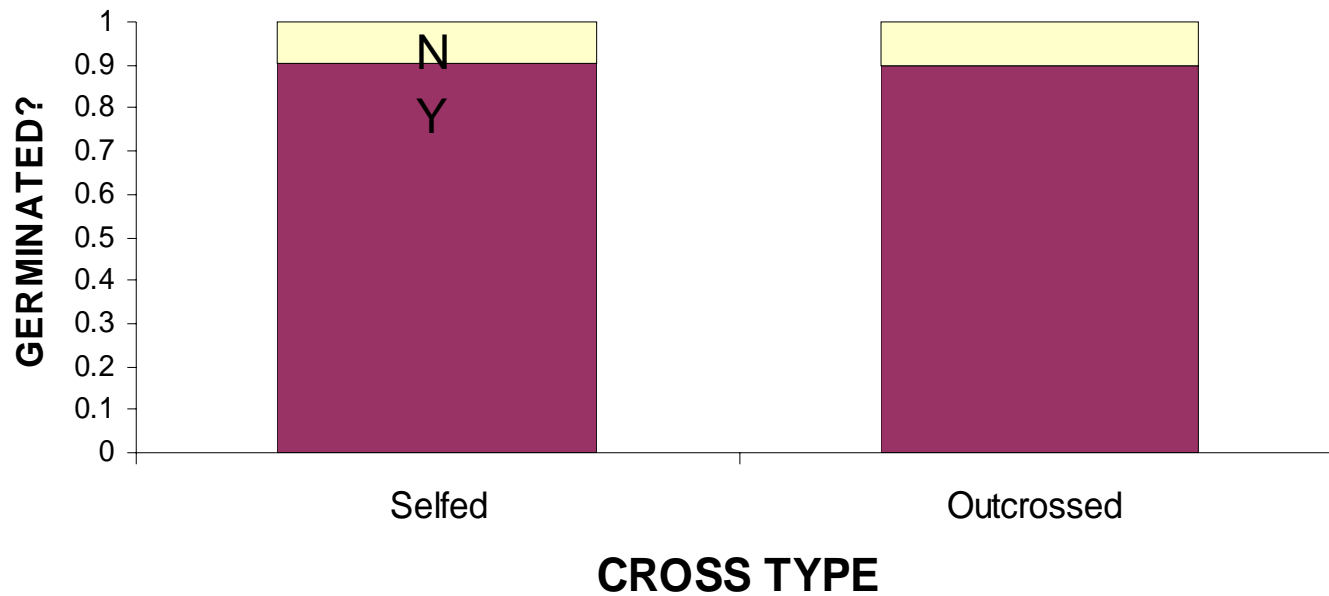
- Seeds planted September 2003
- Dormancy: 18-22 months
- 3 germinated in 2004!





# Germination

## Inbreeding



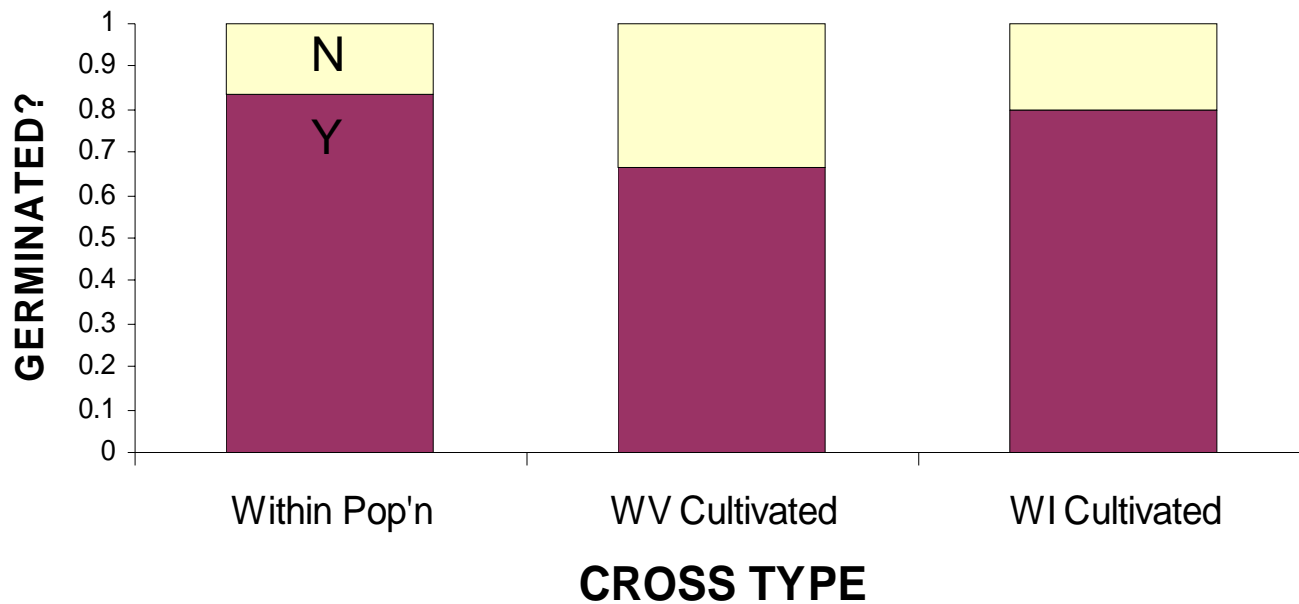
$$\chi^2=0.341 \quad p=0.5592$$





# Germination

## Outbreeding



$$\chi^2=4.686 \quad p=0.0961$$



# Growth and Survival

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- Stem height, leaflet length and width
- Leaf area:



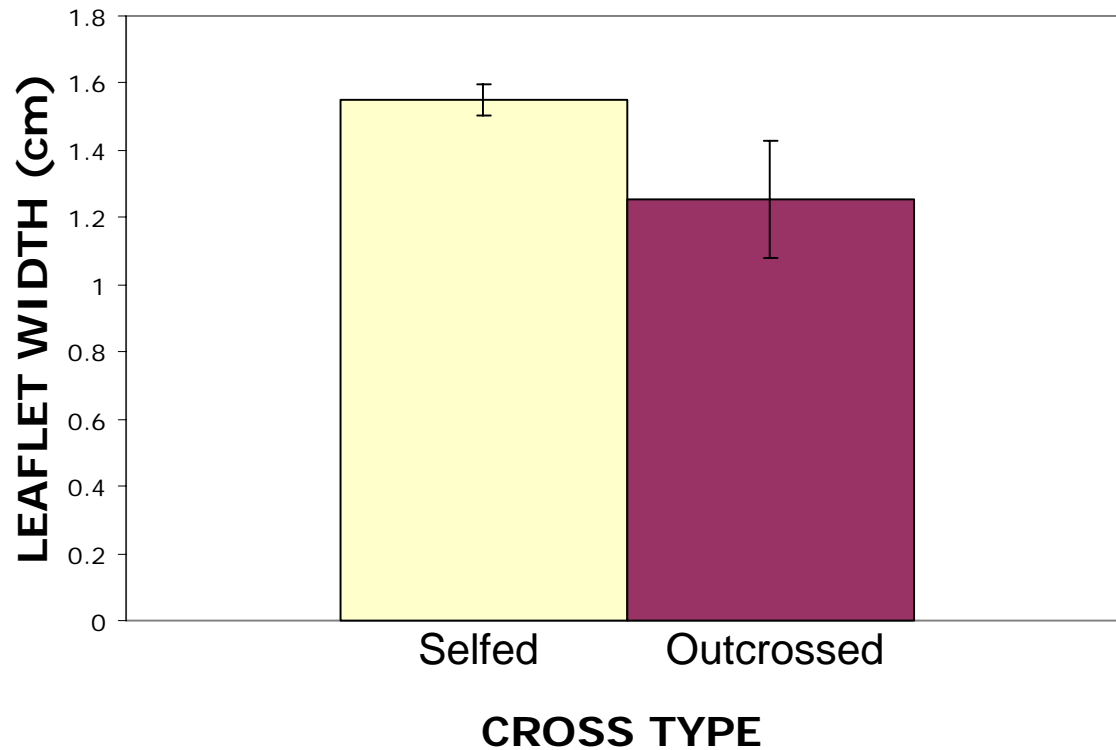
- NIH Image v. 1.62
- Plants monitored bi-weekly through 9/05





# Leaflet Width

## Inbreeding

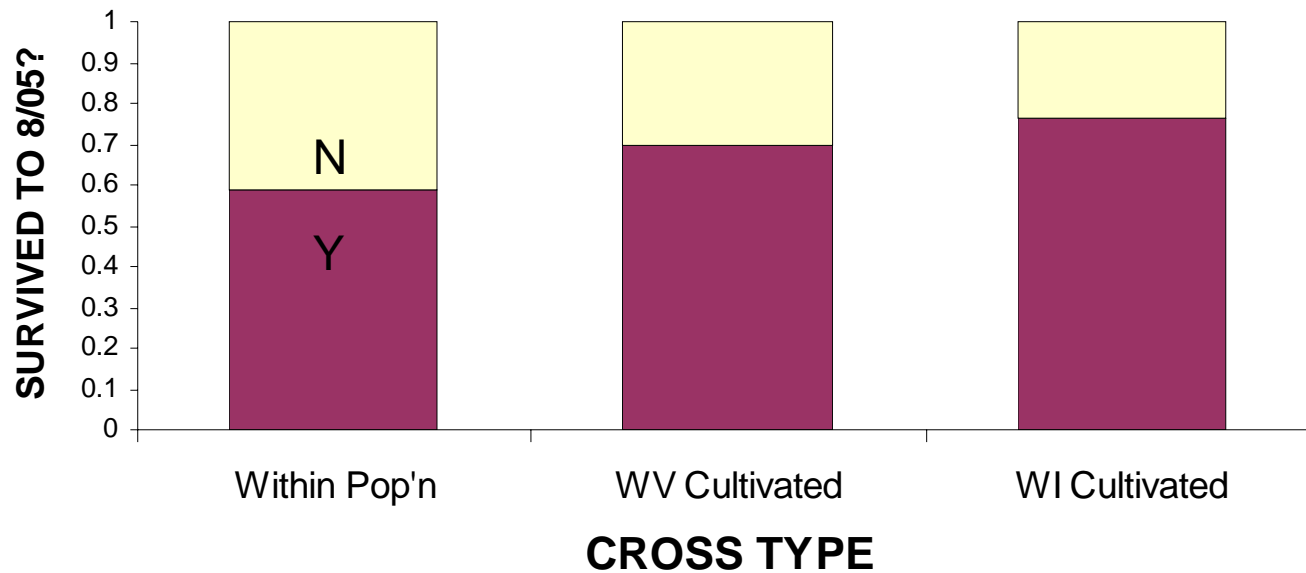


One-way ANOVA;  $F = 5.231$   $p=0.0293$



# Survival 5/05 - 8/05

## Outbreeding



$$\chi^2=6.317, p=0.0425$$



# Preliminary Indications

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- **Seed set**
  - Higher success of self-pollinations
  - Trend toward lower success of crosses with WI plants
- **Germination**
  - Selfed vs. outcrossed w/in population similar
  - Trend toward lower germination of WV plants
- **Survival to 8/05**
  - Trend of more outbred seedlings having higher survival rates



# Other Projects

- Does size/fitness relationship change when a population is harvested?
  - Harvest Simulations
  - 4 harvesters
  - Tracked with GPS
- Yes - exacerbated by seed removal





# Other Projects

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- How does growth of ginseng compare in harvested vs. protected populations?
  - 10 populations in 6 states
  - Plant size / age → growth rate



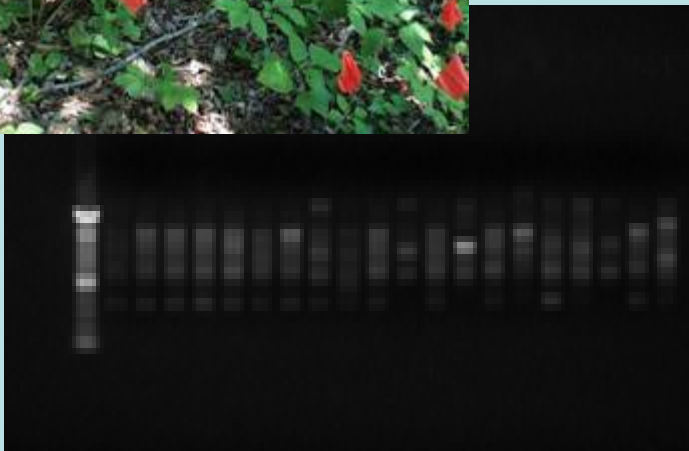


# Other Projects

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- What is the relationship between genetic diversity and projected population survival?
  - Monitoring of 25 populations
  - RAPD markers
  - DNA sampled from 20 plants per population





# Thank you!

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- Advisor: Jim McGraw
- Committee: Brent Bailey, Jonathan Cumming  
Donna Ford-Werntz, Keqiang Wu
- Field help:
  - Britni Schoonover, Nathaniel Lee, Alyssa Hanna,  
Matt Kaproth, Mary Oliver, Sara Lightner
- Support:
  - The Phipps Conservatory, The Nature  
Conservancy, E.N. Huyck Preserve