Master's Defense:

Water Use and Competitiveness of *Senecio sylvaticus* in Young *Pseudotsuga menziesii* Plantations

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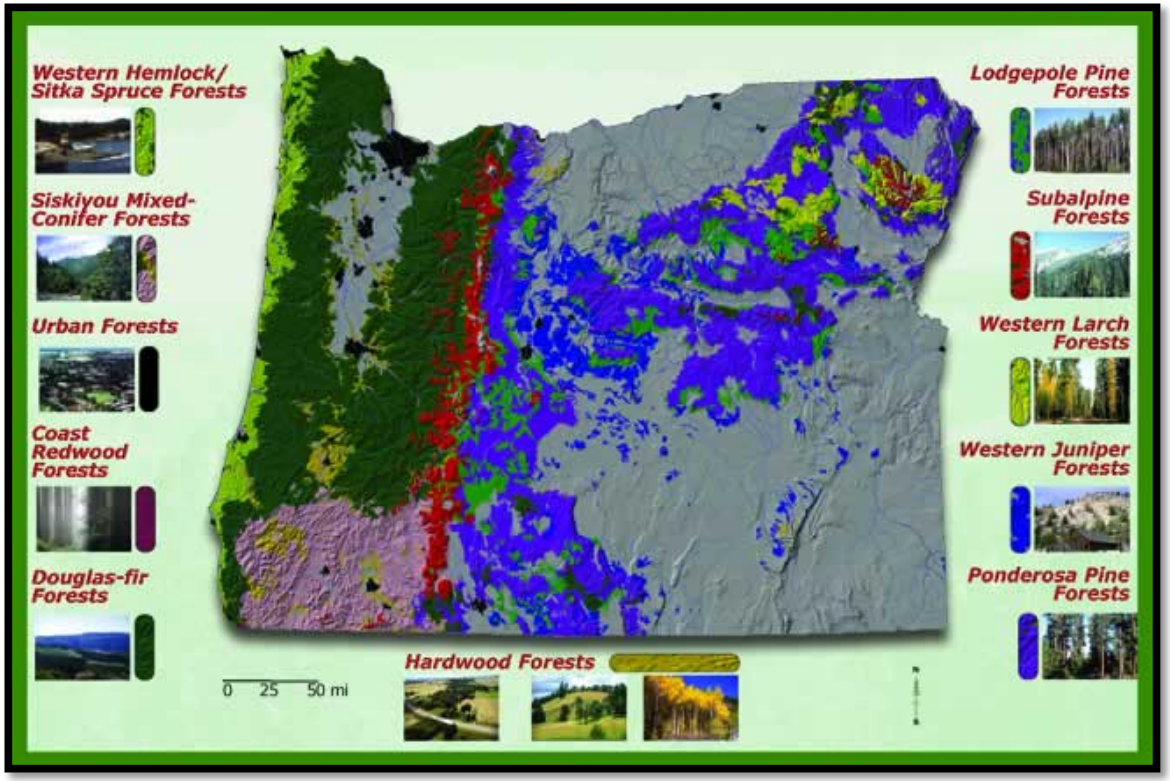
Forestry

- Forestry's relevance is increasing with the exponential growth of the human population:
  - Pressure for fuel, timber, forage production, as well as land-clearing for agricultural purposes
  - Meeting this demand requires optimally establishing long-lived and healthy crop trees
- Optimal growing conditions are compromised by many factors, including drought stress, which can be augmented by the abundance of competing vegetation
- Understanding how trees respond to environmental factors is useful in many different applications

Wikipedia

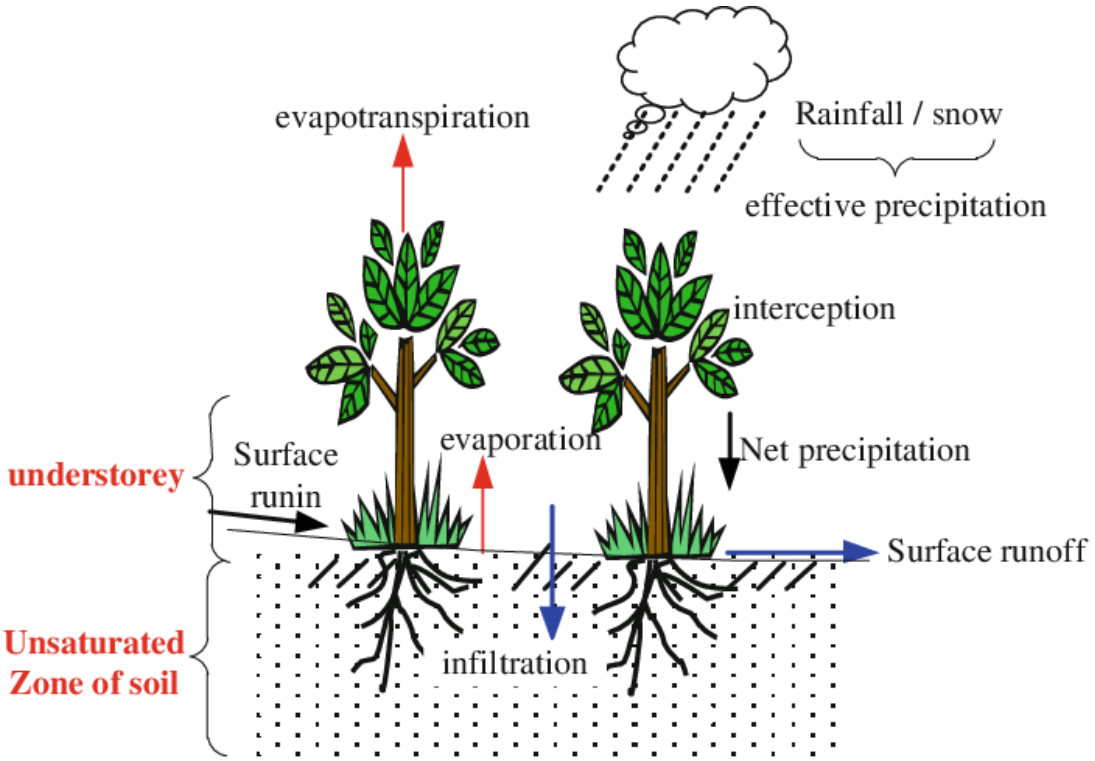
PNW Forestry

- The Pacific Northwest (PNW) is renowned for its productive coniferous forests.
- Oregon produced 5,459 million board feet, or 16.2% of total softwood lumber in the US in 2017
- About half of the land area of Oregon is classified as forestland
  - 80 percent of this classified as "timberland"
- Most important crop tree is Douglas-fir: 70% of total timber volume harvested
- Forest Vegetation Management buffers against competing vegetation



Optimal Forestry

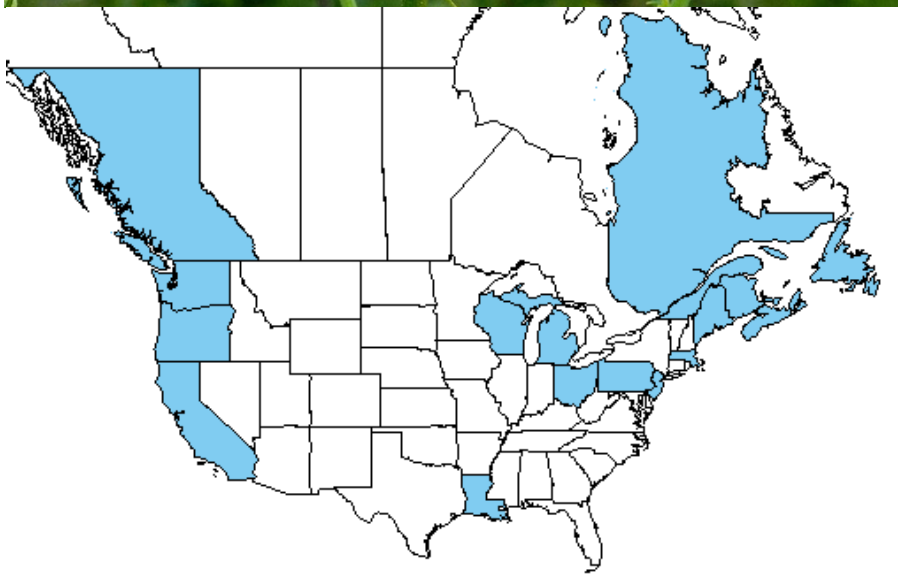
- Several hundred grams of water are required to produce a single gram of dry plant matter
  - >95% of this water is lost by transpiration
- Because of changing climate trends in the PNW towards warmer summers, the "optimal" tree-growth question exists in an uncertain context
- IPCC predicts increases in temperature and the frequency/intensity of heat waves
  - This will affect forest growth and productivity as a result of increasing air temperature and CO_2 concentrations
- But, responses between species differ…



Researchgate.net

Senecio: History

- Invasive annual forb introduced from Eurasia to the US in the 1920s
- Adapted to short term dominance and rapidly colonizes forest sites following disturbances such as timber harvest
- Able to produce ~190,000 wind-dispersed seeds per m^2 from around July 15th to September 1st
- Difficult to control. Often the most abundant competitor on sites treated with only a chemical fall site preparation



plants.sc.egov.usda.gov

Senecio: Life History

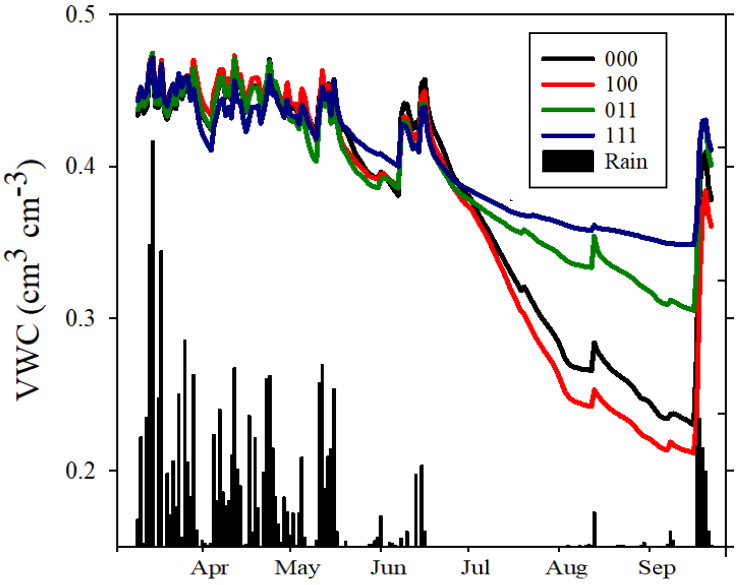
- Previous research shows Senecio responds to both increased CO_2 and soil moisture levels:
  - at 350 ppm CO_2, average root length 2.0 cm and 4.3 cm in the dry and wet sites, while at 750 ppm, root length 4.6 and 11.7 cm
- Therefore, species in the genus Senecio are likely to increase in competitiveness given the projected increase in atmospheric CO_2 concentration in the future
- While woody-stemmed species like Douglas-fir generally are not as responsive

Senecio: Early Seral Competitor

Impetus of this study:

- Results from VMRC studies have indicated Senecio is a strong competitor for soil moisture
- Senecio rapidly utilizes site resources before producing seed and senescing
- Competition between Senecio and Douglas-fir seedlings is often intense and can impact tree seedling physiology, growth and likelihood of mortality
  → These relationships are not well understood

BW CoSInE →



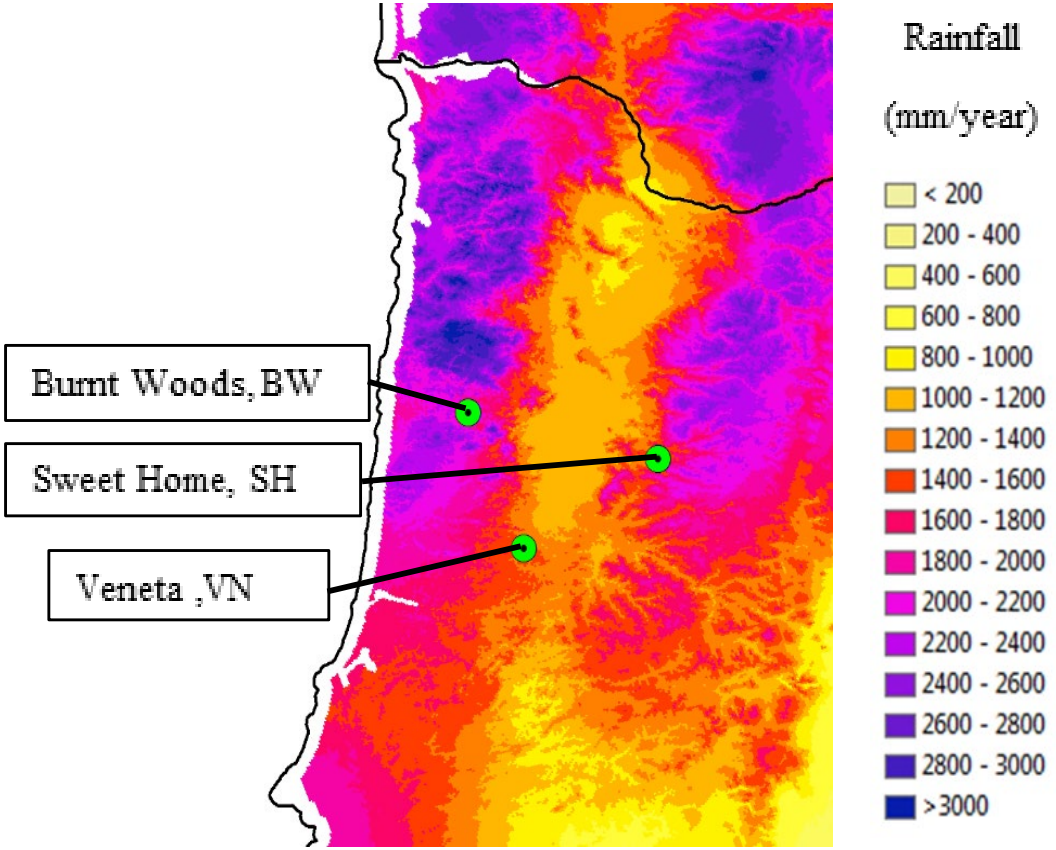
Project Goals

Investigate the consequences of Senecio presence in PNW newly-planted Douglas-fir stands and quantify this impact

1. Quantify soil moisture dynamics under varying abundances of Senecio at different sites in western Oregon
2. Assess the impact of Senecio cover on Douglas-fir seedling drought stress
3. Investigate the different biomass partitioning responses of the two species across sites

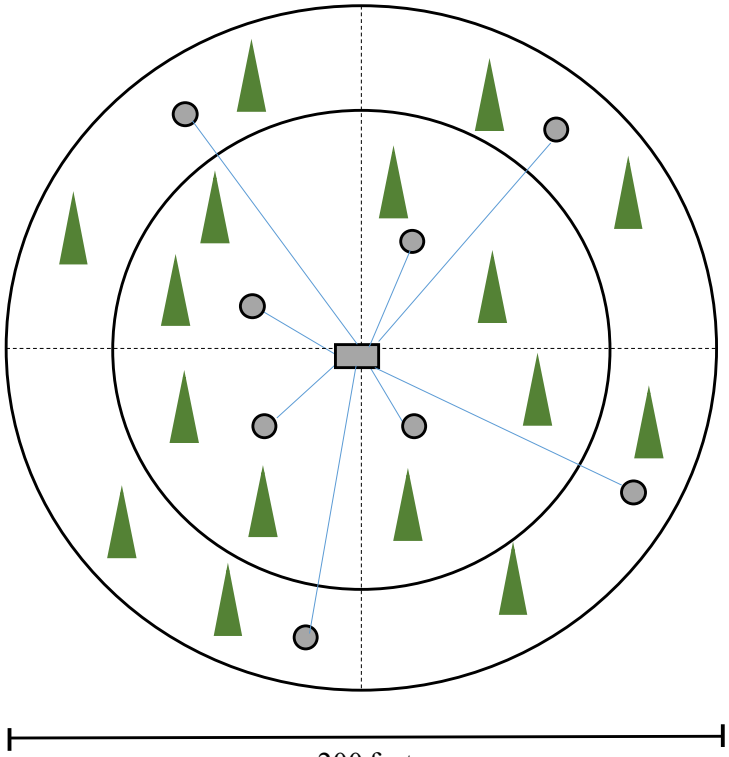
Site Selection

- Three study sites were selected:
  - BW: Wet site (ODF)
  - SH: Intermediate site (CTC)
  - VN: Dry site (RFP)
- Newly planted DF sites
- All sites had a chemical FSP treatment
- A 200 ft x 200 ft study area was excluded from any further herbicide applications



Site Layout

- Study areas were 0.72 acres:
  - 2 circles with equal area:
    - 0-70.7 ft
    - 70.7 ft – 100 ft
  - 8 octants (.09 acres)
- One 30 cm long TDR soil moisture sensor was installed in each octant of each circle (8 total), random azimuth and distance
- A data logger and weather station were installed at the center of each site
- 16 Douglas-fir seedlings in the study area surrounded by varying levels of Senecio were selected for vegetation survey, water use, and drought stress measurements



Methods

- **Weather:** temperature, relative humidity, radiation, rainfall (30 minute averages)
- **Soil Moisture:**
  - 8 continuous 30 cm long sensors (30 minute averages)
  - Measured next to each DF seedling every two weeks using 20 cm handheld sensor
- **Drought Stress:** pre-dawn and midday water potential were measured for both DF and Senecio:
  - Monthly from April-September
  - 16 DF seedlings
  - 5 Senecio plants

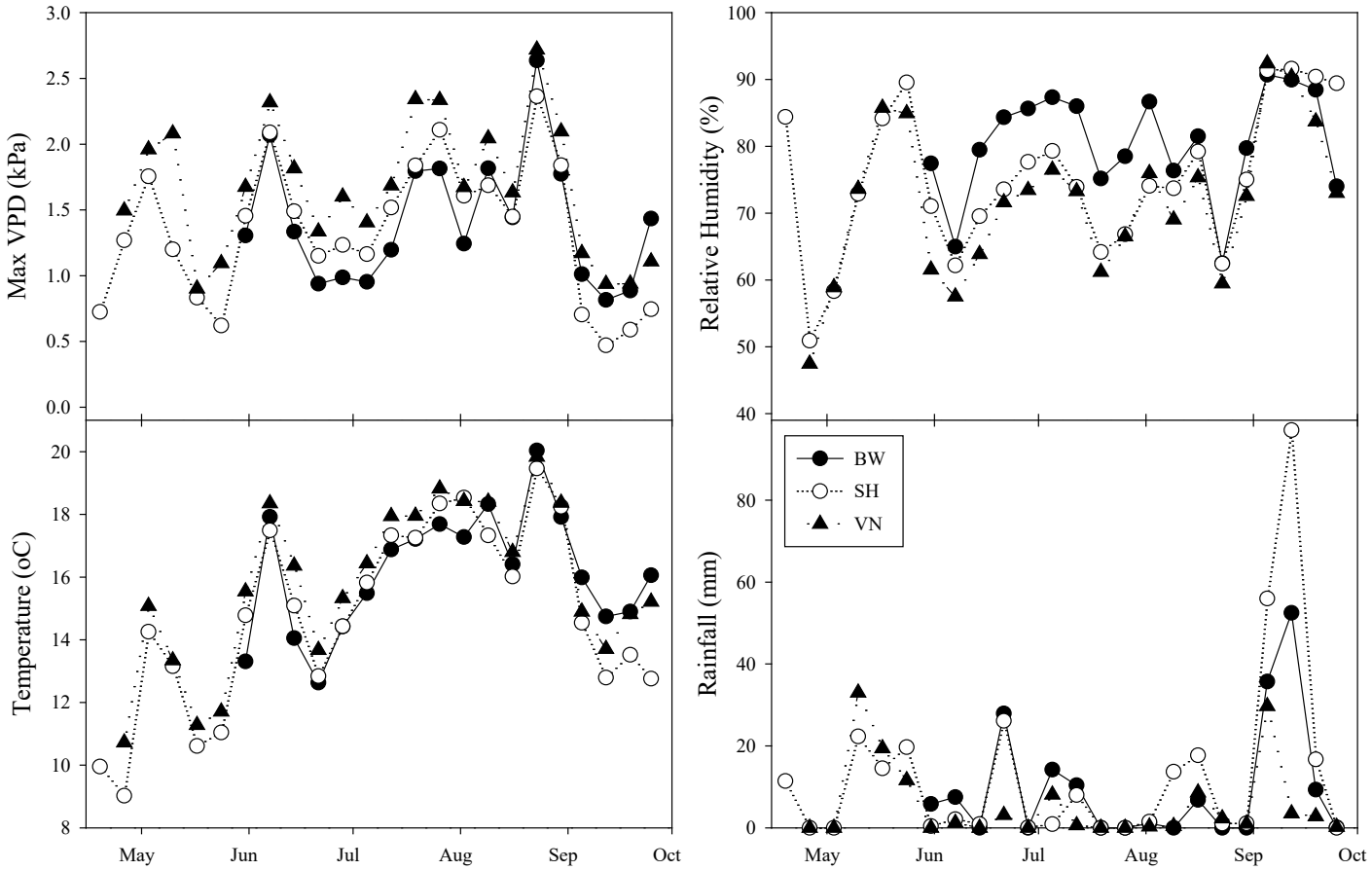
Methods

- **Senecio Abundance:** visual estimates of vegetation cover and height conducted every 2 weeks
  - 1 m^2 plots
  - Measured at each VWC probe (8 per site)
  - Measured at each tree (16 per site)
  - Non-Senecio species (>5% cover) removed
- **Biomass per ground area:** Three clip plots (1 m^2) per measurement date (April-September) per site
- **Biomass per plant:** 10 complete (root + shoot) Senecio and Douglas-fir per site were excavated in late summer (10*3*2=60):
  - Height
  - Vertical and horizontal root length
  - Root Volume (water displacement)
  - Biomass (shoot and root)
  - Number of root tips (WinRhizo)

Results: Weather

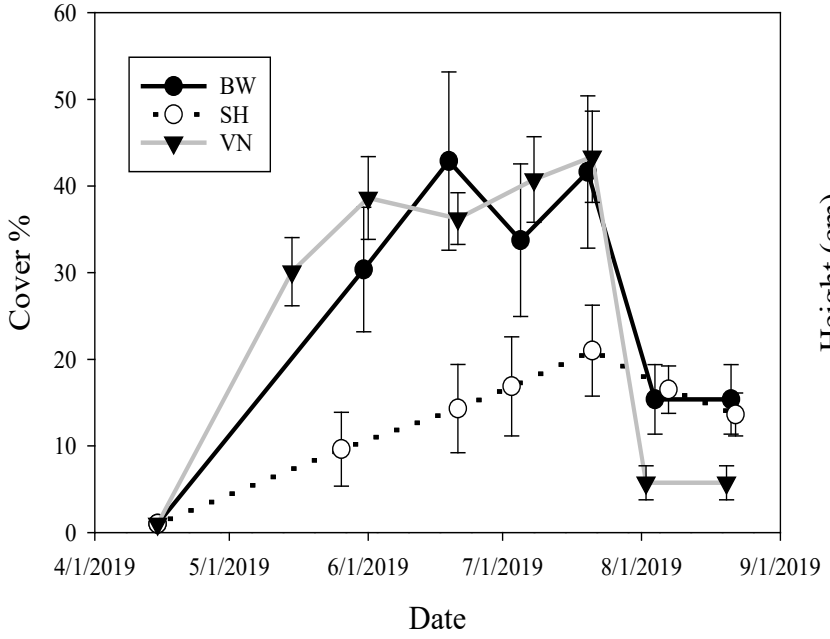
- Over the shared measurement period (5/31/19 - 9/27/19):

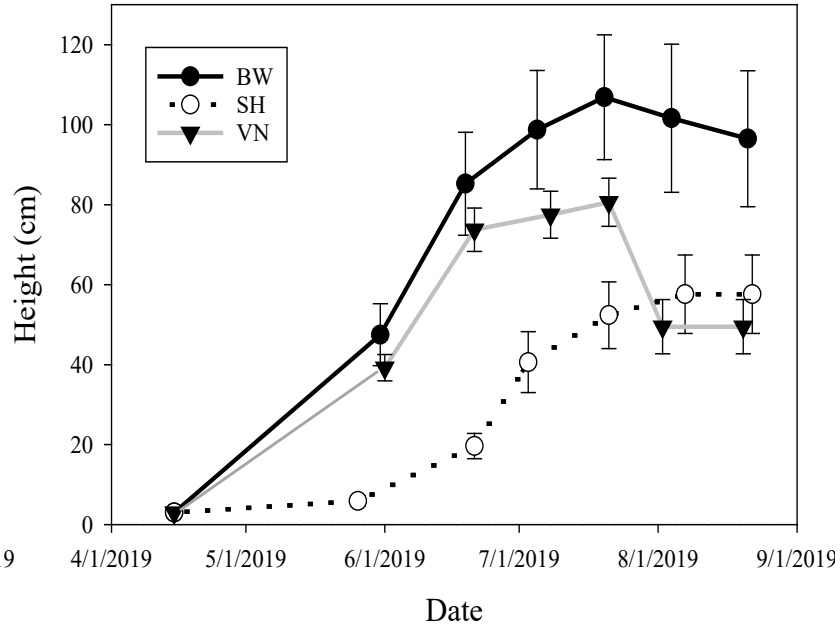
Site	Rainfall (in)	Temperature°F	Relative Humidty
BW	6.7	61.2	81
SH	8.9	61.0	75
VN	2.4	62.4	72



Results: Senecio Abundance Dynamics

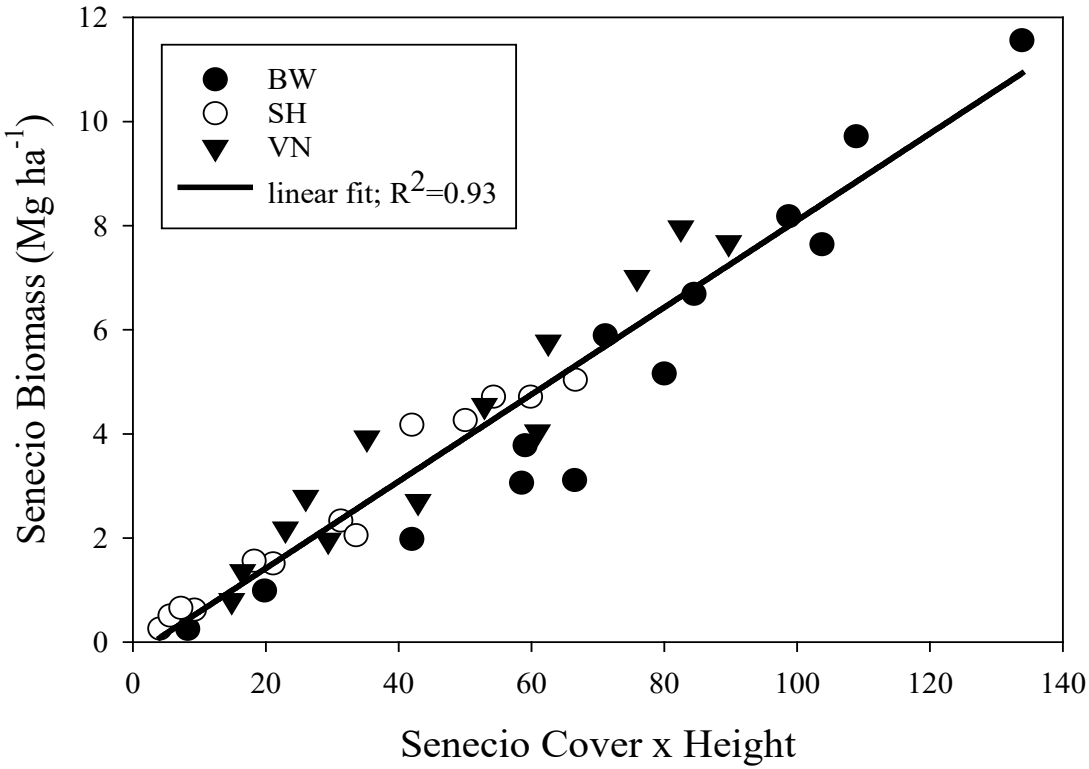
- There was no Senecio cover at all sites at the start of the measurement period
- Senecio cover and height increased rapidly as the growing season progressed, especially mid-April to beginning of June
- BW had the tallest Senecio, SH had the shortest Senecio and lowest cover
- BW experienced intense intraspecific competition and some loss of cover





Results: Senecio Biomass

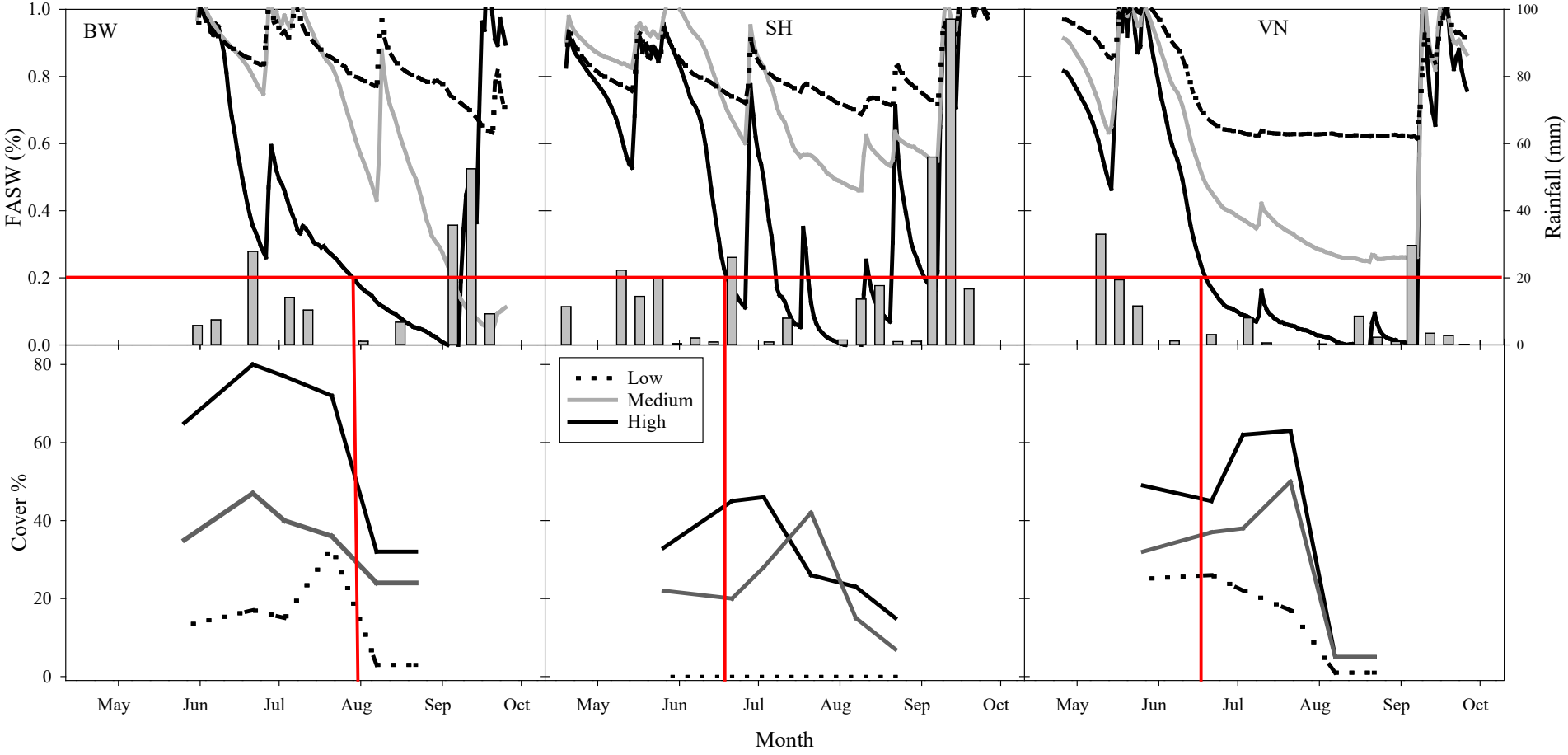
- There was a strong relationship between Senecio Cover (%) by Height (m) and Senecio ground-area biomass (Mg ha^{-1}) shared across all sites



$$SB = -0.0387 + 0.0757 * CxH$$

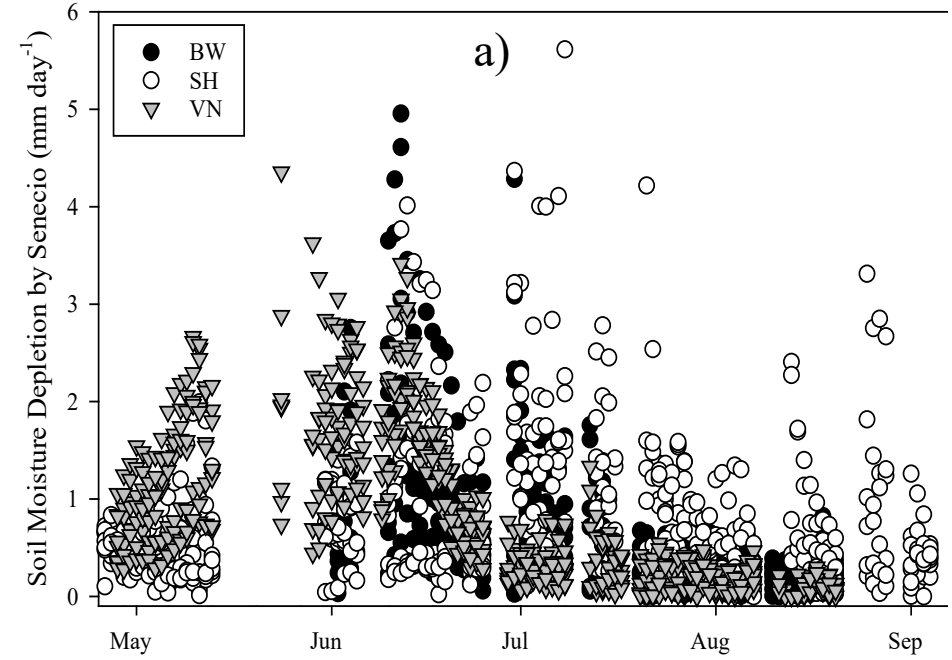
Results: Soil Water Dynamics

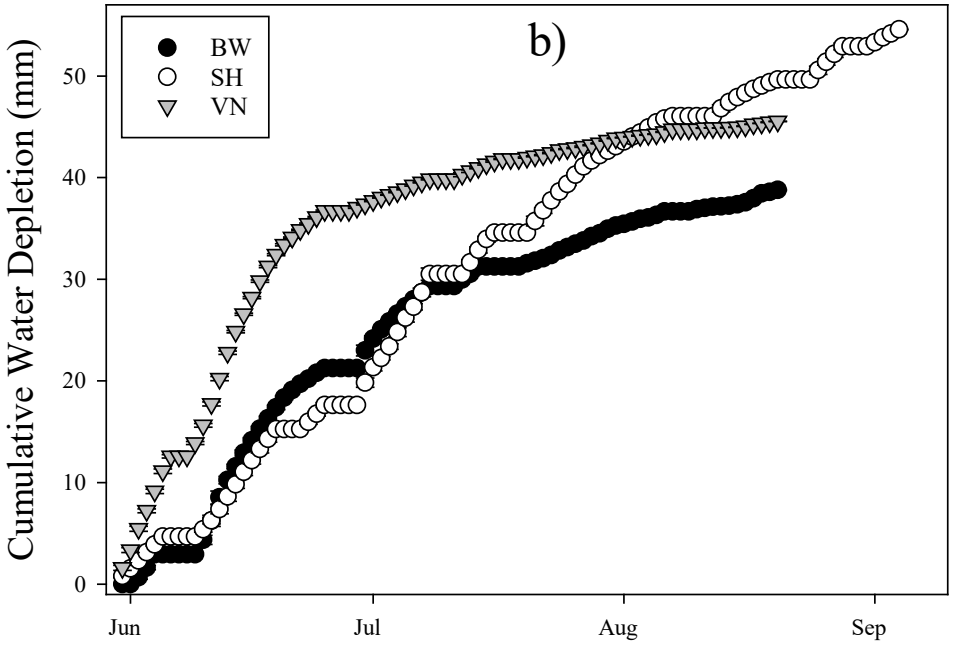
- Soil moisture probes surrounded by higher levels of Senecio had more rapid reductions in fractional available soil water (FASW) at all sites (reflecting higher Senecio water use)



Results: Senecio and Water Depletion

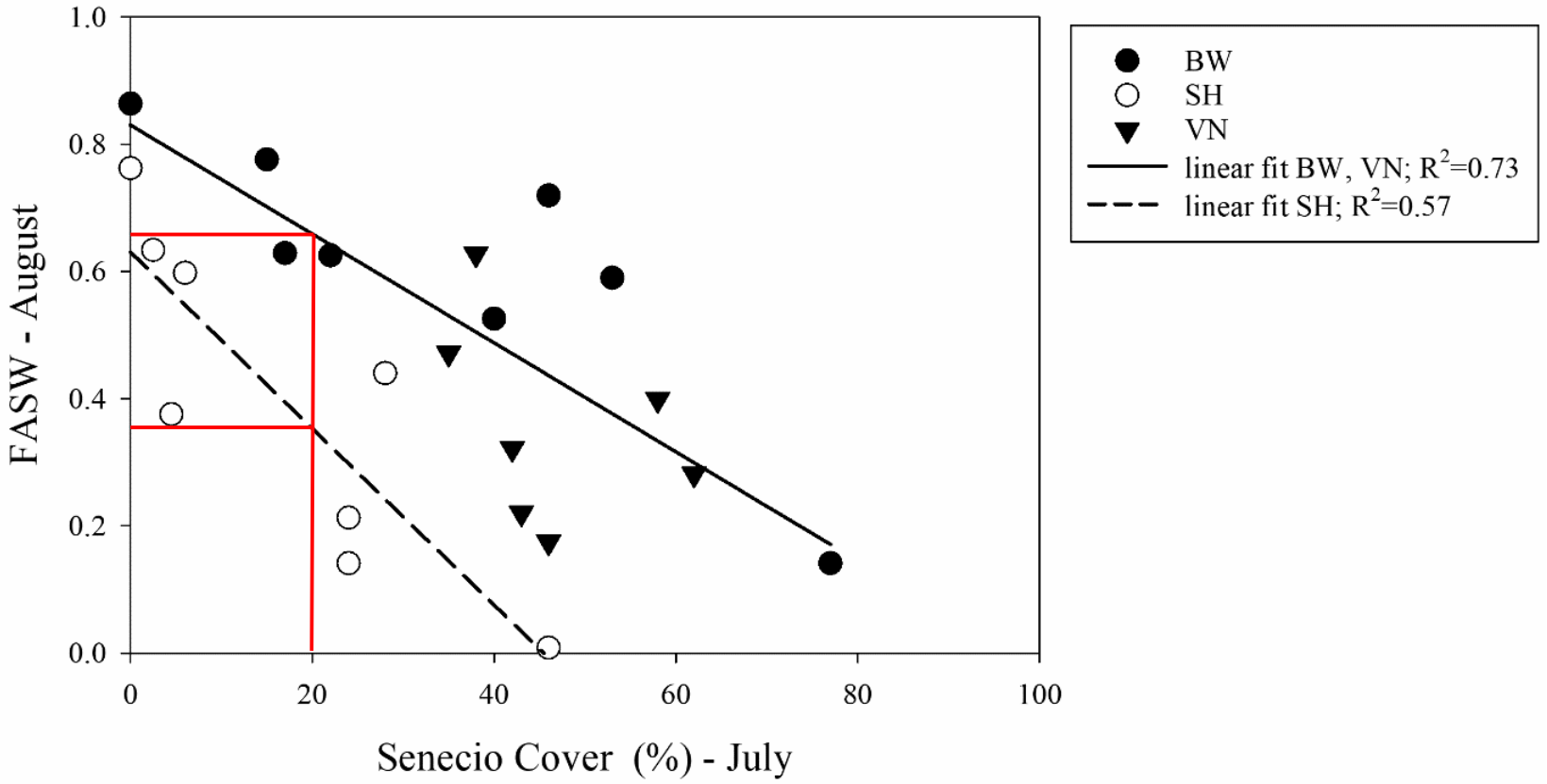
- a) Seasonal dynamics of soil moisture depletion
- VN earliest and most intense soil water depletion mid-May (4.5 mm day^{-1}), BW had the next peak (5 mm day^{-1}) in early June, and SH had the latest peak in July with 5.6 mm day^{-1}
- b) Average water use by Senecio across the growing season: 46 mm for the 82-day period for VN; 55 mm for SH; and 39 mm for BW
- Average site use during 6/3-6/22: VN—1.63 mm day^{-1}; SH—1 mm day^{-1}; BW—1.3 mm day^{-1}





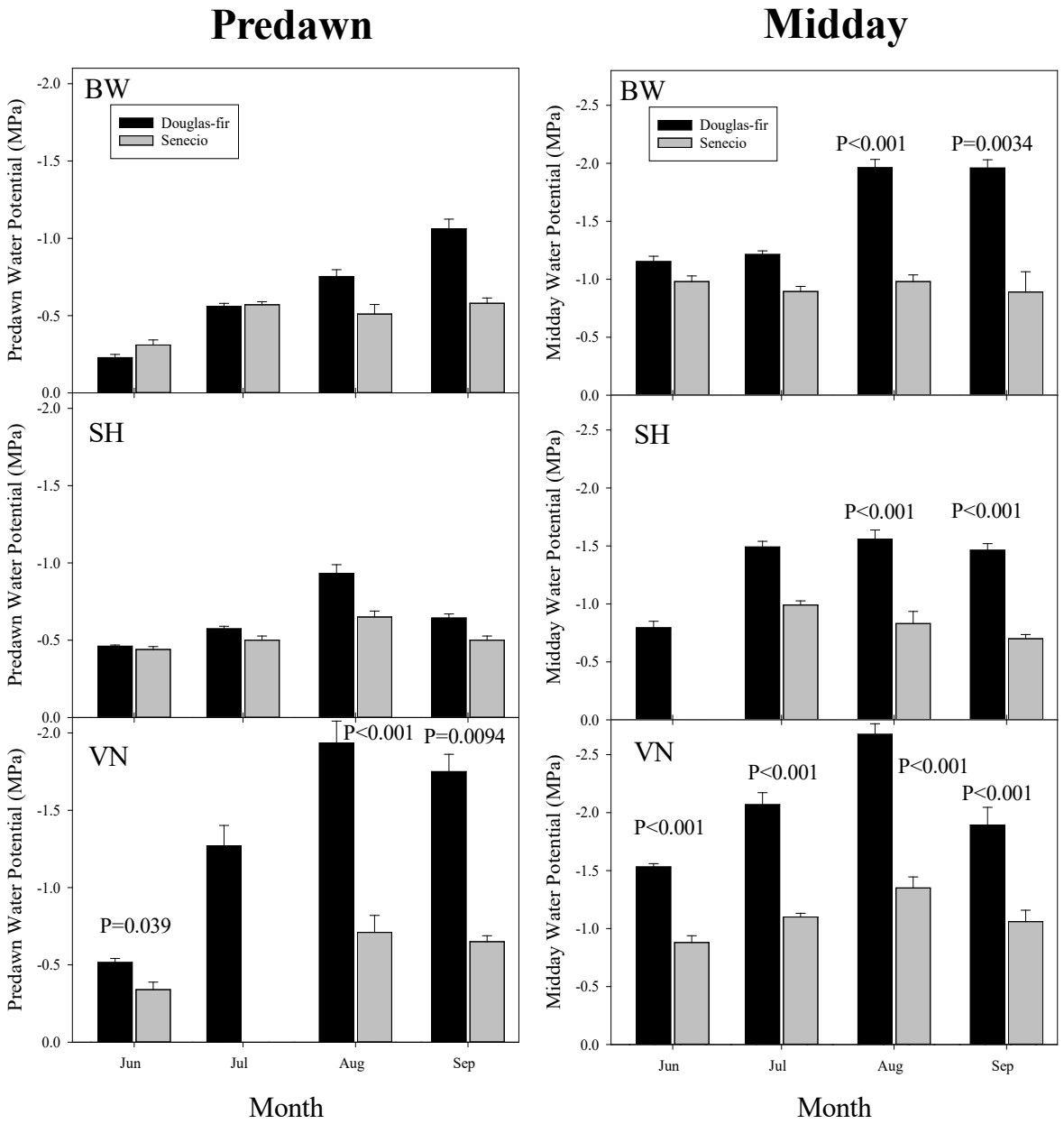
Results: Senecio and Water Depletion

- Senecio cover in July was well correlated with fractional available soil water (FASW) in August
- At the SH site the effect of Senecio abundance was stronger
- 20% Senecio cover can potentially reduce FASW down to 35% in sites like SH compared to 65% (VN and BW)



Results: Xylem Water Potential

- Pre-dawn and Midday water potential of Senecio was stable throughout the growing season
- Douglas-fir Pre-dawn and Midday water potential increased throughout the growing season
- Significant differences between species at all sites in August and September for MD

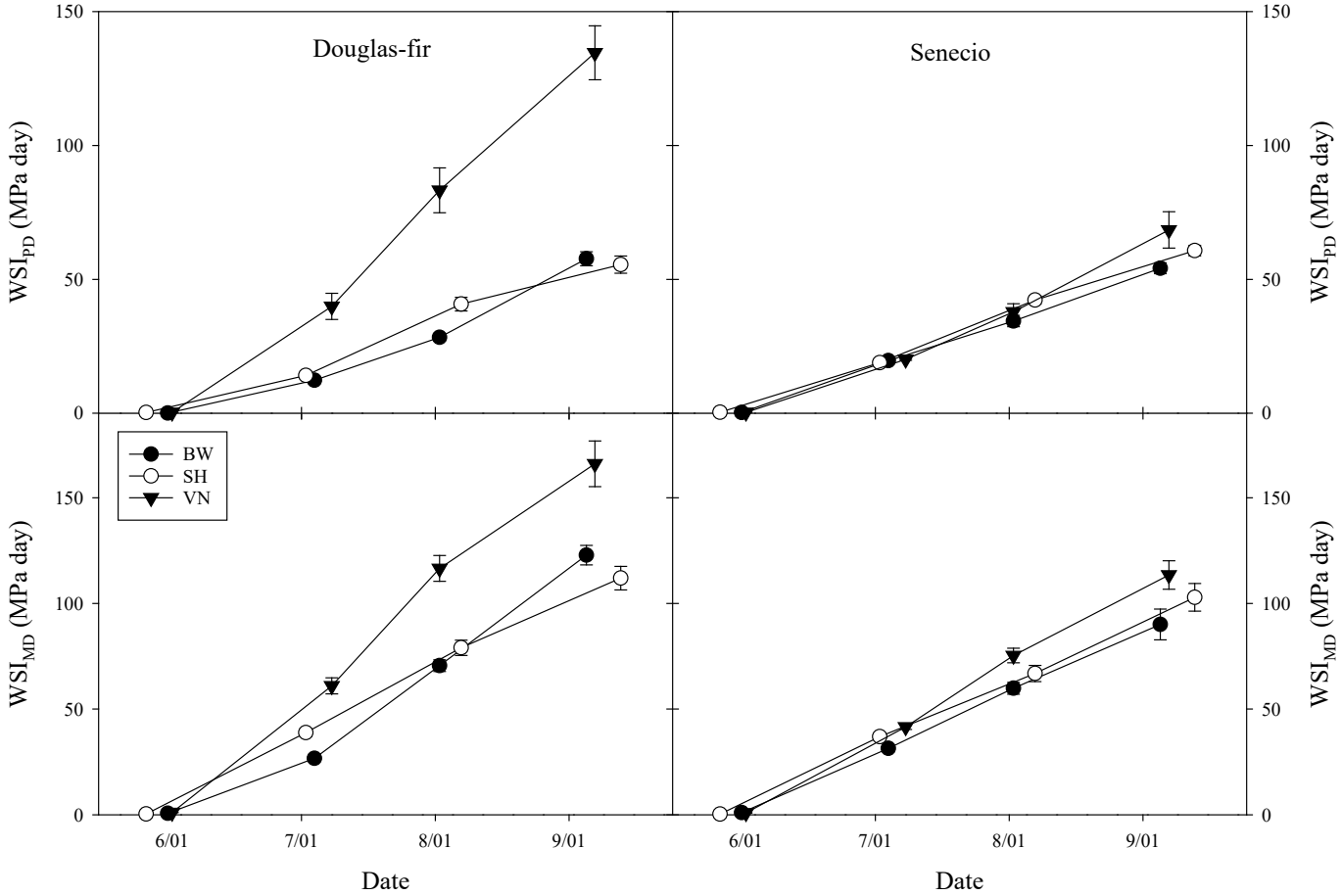


Results: Water Stress Integral

- Water Stress Integral (WSI) is the cumulative water stress during the growing season for both Douglas-fir and Senecio
- WSI_{PD} differences were significant for species by site ($P<0.0001$). WSI_{MD} differences were significant for site ($P<0.0001$) and species ($P=0.0008$), but not for species and site interaction ($P=0.19$)

Predawn WSI

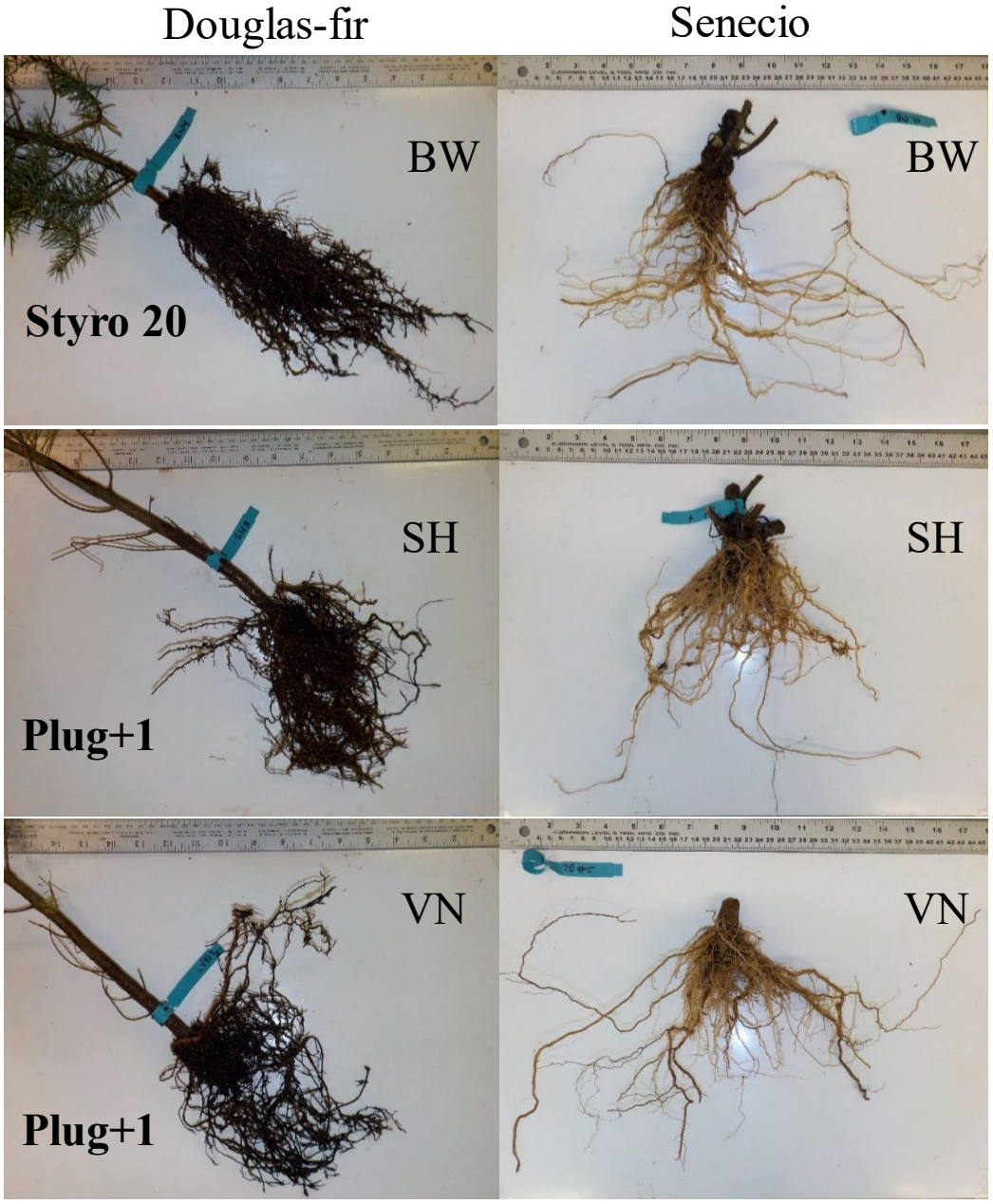
Midday WSI



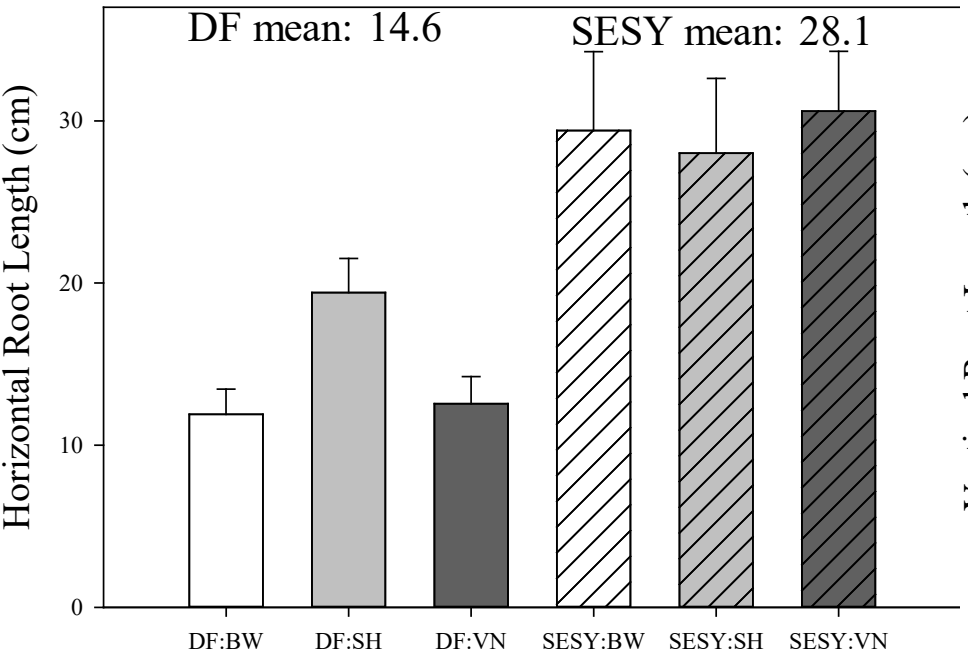
Results: Root Morphology

- Examples of root architectural forms of Senecio and Douglas-fir across sites

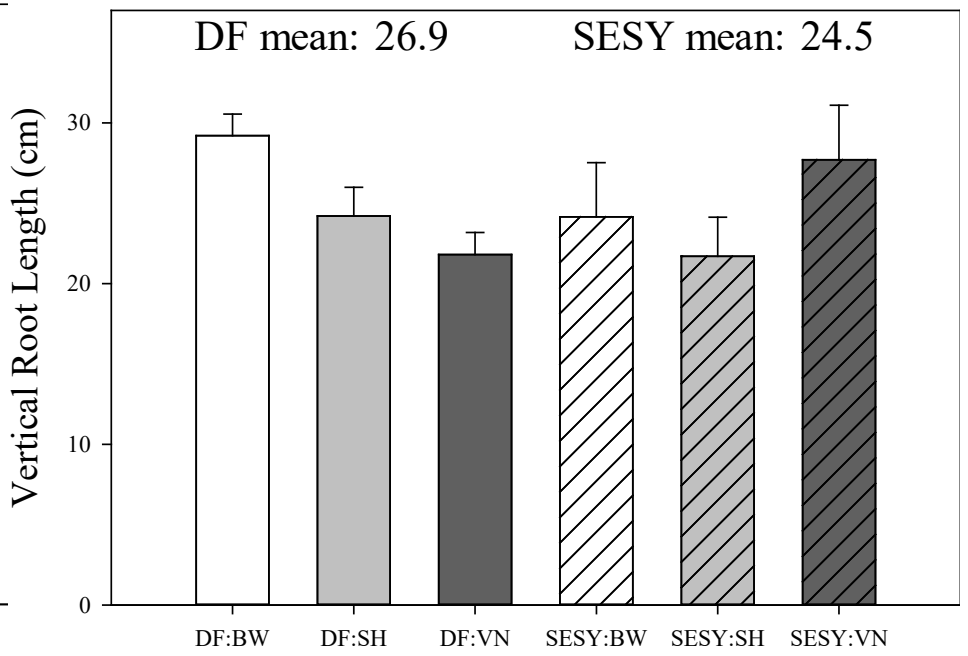
- Douglas-fir grew dense matted roots in a limited area, which increased the biomass values over Senecio, but it had about half the area of influence



Results: Species Comparison of Allometry



RHL



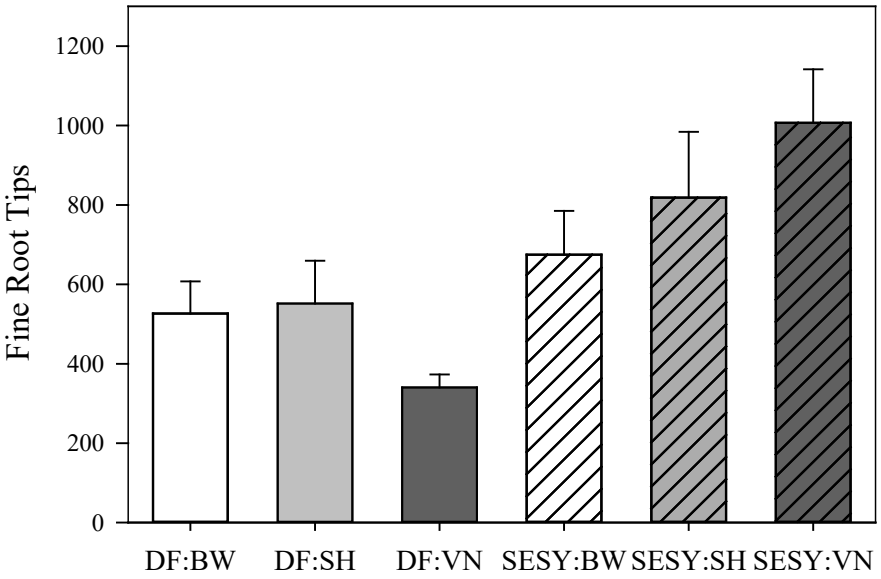
RVL

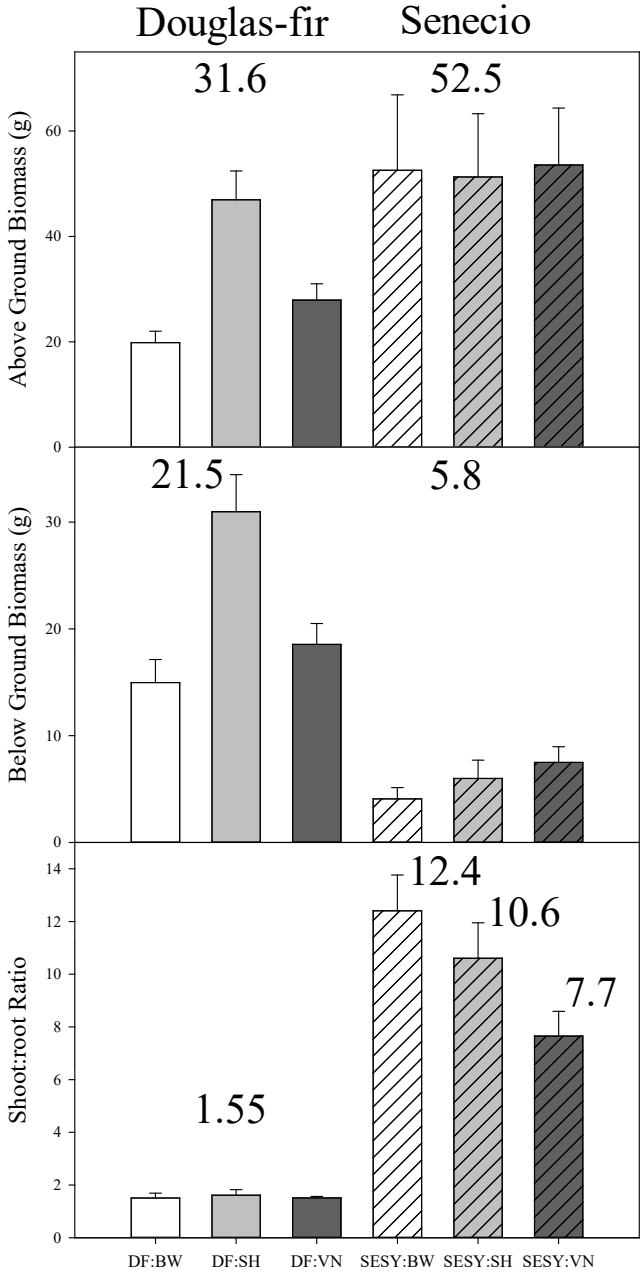
- Douglas-fir (DF) had more belowground biomass, but RHL was significantly lower than Senecio (SESY) ($P<0.0001$)
- However, RVL was not different across species or sites ($P=0.78$)

Results: Biomass and Root morphology

- Senecio shoot:root ratio was the highest at BW for the three sites. This difference was significant compared to VN (P=0.0091), and nearly so compared to SH (P=0.087)

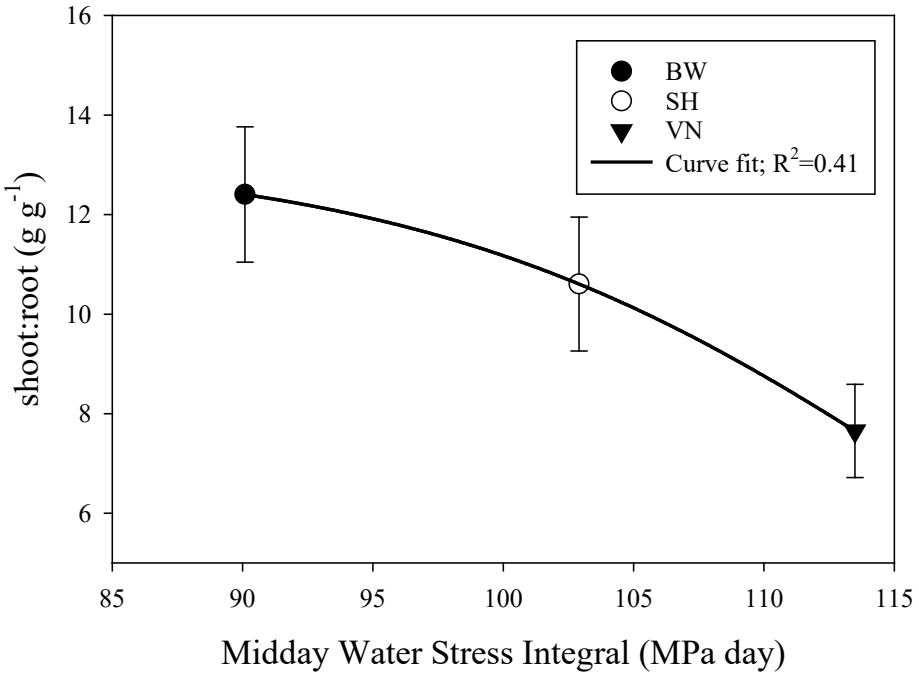
- At the VN site, Senecio had more root tips than Douglas-fir





Results: Senecio WSI Response

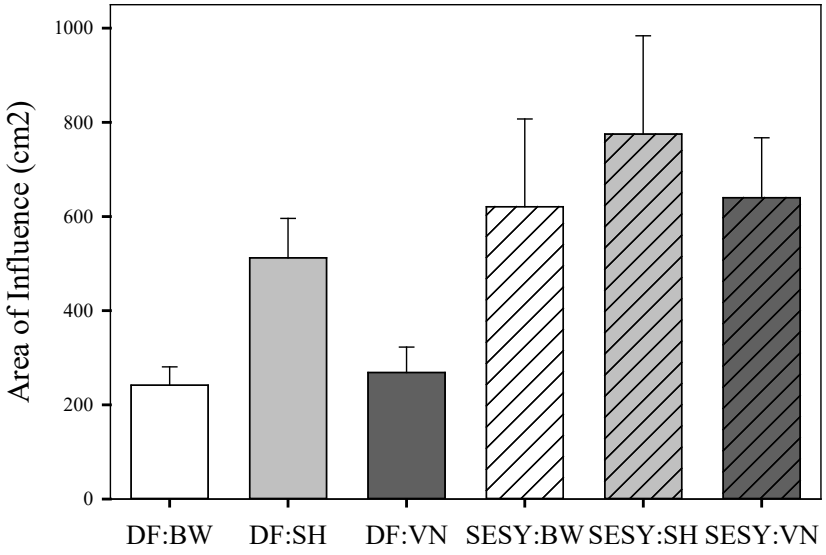
- Relationship between midday water stress integral (WSI_{MD}, MPa day) at the end of the growing season
- As WSI_{MD} increases (greater water stress), shoot to root ratio decreases (more allocation to roots)
- Senecio has greater phenotypic plasticity, which preferentially allocates biomass to the limiting resource
    - Senecio shoot:root ratio is much greater (12.5 for BW, 11 for SH, and 8 for VN) than for Douglas-fir, whose ratios were similar across sites: 1.51 – 1.62

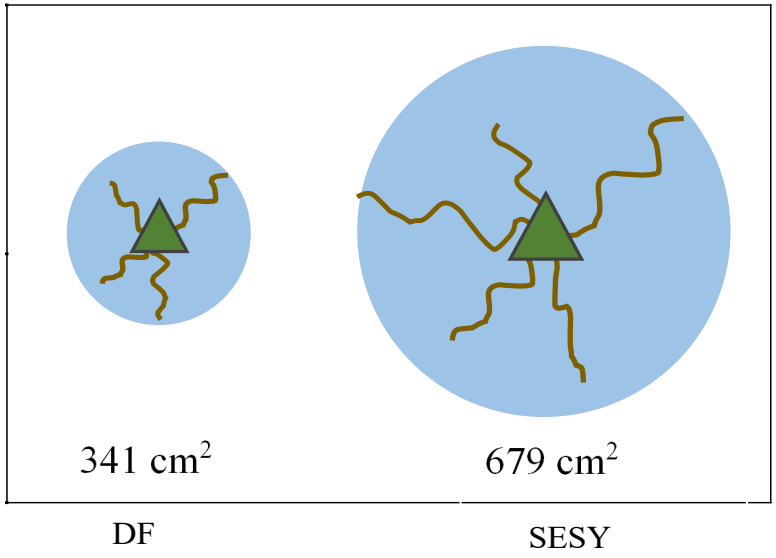


Results: Species Comparison of Allometry

- Scaled representation of the amount of planar area occupied by the different species across sites

- Senecio individuals across all sites had approximately 2 times the area occupied per individual Douglas-fir ($P<0.0001$)





Conclusions

- Senecio **aggressively invaded all** of the study **sites**.

- However, the degree of **Senecio impact differed across sites**, depending on characteristics such as water holding capacity, amount of rainfall, and atmospheric conditions.

- Although Senecio phenotype differed across sites, there was a **strong relationship between Senecio Cover x Height and ground-area biomass shared for all sites**.

Conclusions

- Soil moisture probes surrounded by **higher levels of Senecio had more rapid reductions in soil moisture**.

- As Senecio depleted sites of water, **cumulative water stress (WSI) of Douglas-fir increased, especially at the dry site** (VN).

- **Senecio water potential was stable throughout the growing season**, but Douglas-fir water potential became more negative over time.

Conclusions

- **Senecio showed more plasticity in biomass allocation**, while Douglas-fir showed no differences (perhaps due to effect of seedling size and morphology from nursery environment).

- These allocation prioritizations resulted in **Senecio having a greater root zone of influence** per individual.

    - The density of inhabitation was also much higher for Senecio than for Douglas-fir.

Management Implications

- FVM for Senecio necessitates management decisions based on site conditions (site specific silviculture).
- Not all competition is the same:
  - Differences between and within species, as well as types of vegetation.
  - SR after a FSP will have positive effects on seedling growth and survival in sites with high water deficit during summer.
    - Prioritize SR in those sites that are at-risk.
- The data from this experiment will be used, together with other VMRC studies, to create a Senecio-specific water use model.

Thanks!

ACKNOWLEDGEMENTS

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