Winter-annual legume cover crop performance in Upper Midwest organic high tunnels

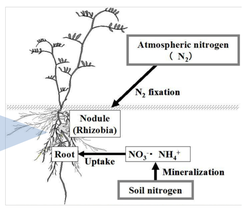
Charlotte Thurston[1], Julie Grossman[1], Anne Pfeiffer[1], Andrew Bernhardt[2], Timothy Page[3], Cherry Flowers[3], Rodrigo Cala[4] , Janssen Hang[5], Mark Zumwinkle[5], Lindsey Miller[1]
[1]University of Minnesota Twin Cities, Department of Horticultural Science, [2]The Good Acre, [3]Page and Flowers Farm, [4]Cala Farm, [5]Hmong American Farmers Association

Introduction

High tunnel under snow in January 2018 at HAFA Farm

- High tunnels are a widely used season extension tool for Upper Midwest organic farms
- Intensive cultivation can lead to soil health degradation
- Cover crops can be grown during winter and **provide soil health benefits** to organic high tunnels
- Winter-annual legume cover crops can also supply **nitrogen fertility** through **Symbiotic Nitrogen Fixation (SNF)** in partnership with soil bacteria
- However, extreme daily temperature fluctuation during winter may reduce legume cover crop cold hardiness and SNF, lowering nitrogen provision and plant survival

The process of N uptake from soil and N fixation from atmospheric N through SNF (Sato et al, 2014).



Objectives

Investigate legume cover crop vigor and SNF during the winter annual season in high tunnels, with specific objectives to:

1. Compare four legume cover crop species for survival and biomass at seasonal time-points
2. Compare four cover crop mixes for spring biomass production
3. Quantify nodulation at seasonal time-points
4. Quantify SNF at these same time-points

Methods

Cover crop treatments

Monocultures

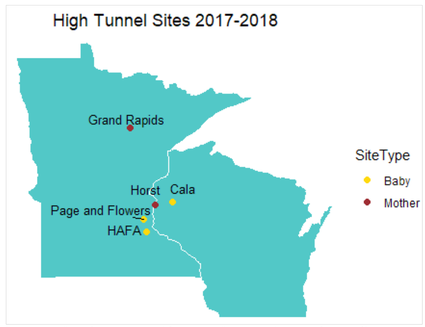
Crimson clover, *Trifolium incarnatum*
Seeding Rate: 12 lbs/ac

Red clover, *Trifolium pratense*)
Seeding rate: 25 lbs/ac

Mixes

Winter pea, *Pisum sativum* + winter rye, *Secale cereale*
Seeding Rate: 37.5 lbs/ac (each species)

Hairy vetch, *Vicia villosa* + winter rye + tillage radish, *Raphanus sativus*
Seeding Rate: 75 lbs/ac (pre-combined mix)



Mother-Baby design, replicated mother sites for analysis, un-replicated baby sites for demonstration and education

Data Collected

Field

- Legume biomass
- Nodule number, and pink nodule occurrence
- Nodule mass
- Air temperature
- Soil nitrogen
- Final biomass

Lab

- SNF: % Nitrogen derived from the atmosphere (Ndfa)

Cover crops mowed and incorporated

Late Aug/Early Sept- Cover crops broadcast and raked in

Water lines shut off, Row covers put on

Early establishment

Sampling Time-point 1 Late Fall

Sampling 2 Winter

Sampling 3 Early Spring

Sampling 4 Termination

September | November | January | March | April/May

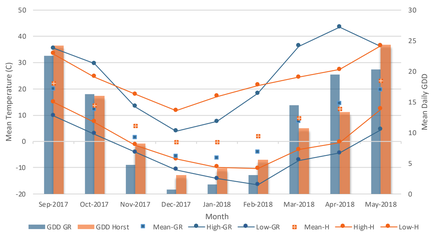
High tunnel cover crops over the winter-annual season at Grand Rapids, Minnesota

Results

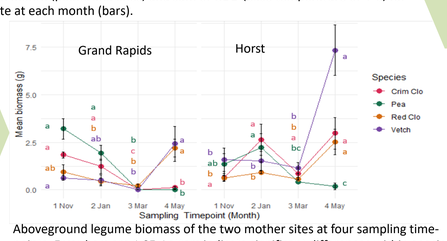
Biomass

- Legume biomass overall greater in fall and late spring than winter
- Differed by site and species
- Hairy vetch and red clover most winter hardy, Austrian winter pea the least

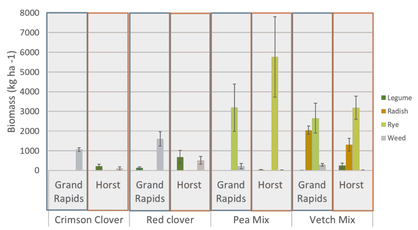
- Mixes = Monocultures
- In mixes, rye biomass crowded out legumes
- Weeds abundant in monocultures, but were never the dominant species



Average daily minimum, mean, and maximum temperatures (°C) at mother sites for each month (points and lines) and sum of GDD (base temperature of 4°C) for each site at each month (bars).



Aboveground legume biomass of the two mother sites at four sampling time-points. Error bars are 1 SE. Letters indicate significant differences within species and site, means were separated by Tukey's HSD, α = 0.05.



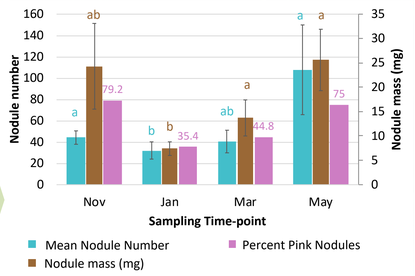
Biomass of cover crop species and weeds the time of termination. Error bars are 1 SE of the mean.

Temperature

- Temperature fluctuation greatest in spring
- Horst warmer than Grand Rapids, Grand Rapids had larger diurnal temperature fluctuations
- Heat accumulation, in Growing Degree Days (GDD) was greatest in fall and spring

Nodulation

- Nodule number and mass reduced in winter, yet both recovered in spring
- Pink nodules observed at all sampling times

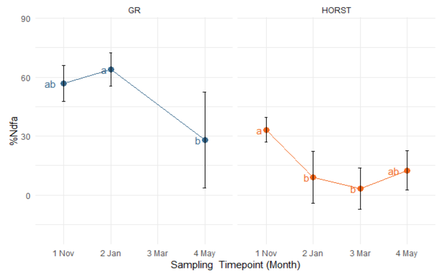


Nodule number, mass and percent of plots with pink nodules at both sites for four sampling times. Letters indicate significant differences among bars of the same color, means separated by Tukey's HSD.

SNF and Soil N

- SNF decreased over the winter, did not surpass fall levels by May termination
- Horst overall lower SNF than than Grand Rapids
- Soil N greater at Horst than Grand Rapids, leading to overall lower SNF

Site	NO3 (mg/kg)
Grand Rapids	11.8
Horst	178.7



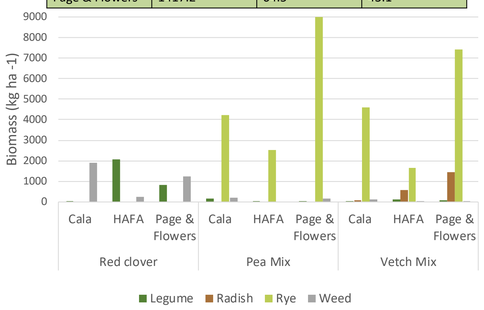
SNF measured by % Ndfa at each sampling time. Sampling TP 3 was omitted from the Grand Rapids analysis due to high plant mortality. Error bars are 1 SE. Means sharing a letter within site are not significantly different, means were separated by Tukey's HSD, α = 0.05.

- Soil Nitrate at Horst and Grand Rapids, from baseline soil tests

Baby Sites

- Cover crop stands were robust at the three baby sites by termination.
- Cala cover crops germinated in spring → lower %Ndfa, fewer accumulated GDD
- HAFA had greatest %Ndfa, but Page and Flowers had greater final biomass overall.

SITE	Total GDD	%Ndfa (SNF)	Soil Nitrate
Cala	720.0	8.8	21.3
HAFA	2153.9	80.9	11.0
Page & Flowers	1417.2	64.5	43.1



Cala

HAFA

Page and Flowers

Conclusions

- Legumes fix nitrogen in high tunnels throughout the winter season
- Active period of cover crop growth and nodulation extends late into the fall and begins early in the spring in high tunnels
- Temperature fluctuations in high tunnel environments may have delayed recovery of SNF and, in some species, biomass
- SNF differences between mother sites was likely due to high initial soil N content at Horst
- Slow spring recovery of SNF suggests farmers should delay termination to increase legume nitrogen contributions

Summary: legume cover crops may be successfully overwintered in high tunnels in the Upper Midwest in mono-cultures or mixes. Depending on high tunnel conditions, they can accumulate N through SNF through most of the winter and serve as a green manure for farmers in the spring

Hairy vetch in bloom in May at Horst farm in Osceola, WI.

Acknowledgements

This project was funded through NCSARE grant ONC17-029 and the Horst-Rechelbacher Estate.
Farmer collaborators were Rodrigo Cala, Timothy Page and Cherry Flowers, and staff at the Hmong American Farmer's Association (HAFA).
Research sites were graciously provided by Grand Rapids NCROC and the Horst-Rechelbacher Farm.
Support was provided by The Good Acre, Grossman Lab undergraduate and graduate students, and other members of the UMN Department of Horticultural Science.

Red Clover in bloom at termination.

Contact thurs058@umn.edu or jgross@umn.edu with questions or comments.