Tips for Improving Winter Greens Production and Storage for Cold Climate Farmers

Funded by Western SARE and Montana State University

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Improving Winter Greens Production and Storage for Cold Climate Farmers was a three year project designed to provide Northern US growers with profitable solutions to winter production challenges. Western Montana and regions with similar plant hardiness zones currently face limited options for fresh produce in the winter months. Greens available in our stores and restaurants have traveled many miles and many days, resulting in low quality food with no economic benefit to the local community. On the other side of the equation, most vegetable producers in Montana have the infrastructure but lack the knowledge and technology necessary to successfully grow year-round, and their businesses suffer seasonal gaps in farm income starting soon after field crops freeze.

Focus of Research:

- Frost Protection Layers
- Cold Conditioning of Winter Greens
- Storage Conditions and Duration

Missoula Grain and Vegetable Co. is a farmer-owned business based in Montana's Bitterroot Valley. They serve over 400 CSA members year-round in Hamilton, Helena, Kalispell, Missoula, and Stevensville.

Technology to Improve Efficiency, Inform Improvements, and Improve Crop Storage and Growing Conditions:
Unpredictable temperature swings can drastically impact crop survival and productivity within winter growing structures and underneath row cover. A weather station and a remote temperature monitoring system with multiple wireless sensors were key in informing decisions and observations throughout this project, and in terms of improving success for winter crop production.

Weather Station	**Monnit Remote Monitoring System**
Wireless	Multiple wireless sensors
Real-time updates to app and console	Real-time updates to app and web portal
Data Collection	Alert System
Pertinent Metrics: ● Outdoor Temperature ● Wind Speed ● Wind Direction	Pertinent Metrics: ● Temperature
	Locations: ● High tunnels ○ Under row cover ○ Above row cover ● Caterpillar tunnels ● Greenhouse ● Low tunnels ● Cooler Storage Spaces ● Dry Storage Spaces

These two pieces of technology informed decisions on:

- Tunnel side venting
- Tunnel peak venting
- Identifying and addressing leak-points on tunnel structures and temperature controlled storage spaces
- Row cover layering, application, and removal
- Optimum temperature alert levels for tunnel structures and temperature controlled storage spaces

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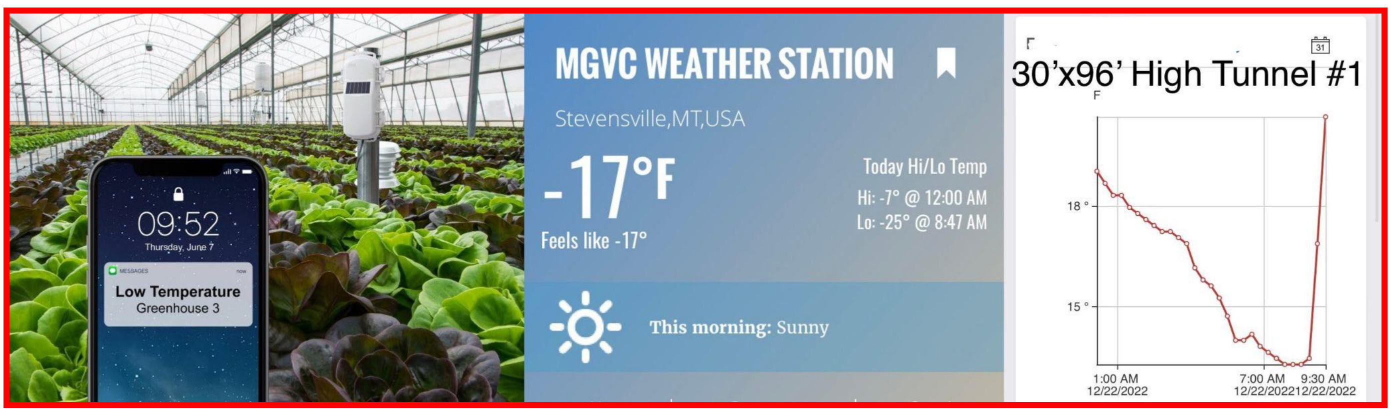
Key Examples of Improved Efficiency:

- Prior to the Monnit wireless sensors in tunnels:
    - Time consuming in-person observation and non-wireless sensors to check temperatures and when crops were ready to harvest in the high tunnels
    - Guessing when greens would be thawed and warmed enough to harvest, time spent checking crops in tunnels and the non-wireless sensors, as well as local weather from NOAA site, which proved to too inaccurate
    - After the sensors:
        - Pinpoint temperature at which greens are fully thawed and ready to harvest
            - Temperature alert set for this point in tunnels
                - Harvesters could be informed on when to start harvesting, can better spend their time prior to this with other work

        - Pinpoint temperature at which row covers would begin to freeze
            - Temperature alerts for when to begin row covering tunnel crops at the end of the day
                - If row cover freezes before being re-applied it will freeze together and be more time consuming to pull apart and spread across crops in tunnels
                - Alternatively, if covers are applied too early, then harvest time, crop sun exposure, airflow exposure are decreased. These are especially critical points to maximize when winter growing in unheated tunnels
- Prior to the Monnit wireless sensors in temperature controlled storage spaces:
    - Time consuming in-person observation and non-wireless sensors to check temperatures
        - Important during cold periods of single digits or lower when these spaces may be in danger of freezing and required more frequent monitoring and/or preemptively turning on heaters, which increased costs
    - After sensors:
        - Alerts for these spaces to turn on heaters or trigger them to turn on
        - Less time spent checking, especially in middle of night, and less energy costs
- Temperature alerts via Monnit, and Wind Speed and Outdoor Temperature via the Weather Station
    - Informed a protocol for opening and closing side vents and peak vents on tunnels
        - Improved crop growing conditions in tunnels, which improved crop quality

- Faster harvesting, which is critical in winter production in unheated high tunnels due to harvest windows that are short and at times unpredictable
- Improved storage life of harvested winter crops,
    - Improves washing and packing speed of product
    - Improves/Maintains customer satisfaction

Comparing outdoor temperatures to greenhouse temperatures:
The graphic below shows just how dramatic the difference a structure can make. Aided by insulatory 3” snow-buildup on the sides of a 30’x96’ high tunnel, *Monnit* sensors recorded a low temperature of 13 degrees fahrenheit. That same night, a SARE-funded weather station placed outdoors recorded the lowest temperature at -25 degrees fahrenheit. This allowed for a key observation, that when snow is built up around a tunnel when low temperatures hit, it has a sealing effect. This allows for a more gradual temperature drop and greater temperature differential between indoor and outdoor temperatures, which leads to less plant stress. Granted, the sensor inside the greenhouse was under two layers of GG-40 row cover manufactured by Atmore Industries.



These key pieces of technology significantly minimized plant stress and increased crop quality, prevented errors and decreased chance of crop loss in tunnels and storage,

All these technologies are easy to install and maintain, and pay for themselves through better plant yields due to timely and informed actions based on temperature and weather data and alerts, and lowered labor costs. Technology used in this project also greatly impacted the peace of mind of the farmer managers/owners and farm workers, which is invaluable in a challenging industry and in a challenging climate.

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CROP SELECTION FOR WINTER PRODUCTION			
Crop Species	**Recommended Varieties**	**Winter Hardiness**	**Notes**
Baby Kale	'Wild Garden Kale Mix'	Good	-Great overwintering harvest candidate. -Great November harvesting potential. -Multiple winter storm events of single digit and negative outdoor temps (in both caterpillars and high tunnels) produced tremendous leaf damage. Plants survived, but harvesting time increased. -Baby Kale is a very light-weighted green. So it's hard to justify growing especially when labor costs are high. It's not profitable unless price per pound reaches well above $12/pound.
Spinach	We recommend most slow-growing varieties trialed ('Red Kitten', 'Tundra', 'Lizard') & some fast-growing varieties ('Flamingo Improved')	Excellent	-Reliable production in both caterpillar and high tunnels. -Can be very susceptible to disease and rodent predation, so implementing pest management plans are key to reducing risk and profitable production. -Great in refrigerated storage (3-5 weeks) if harvest temps are low. 'Lizard' seems to degrade quicker than other varieties trialed.
Mustards	'Green Wave' & 'Dragon'	Poor	-Worst storage in cooler (0-2 weeks)
Claytonia	We used both standard varieties from Johnnys and High Mowing seed companies.	Excellent	-Great yield/bed foot. -Great survivability. -Successful storage in cooler for 3 weeks -Claytonia seed seems to be wrought with chickweed seed

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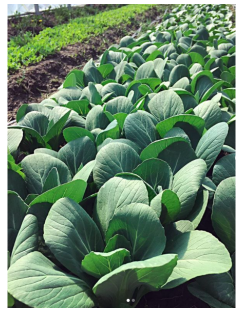

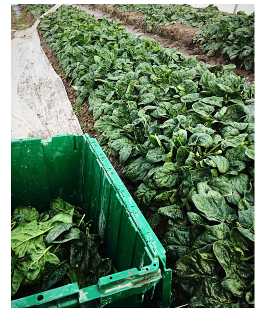

Key Findings for Winter Crop Production in Unheated Tunnels

- Different structures require slightly different seeding dates for maximum production and minimal crop loss.
    - Seeding in the field and building a temporary caterpillar tunnel allows for earlier seedings (2-3 weeks earlier) because the heat units don't create the conditions for quick growth in October and November. This allows for better cold conditioning of crops before they are covered with a tunnel structure
    - Tunnel seedings need to be delayed so leaves don't get too big too fast, which increases susceptibility to hard frosts.
- Some plant species (mustards, brassicas, and many lettuces) are too frail for reliable winter production in our climate, regardless of whether they're grown in high tunnels or caterpillars.
    - It's not that they don't produce food; it's that the time it takes to harvest makes growing and protecting these greens unprofitable compared to other greens like green spinach, red spinach, chard, kale, claytonia.
    - A winter production farm only has so much time to harvest during thawed windows of time. This scarcity informed a study design change between the winters of 2019-2020 and 2021-2022. Our data collection scope shrunk so that we could answer questions related to different spinach varieties seeded at different time periods in these different structures.
- Mustards grown in high tunnels and caterpillar tunnels were far less productive than spinach unless these mustards were harvested before single digit outdoor temps (typically before December).
- Spinach yielded best (.150-.158 pounds per foot) when the following criterion was met:
    - Seeded at the optimal periods for their given structure (high tunnel or caterpillar tunnel)
    - When outdoor temps dropped into the teens and single digits, spinach only under 1 layer of row cover
        - Additional row covers on spinach when outdoor temps are in teens or single digits led to lower yield and increased probability of damage due excess moisture and disease
    - Covered with additional row covers if outdoor temps were in the negatives
    - Minimal/no eating damage from voles, mice, shrews, and pocket gophers

- Yield of spinach seeded too early and minimally protected (0.06lbs/row ft) appeared just as unproductive as highly protected spinach that was impacted by rodents (.02lbs/row ft).

Key Findings for Winter Greens Crop Storage

- **Qualitative Farmer Observations**
  - No spinach from samples harvested on 1/26 and stored through 3/2 was discarded after this long-term storage. It was all deemed high-quality visually after this storage period. There were no signs of yellowing or dehydrations.
  - When harvested and handled at optimum conditions, see list below, spinach was able to be stored with minimal yield loss for up to 1 month before sale to end customer
    - Between 40-60 degrees without intense direct sunlight in tunnels,
    - Prompt transfer to cooler storage,
    - Maintaining humidity of harvest container in storage by applying cool water between harvest and cooler storage entry,
- **Lab Nutritional Sample Findings**
  - For future samples, we recommend using NP analytical for nutritional testing. They are willing to measure time-sensitive samples the morning after overnight shipping.
  - Vit C and folate dropped significantly which our consultant, Wan-Yuan Kuo, said was to be expected. She said just 15 days can drop Vit C, so the 6 day delay in shipping and awaiting analysis at the lab might already have dropped vit C levels
  - Vit A seemed to increase slightly, which may be due to moisture loss or postharvest biochemical synthesis
  - Vit K did not seem to drop significantly. And, unlike the other nutrients, the results of Vitamin K did not draw a comment from Wan-Yuan Kuo, Ph.D

Please contact us with any questions or comments at farmers@missoulagrainandvegetable.com
Our farm is always changing based on learning and observations and our current practices may differ from this handout as a result.

See our short video on the research project here, which includes key findings:
https://www.youtube.com/watch?v=VwCZ9geEc1o

This project is researching cost-effective methods of high tunnel ventilation, efficient passive solar heating, passive frost protection measures, optimal storage practices, and high-yielding and cold-hardy greens varieties. We are experimenting with passive solar frost protection within high tunnels and mobile caterpillar tunnels, employing temperature sensors and a weather station to track conditions. We are also exploring ways to make winter-produced greens crops last longer in storage including tracking different harvest methods and washing procedures for kale and spinach. Winter greens from Missoula Grain and Vegetable Co. will be compared with store-bought alternatives through nutrient testing of leaf tissue. Records of labor and input costs will help growers make low-risk business decisions in regards to winter growing techniques and infrastructure.



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