Cornell Cooperative Extension
Eastern NY Commercial Horticulture Program

HUDSON VALLEY FARM HUB

Mitigating the Abiotic Disorder Tip Burn in Overwintered Spinach

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2023-24 Annual Report

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Summary

Over two growing seasons, Cornell Cooperative Extension vegetable specialists Teresa Rusinek and Ethan Grundberg conducted field trials investigating potential solutions to reduce the incidence of tip burn in overwintered high tunnel spinach grown at the Hudson Valley Farm Hub (HVFH). The 2023 trial evaluated the potential impact of foliar calcium (Ca) applications on tip burn severity. In that trial, foliar Ca applications did not have a significant effect on tip burn. The 2024 research focused on two other cultural practices intended to increase Ca availability and uptake: 1) raising the level of soil available Ca by amending treatment plots with gypsum (calcium sulfate dihydrate) before planting and 2) maintaining higher soil moisture levels based on an established threshold measured with buried soil moisture sensors. Leaf samples were sent to Waters Ag Lab for nutrient analysis while tip burn incidence, yield, and crop quality data was collected over four harvests.

Key Research Findings from the 2022-23 Trial

- Ca foliar applications did not significantly impact the occurrence of tip burn in the trial
- There was a significant effect of spinach cultivar on tip burn severity. At HVFH, 'Space' had significantly more tip burn across all the harvest evaluations than 'Flamingo.' However, data collected from a replicated trial in Wilsboro, NY found the opposite trend in the effect of cultivar on tip burn severity. More information is needed on the environmental conditions and harvest practices that may impact the interaction between tip burn severity and variety.

Key Research Findings from the 2023-24 Trial

- Higher soil moisture content and pre-plant gypsum amendment resulted in a numeric increase in spinach foliar Ca concentration, though the differences were not statistically significant.
- There was a trend toward decreased tip burn incidence (as a percent of the total harvest) in plots where higher soil moisture was maintained and gypsum was applied before planting. These differences were not, however, statistically significant.
- There was a numeric trend toward higher total yield in treatments receiving extra irrigation.

I. Background

Leafy greens such as spinach often develop a condition known as tip burn during winter production in high tunnels. Tip burn is an abiotic disorder caused by inadequate transport of calcium to growing plant tissue at leaf margins. Affected tissue collapses and eventually becomes necrotic or "burned" looking. Tip burn on baby lettuces and other leafy greens both reduce the crop's shelf-life post-harvest and, even if minor, can make them unsellable.

Calcium is not mobile within plants; instead, it is passively carried through the plant vascular system along with water that is drawn through the plant by the process of transpiration. Stomata on leaf surfaces open to take in carbon dioxide for photosynthesis, releasing water in the process. Transpiration drives water movement up to new growth points on plants and, in so doing, carries calcium to rapidly growing leaves to reinforce cell walls. Spinach transplants growing in a cool greenhouse at high relative

humidity and low light levels transpire slowly and, as a result, don't move calcium to leaf margins effectively. When temperatures rise and light intensity increases in late winter, plants grow and transpire quickly, but can't immediately supply the calcium demand at growth points which results in tip burn that can be quickly colonized by secondary foliar pathogens such as *Anthracnose*.

Teresa Rusinek and Ethan Grundberg, vegetable specialists with Cornell Cooperative Extension's Eastern NY Commercial Horticulture Program, designed research trials to evaluate the potential of different cultural practices to reduce the incidence of tip burn in overwintered high tunnel spinach. The first two seasons of their research were focused on the following:

2022-2023-Foliar Ca fertilizer applications are often promoted to growers by industry professionals to manage this and other calcium deficiency disorders (i.e. bitter pit in apples, blossom end rot in solanaceous crops); however, the benefits of these applications have been inconsistent in research trials. Furthermore, there are multiple types of foliar Ca fertilizer formulations, including those containing calcium chloride and calcium carbonate, with claims of being more readily absorbed by plant tissue. In addition, some cultivars appear to be more susceptible to tip burn than others, but winter production variety trials have also yielded conflicting results. The research evaluated the effect of two different commercially available OMRI-listed foliar calcium fertilizers on tip burn and Ca concentration in leaf tissue. There were numeric trends toward higher yield in plots where foliar Ca fertilizers were applied, but the effects on tip burn incidence were not statistically significant.

2023-2024 HVFH Greenhouse 3 soil samples collected and analyzed by Saturated Media Extract analysis at the University of Maine soil testing lab the first week of October 2023 indicated low soluble calcium ($Ca2^{+}$) levels at 26 PPM indicated levels below the optimal range of > 250 PPM. Gypsum (CaSO4) is a fertilizer product that supplies the crop-available form of calcium or $Ca2^{+}$. Gypsum has higher Ca solubility than limestone (CaCO3) and will not raise soil pH, therefore it is a preferred material to supply $Ca2^{+}$. In addition to studying whether the addition of gypsum can help mitigate tip burn in overwintered high tunnel spinach, the research will also explore the potential interaction between gypsum amendment and irrigation practices. Maintaining higher soil moisture throughout the production period compared to the grower standard irrigation schedule should ensure that the Ca in the soil is available for plant uptake.

II. Materials and Methods

Trial Design

The trial was hosted by the Hudson Valley Farm Hub (HVFH) in Hurley, NY (41.918901, -74.082975). The researchers used a small plot randomized complete block design with four replicates and four treatments. Each plot was 8' long by 5' wide consisting of eight rows of transplanted spinach with a 2' buffer between plots. The variety 'Space' was selected as it had been observed to have the most severe tip burn of the varieties previously grown at HVFH in 2022-2023 trial. Two treatments were planted into plots that were amended with gypsum at a rate of 3 lbs. per 40 ft^2 (intended to raise soil $Ca2^{+}$ levels to the optimal level of > 250 PPM based on the U Maine SME test results and recommendations). The

other two treatments were planted into plots that were amended only with the grower standard fertilizer, but not with additional gypsum. One of the gypsum-amended treatments and one of the unamended treatments were each irrigated more frequently to maintain higher soil moisture throughout the production period. See below for additional product information and rates. The four treatments are detailed in the table below.

Treatment	Gypsum	Irrigation
1- Grower Standard	None	Standard irrigation
2- High soil moisture	None	Supplemental trickle irrigation
3 -High gypsum	3 lbs/40 ft^2	Standard irrigation
4- High gypsum and moisture	3 lbs/40 ft^2	Supplemental trickle irrigation

Gypsum application

Gypsum was weighed using an Ohaus Catapult 1000 compact bench scale with 0.02 lb. resolution broadcast by hand into the plots to be planted with treatments 3 and 4 on October 18, 2023 after beds had been formed and amended with the grower standard fertilizer program. The gypsum was lightly incorporated into the beds using a hard rake after application.

High tunnel trial establishment

Spinach was seeded on September 15, 2023 in 72 cell trays at a rate of three to four seeds per cell in the HVFH greenhouse and transplanted into High Tunnel 3 on October 19, 2023. Plugs were planted at six-inch in-row spacing with six-inches between rows, eight total rows per bed. There was no supplemental heat in the high tunnel.

Irrigation and soil moisture monitoring

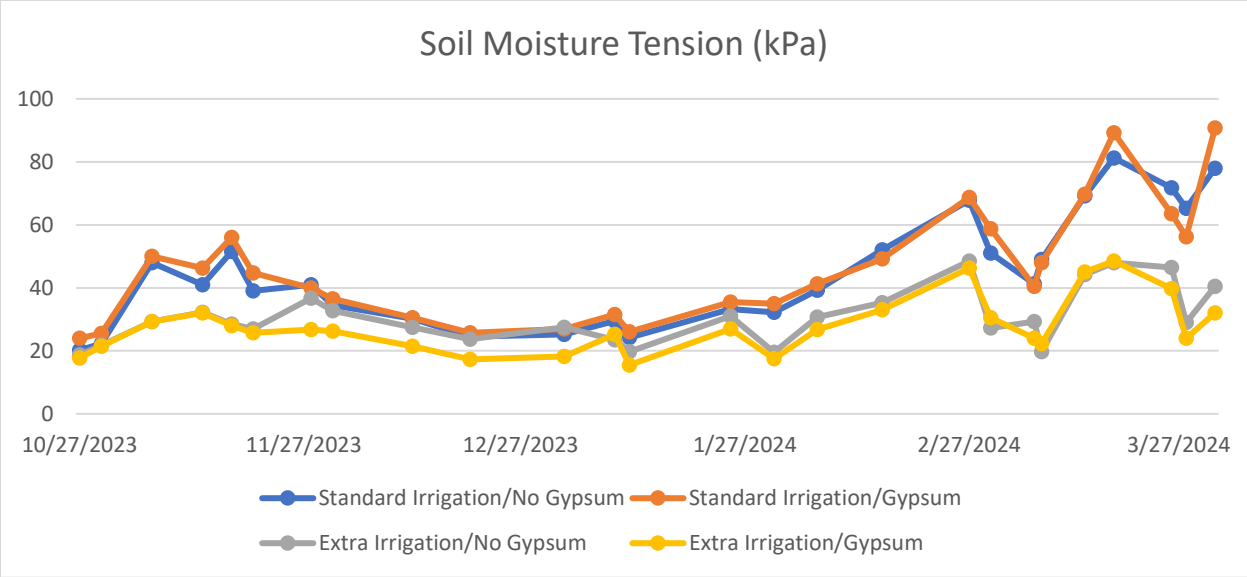
A trickle irrigation system was designed so that each plot could be irrigated independently of the others. 4 lines of drip tape were run between 8 rows of spinach planted in the plot. A header with quarter turn shutoff valves ran across the end of each plot. All plots were irrigated immediately after transplanting.

Based on UC Davis tensiometer guidelines for irrigation, a 35 kilopascals (kPa) threshold was established to trigger irrigation for treatments 1 and 2. A threshold of 25 kPa was used to trigger irrigation in treatments 3 and 4. Manual and remote soil moisture monitoring systems were installed in the trial using Watermark 200SS granular matrix soil moisture sensors. The sensors approximate how hard it is for the plant roots to pull water out of the soil with higher kPa readings corresponding to drier soil conditions. The soil moisture levels recorded manually can be observed in the graph below.

Manual Moisture Monitoring- 1 sensor installed in each plot at 6 “depth and left in the soil to be read with a Watermark 30KTCD-NL handheld meter.

Remote Toro Tempus System- 1 sensor installed in each plot at 6” depth wired to a relay used to connect each sensor to Toro Tempus Wi-Fi base station logging device.

Soil Moisture Readings



Harvest Evaluations and Tissue Sampling

In each plot, the central four-bedfeet of spinach were manually harvested on the dates listed in the table below. Harvested spinach was sorted as marketable, unmarketable other (insect damage or disease pressure), or unmarketable due to tip burn. Yields were measured using an Ohaus Catapult 1000 compact bench scale with 0.02 lb. resolution.

Tissue samples were collected from each plot on November 21, January 2, February 9, March 1, and March 21 and shipped to Waters Ag Lab in Warsaw, NC for foliar nutrient analysis.

III. Statistical Analysis and Results

Spinach Foliar Calcium Concentration (%) by Date and Treatment

Treatment	Irrigation	Gypsum	21-Nov	2-Jan	9-Feb	1-Mar	21-Mar	Season Mean
1	Standard	None	0.49	0.40	0.34	0.28	0.38	0.38
2	Standard	Gypsum	0.54	0.38	0.35	0.37	0.38	0.40
3	Extra	None	0.53	0.42	0.31	0.32	0.41	0.40
4	Extra	Gypsum	0.59	0.39	0.34	0.37	0.45	0.43
		P-Value	0.8958	0.8728	0.4261	0.7590	0.6099	0.9402

There was no statistically significant difference in spinach foliar Ca concentration between the treatments; however, numerically the treatment with extra irrigation and gypsum amendment had the highest Ca tissue concentration when averaged over the season.

Season-Long Mean Spinach Yield Data

Treatment	Irrigation	Gypsum	Total Yield (lbs)	Marketable Yield (lbs)	Unmarketable Yield (lbs)	Tip Burn Yield (lbs)	Tip Burn Yield (%)
1	Standard	None	3.42	2.73	0.17	0.52	15.54
2	Standard	Gypsum	3.49	2.76	0.15	0.59	15.88
3	Extra	None	3.54	2.83	0.17	0.53	15.12
4	Extra	Gypsum	3.85	3.02	0.22	0.60	13.62
		P-Value	0.6456	0.7006	0.5308	0.9831	0.5049

There was no statistically significant difference in total yield or marketable yield between the treatments when averaged over the four harvest dates. However, there was a numeric trend toward higher total yield in treatments receiving extra irrigation. Treatments 3 and 4, both of which were irrigated more frequently, averaged 6.65% more yield over the season when compared to standard irrigation spinach yields (p= 0.3622). There was a numeric trend toward lower percent tip burn yield, a decrease of 1.34% in the treatments receiving extra irrigation on average. There were no statistically significant differences in yield or tip burn on any of the individual harvest dates; those data are presented in the appendix.

IV. Discussion and Future Investigations

Extra irrigation and pre plant gypsum applications

While there are promising trends in the data suggesting that extra irrigation and gypsum applications may increase total yield and decrease tip burn severity, the lack of statistically significant differences in the tip burn severity or foliar Ca concentrations raises concern about the potential return on investment in implementing these practices. It is not clear that commercial winter spinach growers will be willing to absorb the additional labor and materials costs of these practices. Though we did not observe any disease issues in this year's trial, there is concern that increased irrigation may promote disease development, particularly when the crop is covered with row cover fabric restricting air flow and increasing humidity.

Future Research

The 2023-24 trial evaluated the potential impact of pre-plant soil amendment with gypsum (calcium sulfate dihydrate) and more frequent irrigation. Since neither the gypsum application nor the more frequent irrigation significantly reduced tip burn in the crop, the 2024-25 research will focus on increasing the Ca concentration in the plants during the greenhouse propagation process before transplant. Foliar tissue samples from spinach transplants have been submitted for nutrient analysis both in 2022-23 and 2023-24; transplants were severely Ca deficient in both years making it difficult for the plants to recover to a point of optimum Ca concentration during the production cycle. Rusinek and Grundberg will focus on improving Ca concentration in the transplant production process by amending potting media with gypsum and applying an OMRI-listed Ca foliar fertilizer in the greenhouse. Plants receiving supplemental forms of Ca in the transplant production stage will be compared to plants grown without the additional Ca. Both the untreated control and Ca amended transplants will be planted into two of the three high tunnel beds amended with gypsum and irrigated when the soil moisture sensors installed in the trial average 20 centibars. Baseline and periodic soil samples will be collected for nutrient and soil properties and shipped for analysis at the University of Maine. Tissue samples will be collected and prepared periodically and shipped to Waters Ag Lab for analysis. A harvest evaluation will be conducted when the crop reaches maturity to assess tip burn severity and yield.

The third bed will be utilized as a complimentary but separate trial to verify that the level of $Ca2^{+}$ increases to the target level of >250 ppm as a result pre-plant gypsum applications. There will be two replications and two treatments: 1) no preplant gypsum application and 2) preplant gypsum application at the rate recommended by the soil test results. Soil samples will be analyzed using the Saturated Media Extract test at the University of Maine periodically to monitor soluble Ca^{2+}.

V. Acknowledgments

This work would not be possible without the support of Jeff Arnold, Jenny Linger, Rosa Villegas, and the vegetable production team at the Hudson Valley Farm Hub.

VI. Appendix

Total yield by harvest date data

			Mean Total Yield (lbs) by Harvest Date			
Treatment	**Irrigation**	**Gypsum Amendment**	**12/12/2023**	**1/24/2024**	**3/1/2024**	**4/1/2024**
1	Standard	None	3.86	2.73	3.64	3.46
2	Standard	Gypsum	3.56	2.76	3.83	3.82
3	Extra	None	4.04	2.87	3.69	3.57
4	Extra	Gypsum	3.84	2.83	3.86	4.86
		P-Value	0.8680	0.8856	0.9854	0.2427

Unmarketable yield by harvest date data

			Mean Unmarketable (lbs) by Harvest Date			
Treatment	**Irrigation**	**Gypsum Amendment**	**12/12/2023**	**1/24/2024**	**3/1/2024**	**4/1/2024**
1	Standard	None	0.28	0.09	0.20	0.09
2	Standard	Gypsum	0.15	0.10	0.13	0.21
3	Extra	None	0.32	0.06	0.17	0.14
4	Extra	Gypsum	0.17	0.05	0.16	0.52
		P-Value	0.9062	0.7745	0.7418	0.1865

Tip burn yield by harvest date data

			Mean Tip Burn (lbs) by Harvest Date		
Treatment	**Irrigation**	**Gypsum Amendment**	**1/24/2024**	**3/1/2024**	**4/1/2024**
1	Standard	None	0.08	0.19	1.82
2	Standard	Gypsum	0.06	0.26	2.04
3	Extra	None	0.10	0.34	1.70
4	Extra	Gypsum	0.13	0.17	2.12
		P-Value	0.6417	0.11	0.6016

Tip burn percent (tip burn yield in pounds divided by total yield in pounds) by harvest date data

			Mean Tip Burn Yield (%) by Harvest Date		
Treatment	**Irrigation**	**Gypsum Amendment**	**1/24/2024**	**3/1/2024**	**4/1/2024**
1	Standard	None	2.75	5.64	53.77
2	Standard	Gypsum	2.07	7.67	53.79
3	Extra	None	3.63	9.25	47.59
4	Extra	Gypsum	4.14	4.25	46.07
		P-Value	0.6931	0.1682	0.8345