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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2022-23 Annual Report

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Summary

Cornell Cooperative Extension vegetable specialists Teresa Rusinek and Ethan Grundberg conducted a trial at the Hudson Valley Farm Hub (HVFH) to test the effectiveness of foliar calcium applications in reducing tip burn on overwintered spinach. Two types of foliar calcium (Ca) fertilizers were evaluated to determine which, if any, increased the Ca concentration in leaf tissue and/or reduced tip burn. The research was also designed to determine if there was a difference in tip burn severity between two different spinach cultivars 'Flamingo' and 'Space'. 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 of 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 of tip burn severity by variety.

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 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 exceptionally slowly and, as a result, don't move calcium to leaf margins. When temperatures warm up and light intensity increases in late winter, plants grow and transpire quickly, but can't immediately supply the calcium demand at growth points which result initially in browning along the leaf edges that eventually turn papery and can be quickly colonized by secondary foliar pathogens such as *Anthracnose*.

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 has 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.

II. Materials and Methods

Trial Design, Foliar Ca Treatments and Rates

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 five total treatments. For each Ca product, the trial design used two different application intervals- a calendar spray application every other week (Biomin Bi-weekly and EnviroCal Bi-weekly) and a targeted application based on foliar analyses when Ca levels begin approaching deficiency level (Biomin Tissue and EnviroCal Tissue). See below for additional product information and rates. Each plot was 9' long by 5' wide plots with a 3' buffer between plots. The trial was designed in split plots including two varieties of spinach, 'Space' and 'Flamingo'. 'Flamingo' was selected as it had been observed to have the most severe tip burn of the varieties previously grown at HVFH.

Treatment	Product and Rate
A	Untreated Control (UTC)
B	Biomin Calcium Tissue @ 2.85 qts or 91.2 fl oz/acre
C	Biomin Calcium Bi-weekly@ 2.85 qts or 91.2 fl oz/acre
D	EnviroCal Tissue @ 3 pints or 48 fl oz/acre + BB5 NC @ .3ml/liter spray water
E	EnviroCal Bi-weekly @ 3 pints or 48 fl oz/acre + BB5 NC @.3ml/liter spray water

NutriAg Enviro Calcium And Biomin Calcium products are both OMRI-listed liquid fertilizers for foliar, fertigation, and soil applications to supplement Ca levels on agricultural crops.

EnviroCal is manufactured by NutriAg. It contains 8.1% Ca weight/volume and is derived from calcium chloride. BB5-NC is an OMRI-listed phosphoric acid-based adjuvant and water conditioner manufactured by NutriAg that is recommended for co-application with Enviro Calcium.

Biomin Calcium is manufactured by JH Biotech. It contains 5% Ca and 1% water soluble Nitrogen weight/volume and is derived from calcium carbonate and hydrolyzed vegetable protein.

High tunnel trial establishment

Spinach was seeded on September 12, 2022 in 72 cell trays at a rate of three to four seeds per cell in the HVFH greenhouse and transplanted into High Tunnel 2 on October 14, 2022. Plugs were planted at six-inch in-row spacing with six-inches between rows (eight total rows per bed consisting of four rows of 'Flamingo' and four rows of 'Space'). There was no supplemental heat in the high tunnel. Spinach was covered with row cover for approximately two weeks beginning mid Dec. when minimum temperatures were in single digits.

Soil Temperature and Moisture Monitoring

Soil temperatures were taken at a depth of three inches at each end and the middle of each bed using a six-inch digital soil thermometer. Plots were irrigated immediately after transplanting and on February 13, 2023. Soil moisture was evaluated in each plot seven times over the production cycle using a Field Scout TDR 350 meter. Time domain reflectometry (TDR) sensors use eight-inch-long parallel rods to transmit low voltage electrical pulses through the soil. The time that the voltage takes to be reflected to the rods is used to approximate the total amount of soil pore space filled with water, or the volumetric water content percentage (%VWC). Higher %VWC readings are associated with wetter soils.

Soil Moisture Readings

Date	18-Nov	2-Dec	6-Jan	26-Jan	10-Feb	21-Feb	6-Mar	21-Mar
Avg % VWC	21.94	19.94	16.4	14.36	14.4	22.46	16.83	14.04

Average soil temperatures by sampling date, by bed

	Bed 5	Bed 4	Bed 3	Bed 2	Bed 1
6-Jan	47.67	48	47.92	47.83	47.5
26-Jan	41.83	43.17	43.33	42.83	41.5
10-Feb	45	45.67	44.83	45.33	44.33
6-Mar	44.33	45.5	45.33	45.67	45
21-Mar	39.27	40.6	40.87	40.43	38.67

Average soil temp over winter growing season by bed

Bed 5	Bed 4	Bed 3	Bed 2	Bed 1
43.62	44.588	44.456	44.418	43.4

Foliar Ca Applications, Harvest Evaluations and Tissue Sampling

All treatments, except for the untreated control (UTC) received foliar Ca applications on dates listed in the table below. All applications were made using a CO_2-powered backpack sprayer calibrated to deliver 39 gallons/acre of spray solution at 40 psi with four twin turbojet nozzles (TTJ60-8003VS) spaced 15" apart.

In each plot, seven-foot lengths including four rows of each spinach variety were harvested separately on the dates listed in the table below. Harvested spinach was sorted as marketable or unmarketable based on presence of tip burn. Yields were measured using an Ohaus Catapult 1000 compact bench scale with 0.02 lb. resolution.

Tissue samples were collected for nutrient analysis from each 'Flamingo' plot (see Field Work Dates table) and shipped to Waters Ag Lab in Warsaw, NC. 'Space' tissue samples were aggregated by treatment and sampled on October 17 and November 28, 2023. The researchers established a threshold of 2% Ca tissue dry weight to determine if Biomin tissue and EnviroCal tissue treatment received a foliar Ca application. Samples from all treatments were below the 2% threshold for the entire production cycle, therefore the two treatments that were to be fertilized only when tissue sampling suggested it was necessary (Biomin Tissue and EnviroCal Tissue) received Ca foliar application on the same schedule (biweekly) as the other fertilized treatments (Biomin Bi-weekly and EnviroCal Bi-weekly). As a result, the data collected from the two "Tissue" interval treatments was combined with the two Bi-weekly treatments; all analyses in the next section reflect that data aggregation and elimination of the application frequency variable.

Field Work Dates

Foliar Ca Application	Harvest	Tissue Sample
31-Oct	9-Nov	17-Oct
18-Nov	6-Dec	31-Oct
2-Dec	15-Feb	8-Nov
6-Jan	17-Feb	28-Nov
26-Jan	23-Mar	17-Jan
10-Feb	24-Mar	6-Feb
21-Feb		
6-Mar		

III. Statistical Analysis and Results

'Flamingo' Spinach Foliar Calcium Concentration by Date and Treatment

Treatment	3-Nov	10-Nov	2-Dec	20-Jan	9-Feb	2-Mar	16-Mar
UTC	1.12	0.62	0.71	0.54	0.46 a	0.46	0.60
Biomin	1.08	0.56	0.72	0.50	0.37 b	0.41	0.57
EnviroCal	1.14	0.54	0.68	0.48	0.38 ab	0.46	0.57
P-Value	0.89	0.07	0.62	0.21	0.04	0.16	0.86

There was no statistically significant difference in tissue Ca concentration between the foliar Ca treatments and the UTC except on one date, Feb. 9 where the Ca level in the UTC plots was statistically significantly higher than the Biomin treatment.

'Flamingo' Spinach Foliar Calcium Concentration Change Δ

Treatment	Δ11/3--11/10	Δ 11/10--12/2	Δ 12/2--1/20	Δ 1/20--2/9	Δ 2/9--3/2	Δ 3/2--3/16
UTC	-0.50	0.09	-0.17	-0.09	0.00	0.15
Biomin	-0.52	0.16	-0.23	-0.13	0.04	0.16
EnviroCal	-0.60	0.14	-0.20	-0.10	0.08	0.12
P-Value	0.76	0.49	0.69	0.35	0.08	0.38

There was no statistically significant change in tissue calcium concentration over the winter growing under the Biomin and EnviroCal foliar Ca treatments.

Season-Long Aggregate Spinach Yield Data by Variety

Treatment	Aggregate Yield (lbs)	Unmarketable Tip Burn (lbs)	Percentage Aggregate Yield with Tip Burn (%)	Visual Tip Burn Estimate (%)
Flamingo	190.35	10.73	5.63 b	2.85 b
Space	185.10	20.42	11.03 a	7.25 a
P-Value	0.38	0.41	0.0006	<0.0001

There was a statistically significant effect of variety on the percent of crop by weight with tip burn and visual tip burn estimate. The variety 'Space' had significantly more tip burn than 'Flamingo' across the four harvest evaluations.

Season-Long Aggregate Spinach Yield Data by Foliar Fertilizer Treatment

Treatment	Aggregate Yield (lbs)	Unmarketable Tip Burn (lbs)	Percentage Aggregate Yield w/ Tip Burn (%)	Visual Tip Burn Estimate (%)
UTC	71.64	8.04	11.22	6.25
Biomin	157.30	12.58	8.00	5.25
EnviroCal	146.51	10.53	7.19	4.25
P-Value	0.22	0.14	0.26	0.33

There was no statistically significant difference in yield by foliar fertilizer treatment. However, there was a numeric trend toward higher total yield and lower percent tip burn in the plots where foliar Ca products were applied when compared to the UTC.

IV. Discussion and Future Investigations

Spinach Variety Selection

As demonstrated above, there was a significant effect of spinach variety on tip burn severity in the trial at HVFH. However, the finding that 'Space' had significantly more tip burn than 'Flamingo' conflicts with both the observations of HVFH staff from previous seasons and with the research findings from a replicated trial conducted by Dr. Elisabeth Hodgdon at the Wilsboro Research Farm over the winter of 2022-23. The inconsistent results suggest that spinach varieties likely respond to differences in cultural management practices (harvest frequency, harvest intensity, etc.) and environmental conditions (humidity, soil moisture, soil type, soil fertility levels, etc.) and may develop more or less severe tip burn symptoms accordingly. Without more extensive research on the potential interactions between these factors, it is difficult to conclude that one variety is genetically more pre-disposed to tip burn than another.

Foliar Ca Fertilizer Applications

While there are promising trends in the data suggesting that bi-weekly foliar Ca fertilizer 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 of foliar sprays. An informal survey of winter greens growers in the region found that many farms would be willing to make three or four foliar Ca applications over the winter if the practice significantly reduced or eliminated tip burn. Given that eight foliar Ca fertilizer applications did not result in a significant reduction in tip burn severity, it is not clear that commercial winter spinach growers will be willing to absorb the additional labor and materials costs of the sprays.

Future Research

Since the foliar Ca fertilizer applications did not significantly impact tip burn severity, Grundberg and Rusinek intend to evaluate other practices that can impact calcium availability and uptake. Specifically, the team will study the effects of 1) soil moisture, and 2) soil available calcium levels. First, the team intends to evaluate the effect of two different soil moisture levels on tip burn in 'Space' spinach. Granular matrix soil moisture sensors will be installed in each trial plot. Half of the plots will receive supplemental irrigation to maintain a soil water tension rating below an established threshold for winter spinach production. The remaining plots will be irrigated following the HVFH standard irrigation schedule. Second, soil available calcium levels will be increased in half of the plots by applying gypsum before transplanting according to soil analysis recommendations. The other half of the plots will be fertilized according to the standard HVFH practice. The interaction between the different soil moisture levels and gypsum applications will also be included in the trial design. The full list of four treatments for the 2023-24 trial is:

1. Standard irrigation + standard fertilization
2. Standard irrigation + additional gypsum
3. Additional irrigation + standard fertilization
4. Additional irrigation + additional gypsum

V. Acknowledgments

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