Cornell Cooperative Extension
Eastern NY Commercial Horticulture Program

HUDSON VALLEY FARM HUB

High Tunnel Tomato Potassium Fertility Study

2023-2024 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) evaluating the impact of foliar potassium (K) applications in conjunction with reflective mulch or black landscape fabric in reducing the occurrence of two common physiological disorders of high tunnel tomatoes: yellow shoulder and white core.

Key Research Findings from the 2023 Trial

- Foliar K applications did not significantly raise tomato plant tissue K concentrations.
- Plants receiving foliar K applications had significantly lower occurrence of yellow shoulders, but not white core.
- The marginal decrease in unmarketable yield due to yellow shoulders needs to be weighed against the cost of multiple foliar K applications.
- Black landscape fabric resulted in significantly lower soil temperatures across all soil depths.
- Foliar K concentrations (% K) were higher in plants grown on black landscape fabric, attributed to a soil cooling effect that is associated with improved root function and soil potassium uptake.
- Black landscape fabric had significantly less occurrence of white core and numerically lower incidence and severity of yellow shoulders.
- None of the treatments had a significant impact on soluble solids (Brix) or marketable yield.

Figure 1. Tomato with White Core Disorder

I. Background

New York State ranks #2 in the US for number of farms growing in protected settings with a total of 489 farms and a value of sales at $28,590,555. In the Hudson Valley, tomato crops are commonly grown in high tunnels and can provide high economic returns; however, growers must maintain high yields of quality fruit. Tomato yellow shoulder is a common disorder known to be triggered by stress factors exacerbated in the high tunnel growing environment. Tissue in the affected area, typically at the top or “shoulders” of the fruit, fails to develop red pigment due to a potassium deficiency. The flesh beneath the yellow shoulders and along the walls of the fruit is a lighter color, firm, and poor tasting. Symptoms range in intensity and presentation resulting in a variety of names given to this disorder including green shoulder, gray wall, white core, and delayed ripening.

The cause of yellow shoulder disorder is complex and not fully understood. Studies have demonstrated that the principal cause of yellow shoulders is due to potassium deficiency during early fruit set. Often this deficiency occurs despite ample preplant and in-season soil potassium fertilizer applications. It has been hypothesized that as soil temperatures rise above 85 °F, root function is impaired, and soil exchangeable potassium becomes insufficient. This theory has been supported by studies where an increase in yellow shoulders incidence is observed when plants are grown under black plastic with coinciding elevated soil temperatures. High soil temperature is one of multiple factors that can trigger yellow shoulders; nutrient interactions, varietal susceptibility, high canopy temperatures, exposure of fruit to direct sun and soil moisture extremes have also been identified as triggers.

Commonly adopted management practices to prevent yellow shoulders is to intensively test leaf tissue and adjust nutrition programs through fertigation and foliar applications of potassium. Because these practices have not provided consistent results for growers, further investigation is warranted. Research conducted by Dr. Jerry Brust, University of Maryland, showed that shading tomatoes during fruiting can improve fruit quality and reduce culls, while research conducted by Dr. Gordon Johnson, University of Delaware, suggests growing tomatoes in white or metalized plastic mulch to cool soils and improve root function and K uptake. These studies have not resulted in practical management options for most growers and recommendations need refinement before they are adopted.

II. Materials and Methods

Trial Design, Mulch

The trial was hosted by the Hudson Valley Farm Hub (HVFH) in Hurley, NY (41.918901, -74.082975) in a 216’ X 42’ Harnois OvalTech High Tunnel with ridge ventilation and roll-up side walls. The researchers used a small plot randomized complete block design with four replicates and four treatments. Each plot was 8’ long by 4’ wide plots with a 3’ buffer between plots. The tomato variety ‘Rebelski”’ was selected as it was observed to be significantly impacted by yellow shoulder disorder when previously grown at the HVFH. Treatments A and B had tomatoes planted into black landscape fabric, of these, only treatment B received foliar potassium applications. Treatments C and D were planted into reflective mulch, of these only treatment D received foliar potassium applications. See treatment table below.

Treatment	Mulch Type/Foliar Potassium (K) Application
A	Black Landscape Fabric / None (Grower Standard)
B	Black Landscape Fabric / Foliar K
C	Reflective Mulch /None
D	Reflective Mulch / Foliar K

High tunnel trial establishment

The indeterminate HT tomato variety "Rebelski" was seeded on 2/22/2023 into 72 cell trays, up-potted into 3.5" square pots on 4/5/2023 and transplanted on 4/20/23 in a double staggered row with 24" between rows and 24" in-row spacing. Pre- plant fertilizer in the high tunnel included 100 lb/acre nitrogen and 100 lb/acre potassium rate. Subsequent K applications were made via fertigation through drip lines (3 drip lines/bed).

Tissue Sampling, Foliar and fertigation K Treatments and Rates

Leaf tissue samples were collected for nutrient analysis from each plot approximately every 3 weeks beginning in May through September and shipped to Waters Ag Lab in Warsaw, NC. Foliar potassium applications were made using Enviro K 0-0-14 @ 3 quarts/ acre rate co-applied with BB5-NC at rate of .3ml/1000 ml when reported plant tissue potassium levels fell below the 4.5 % sufficiency threshold at both vegetative and fruiting stages. For each sampling date, reported % K fell below the established sufficiency threshold for all treatments; therefore, the two foliar potassium treatments, B and D, received foliar K applications throughout the entire production cycle. All applications were made using a CO_2-powered backpack sprayer calibrated to deliver 44 gallons/acre of spray solution at 40 psi with four twin turbojet nozzles (TTJ60-8003VS) spaced 15" apart. See Field Work Dates table for tissue sampling and foliar K application dates.

All treatments received supplemental K fertigation eight times over the course of the production cycle at a rate of 30 lbs./acre of Allganic 0-0-52 through drip irrigation lines. See Field Work Dates table for actual dates. All treatments received a foliar Magnesium (Mg) application using Enviro Mg @ 2 quarts /acre rate on 14 June due to a deficiency detected by observation and tissue sampling.

NutriAg Enviro K and Enviro Mg products are both OMRI-listed liquid fertilizers for foliar, fertigation, and soil applications to supplement K and Mg levels on agricultural crops. Enviro K contains 14% K_2O weight/volume and is derived from calcium chloride. Enviro Mg contains 4% Mg weight/volume. BB5-NC is an OMRI-listed phosphoric acid-based adjuvant and water conditioner manufactured by NutriAg that is recommended for co-application with Enviro K and Enviro Mg to aid with spreading and uptake.

Harvest Evaluations

In each plot, fully ripened tomatoes were harvested and evaluated 13 times (see table below for harvest dates). At each harvest, fruit was removed from the same four tomato plants (two center plants from each row in the plot). Harvested tomatoes were sorted as marketable or unmarketable if yellow shoulder was observed over 25% or more of the fruit shoulders. Yields were measured using an Ohaus Catapult 1000 compact bench scale with 0.02 lb. resolution. At each harvest, all harvested tomatoes

Figure 2. Tomato Fruit with 25% Yellow Shoulder

Figure 3. Tomato with 80% Yellow Shoulder

were individually evaluated for yellow shoulders and white core. Percent yellow shoulders was determined visually by estimating the area of the fruit shoulders showing yellow or green discoloration. Afterwards, each tomato was sliced in half and visually examined for presence or absence of white core. Soluble solids were measured using a portable ExTech Brix Refractometer with ATC (0-32% range) on 26 June, 11 July, 1, 8, 22 August, 6, 19 September.

Field Work Dates

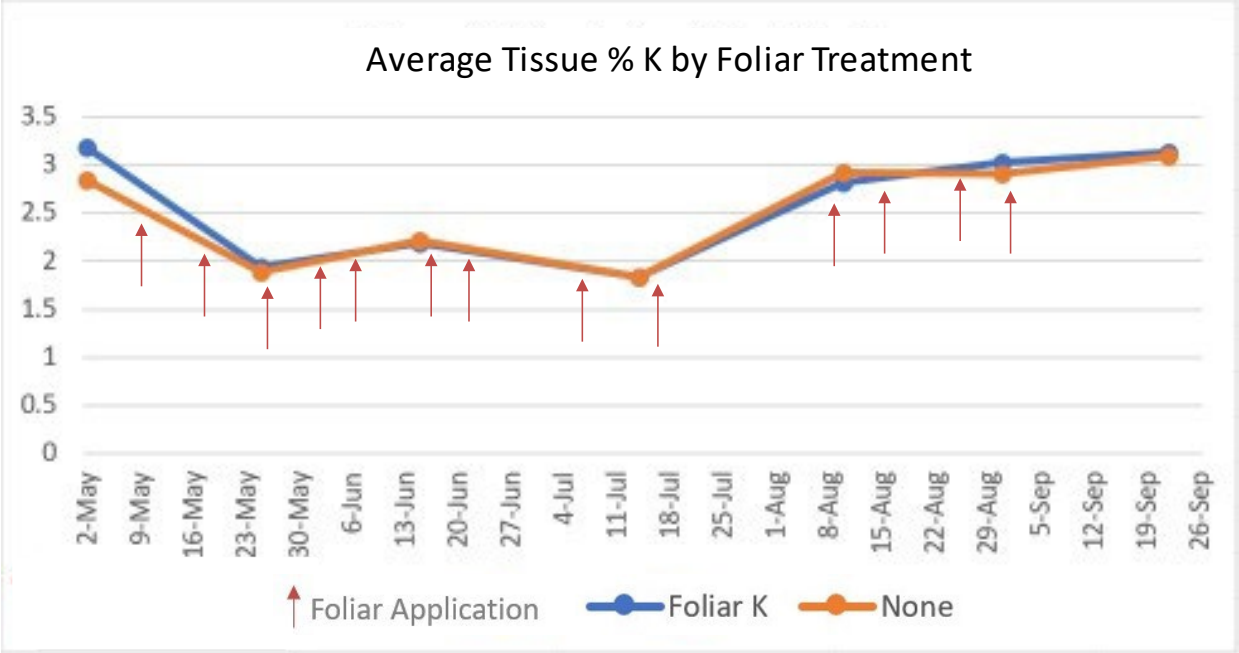
Foliar K Application	Fertigation	Tissue Sample	Harvest
9, 17, 26 - May	9, 27 - May	2, 25 -May	
2, 6, 16, 22 - June	10, 22 - June	15 - June	26 - June
7, 17 - July	7, 27 -July	17 - July	5,11, 20, 27 -July
7, 15, 25 - August	9, 31 - August	10, 31- August	1,8,15, 22, 29 -August
1- September	6, 12, 19 - September	22 - September	6, 12, 19 - September

Soil Temperature

Soil temperatures under the two mulch types were monitored over the production cycle using Watch Dog B100 2K temp data loggers. Loggers were installed under black landscape fabric in plots 103 and 403, and under reflective plastic mulch in plots 203 and 303. In each plot, loggers were placed at 2" depth in-row (a), 6" depth in-row (b) and 3" depth mid-bed (c). Both in-row loggers were buried in the south facing row of the bed and all 3 loggers were centered within the plot to avoid an edge effect from the adjacent plot. Loggers were deployed on 4/24/23 and removed on 9/22/23. Each logger took 12 soil temperature measurements per day on odd hour intervals.

III. Statistical Analysis and Results

Foliar K Application Effect on Plant Tissue K Concentrations



Treatment	Mean K% Over Season
None	2.53
Foliar K	2.59
P-Value	0.6246

Plants receiving foliar potassium applications had slightly higher plant tissue potassium concentrations when averaged over the season, however this effect was not statistically significant when compared to plants not receiving foliar potassium applications.

Foliar K Treatment Effect on Quality and Yield: Season Averages

Foliar K Treatment	% Tomatoes with White Core	% Yellow Shoulder Observed	% Tomatoes with Yellow Shoulder > 0%	% Tomatoes with Yellow Shoulder ≥25%	Mean Unmarketable Yield lbs./ plant YS≥25%
None	32.80	8.94 a	41.47	14.23	0.30 a
Foliar K	31.47	7.25 b	39.96	11.55	0.22 b
P-Value	0.548	0.0429	0.6856	0.1176	0.0251

The % of yellow shoulder observed on fruit and unmarketable yield per plant with yellow shoulders ≥25% was statistically significantly lower in the plots receiving foliar K applications. Numerically, the foliar K plots had lower incidence of tomatoes with white core and yellow shoulder > 0% and ≥25%, though not statistically significant. This trend suggests that multiple foliar K applications can provide some reduction in the incidence and severity of yellow shoulder and white core and increase marketable yields.

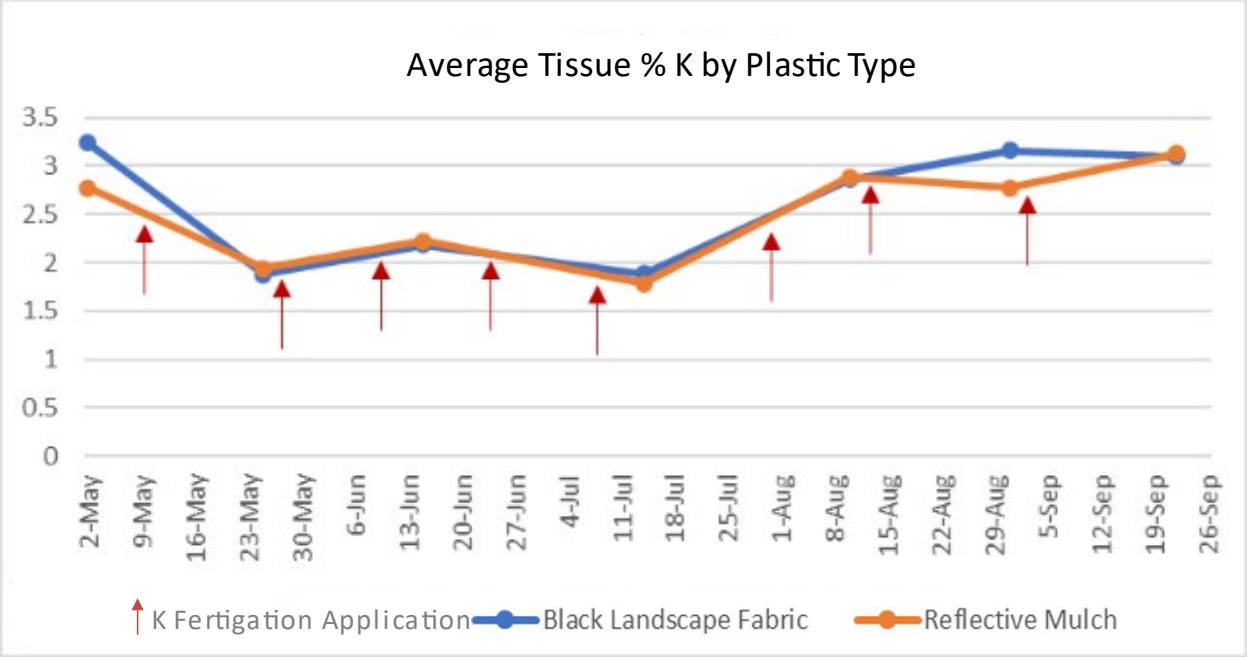
Mulch Effect on Soil Temperature

Mean Soil Temperature (F) by Month by Plastic Type

Plastic	April	May	June	July	August	Sept.	Over Season
Reflective Mulch	65.36	69.59	71.72	78.30	76.45 a	74.94 a	73.77
Black Landscape Fabric	66.05	69.28	70.71	76.86	74.56 b	73.24 b	72.62
P-Value	0.0858	0.6291	0.0804	0.0975	0.0224	0.0071	0.1622

The mean soil temperature under the black landscape fabric was statistically significantly lower for the months of August and September and numerically lower in May, June, July as well as over the season.

Mulch Effect on Plant Tissue K Concentrations



Treatment	Mean %K 31- August	Mean %K Over Season
Reflective Mulch	2.78	2.50
Black Landscape Fabric	3.16	2.61
P-Value	0.0059	0.3398

Plants grown on black landscape fabric had significantly higher plant tissue % K on the August 31 sampling date. When averaged over the season, black landscape fabric had numerically higher tissue % K but not statistically significantly higher than those plants grown on reflective mulch. We hypothesize that tissue % K was higher in plants grown on black landscape fabric due to soil cooling improving root function and soil potassium uptake.

Mulch Treatment Effect on Quality and Yield: Season Averages

Plastic	% Tomatoes with White Core	% Yellow Shoulder Observed	% Tomatoes with Yellow Shoulder > 0%	% Tomatoes with Yellow Shoulder ≥25%	Mean Unmarketable Yield lbs./ plant YS≥25%
Reflective Mulch	35.45 a	8.50	43.21	13.84	0.29
Black L. Fabric	28.82 b	7.69	38.22	11.94	0.22
P- Value	0.0127	0.2880	0.1062	0.2527	0.0525

Plants grown on black landscape fabric had statistically significantly lower % tomato fruit with white core compared to those grown on reflective mulch. This analysis shows a numerical trend where tomato fruit grown on black landscape fabric have a lower percentage of fruit with incidence of yellow shoulder, lower incidence of fruit with yellow shoulder severity at 25% or more and lower unmarketable yield per plant due to yellow shoulder ≥25%.

Season Averages by treatment

Treatment		Avg.% K	Mean Marketable Yield (lbs.) per plant	Mean Unmarketable Yield with YS>25% per Plant	Mean Soluble Solids	Mean % Yellow Shoulder per plant	Mean % White Core
Plastic	Foliar K						
Black L. Fabric	None	2.56	23.22	3.18	4.73	38.61	32.14
Black L. Fabric	Foliar K	2.67	21.71	2.58	4.74	38.88	28.69
Reflective Mulch	None	2.50	21.91	4.55	4.67	45.34	37.05
Reflective Mulch	Foliar K	2.51	22.58	3.01	4.82	42.74	35.29
	P-Value	0.6854	0.9314	0.3967	0.2202	0.606	0.2972

IV. Discussion and Future Investigations

Foliar K Fertilizer Applications

As demonstrated above, there was a significant effect of foliar K applications on the severity of yellow shoulders and mean unmarketable yield due to yellow shoulders. In this trial, foliar K applications did not significantly raise tomato plant tissue foliar K concentrations. Tissue % K levels were below the threshold of 4.5 % beginning with the first tissue sampling the first week of May and remained below

the threshold through the season despite 13 foliar K applications. We hypothesize that the foliar K applications were not as precise once the vines were lowered and leaned on the trellis. Because there were two rows leaning in opposite directions in each plot, it was challenging to not overspray plants that were not supposed to receive a foliar K application. We may have seen a larger difference in foliar K levels between the none and foliar K treatments if there wasn't overspray. In the future it would make sense to design the trial with one row of tomatoes. Though significant, the marginal decrease in unmarketable yield due to yellow shoulders needs to be weighed with the return on investment of multiple foliar K applications. The additional labor and materials costs of applying weekly K sprays may be a viable management strategy for larger HT tomato production operations.

Mulch Selection

It was anticipated that the reflective plastic mulch would cool the soil underneath it; however, in this trial the data revealed that the black landscape fabric is more effective in cooling soil. We believe this is due to the woven structure of the black fabric allowing soil heat to dissipate through the permeable material whereas the reflective plastic mulch is an impermeable film trapping heat. We conclude that foliar K concentrations (% K) were higher in plants grown on black landscape fabric due to a soil cooling effect that is associated with improved root function and soil potassium uptake. This hypothesis is supported by statistical analysis of data which demonstrates that the fruit grown in black landscape fabric had significantly less occurrence of white core and numerically lower incidence and severity of yellow shoulders.

Future Research

Grundberg and Rusinek intend to evaluate the effect of 3 Potash (K20) rates on tomato tissue % K as well as incidence and severity of yellow shoulders and white core disorder in tomato. Organic growers typically front load potassium because it's less challenging than spoon-feeding through fertigation and foliar feeding. Because of the high potassium demand of tomatoes, the concept of 'banking' potassium or applying extra upfront has been gaining adoption. Based on data collected from the 2018 New England High Tunnel Survey, guidelines have been developed for optimizing tomato production in high tunnels. Based on soil tests, K2O applications up to 750 lbs. per acre are recommended for high yields. Additional research is needed to quantify the impact of different management and fertilization practices. The three treatments for the 2024 trial are:

1. 0 lbs. /A K_2O
2. 300 lbs./A K_2O
3. 600 lbs./A K_2O

V. Acknowledgments

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