FINAL REPORT

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SACCHARINA LATISSIMA (SUGAR KELP) FERTILIZER ON-FARM TRIALS

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1. Introduction

Grown and harvested sugar kelp (*Saccharina latissima*) was evaluated for its potential as an amendment for local agricultural crops. Marine plants, such as kelp, have long been used by farmers for their use in improving crop yields, soil health, and overall plant quality (as reviewed in Craigie, 2011). Fertilizer produced from kelp is valued for its ability to improve micronutrient uptake in crops due to kelp fertilizer being a limited source of macronutrients (N, P, K). Numerous research studies have highlighted the biostimulant effects of various species of kelp or seaweed (Craigie, 2011; Battacharyya et al., 2015; Bulgari et al., 2014). In the 2018 farm bill, a biostimulant is described as "a substance or micro-organism that, when applied to seeds, plants, or the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, or crop quality and yield." Various commercial kelp and seaweed fertilizer products are readily available to growers (both seaweed or kelp meal and liquid extract formulations are available, as well as other fertilizer products that incorporate seaweed; examples of trade names include Stimplex, MaxiCrop, Fertrell, Seamax, just to name a few). If kelp can be grown, harvested, and utilized locally, the sustainability of both the marine and agricultural industries on Long Island can improve. Specifically, this project investigated the impact of two different types of kelp amendments on high tunnel grown tomato plants and soil properties as well as the impact of sugar kelp media amendments on greenhouse-grown leafy greens and basil. This report summarizes trial results.

2. On-Farm Tomato Trial: Evaluation of Soil Applied Kelp in High Tunnel Grown Tomatoes

Prepared by Sandra Manasha

A. Materials and Methods

An on-farm trial was established to evaluate the impact different soil applied kelp meals had on high tunnel grown tomato yield, fruit quality, and soil properties. The experiment was arranged as a side-by- side comparison inside a high tunnel with 3 pseudo replications set up per treatment. A total of 3 treatments were evaluated: a no kelp control, Long Island (LI) sugar kelp meal, which was provided by Stony Brook University, and a commercially available kelp meal by Fertrell. Treatment plots were 2 rows wide. Rows were spaced 6 ft apart and plants were spaced 24" apart within each row.

The soil was prepared similarly throughout the high tunnel prior to planting. On 15-April, limestone and compost were applied to the entire area and incorporated. On 19-April, prior to any commercial fertilizer or kelp applications, a soil sample was taken to provide baseline data on the soil chemical properties. On 20-April, fertilizer was applied to all treatments plots at the same rate using a 10-10-10 commercially available blend. Kelp meal was then surface applied by hand to respective beds at a rate of 300 lbs/A and incorporated (Image 1 and 2.). On 21-April, the grower fitted the beds with black plastic mulch and drip irrigation. "Dixie Red" tomatoes were then transplanted by hand into the beds. Plants were trellised using the Florida stake and weave method. Irrigation was supplied as needed and insects, weeds, and diseases were managed according to Cornell Recommendations. Tissue leaf samples were collected on 28-June from the different treatment plots and dried in a drying oven. Samples were sent to Brookside Labs (New Bremen, Ohio) for a complete nutrient analysis to evaluate any difference the soil applied kelp may have on nutrient uptake and density within the plant. Fruit was harvested on 11- July and 25-July. Data on fruit number, weight, and size class distribution were recorded and analyzed.

On 25-July, fruit from each treatment rep was collected and sent to Brookside Labs (New Bremen, Ohio) for a complete nutrient analysis. On 6-August, post-harvest soil samples were collected from each treatment and sent to Pace Analytical Laboratories (Melville, NY). Data was recorded and analyzed. Statistical significance was assessed at the 5% alpha level.

B. Results and Discussion

Yield results from the trial were not significantly different among the treatments evaluated; total marketable yields and the fruit size distribution were all similar (Table 1). A nutrient analysis of the fruit revealed significant differences in micronutrient levels for Phosphorus (P), Zinc (Zn), and Sulfur (S) with levels of all three nutrients significantly higher in the LI Sugar Kelp treatments compared to the Grower Standard treatment (Table 3). The Commercial Kelp treatment was not significantly different from either. A leaf analysis at harvest showed no significant differences in the nutrient levels of the tissue except Manganese (Mn) was significantly higher in the Grower Standard and the commercial kelp treatment compared to the LI sugar kelp treatment (Tables 2 and 3). These results suggest that locally harvested sugar kelp performs similarly to commercially available kelp products regarding yield and can be used as a soil applied amendment in tomato production on Long Island. Additionally, soil applications of Long Island Sugar Kelp improved tomato fruit quality with significantly higher levels of P, Zn, and S in the fruit. Phosphorus and Sulfur have both been linked to improved tomato flavor and taste.

No significant differences were found between treatments on any of the soil parameters measured (Table 4). Heavy metals were not increased with soil applied kelp from either locally harvested or commercially available sources used. Although no significant differences were observed in yield and foliar nutrient concentrations the sugar kelp did significantly impact tomato fruit nutrient concentrations which are known to have a direct impact on tomato fruit taste and flavor. These two factors are vitally important for fresh-market, retail sales. Previous research conducted at the Cornell Long Island Horticultural Research and Extension Center (LIHREC) evaluating LI Sugar Kelp in small plot replicated trials also did not show any significant differences in tomato yield or foliar nutrient content (Menasha, Aller and Catlin, 2020 and 2021). However, some kelp species have been shown to have a biostimulant effect on plant growth and could thus improve crop resiliency to stresses but quantifying these changes is difficult particularly in a field setting. Based on the results of the trial, tomatoes would benefit from soil applied LI Sugar Kelp with improved fruit quality. There may also be other subtle benefits related to crop resiliency and growth, though further study would be needed to document.

Table 1. Effects of soil applied kelp meal on marketable yield and size distribution of 'Dixie Red' high tunnel tomatoes grown in Watermill, NY- 2023.

	Marketable Yield1		Size Distribution (%)			
Treatment	(#/plot)	(lbs/plot)	2.5"	3"	3.5"	>3.5"
LI Kelp	18	12.60	8	18	33	42
Commercial Kelp	20	13.03	5	18	30	47
Grower Standard	27	17.07	8	27	33	32
Tukey's HSD, P=0.05	*0.3845*	*0.3733*	*0.2073*	*0.1330*	*0.6230*	*0.9381*

[1] Total marketable yield included all fruit sizes and were harvested on 7/11 and 7/25.

Numbers in each column with a letter in common or no letters are not significantly different from each other (Tukey's HSD, P=0.05

Table 2. Effects of soil applied kelp meal on tissue nutrient content of 'Dixie Red' high tunnel tomatoes grown in Watermill, NY- 2023.

	Tissue Analysis[1]													
	Nitrogen	Phosphorus	Magnesium	Potassium	Calcium	Sulfur	Boron	Iron	Manganese		Copper	Zinc	Aluminum	Sodium
Treatment	%	%	%	%	%	%	ppm	ppm	ppm		ppm	ppm	ppm	ppm
LI Kelp	2.87	0.49	0.28	2.48	1.55	0.49	36.17	75.77	63.63	b	6.97	17.07	54.00	539.40
Fertrell	2.78	0.52	0.29	2.32	1.82	0.51	44.37	108.40	91.93	a	6.63	16.20	74.67	579.60
Grower Standard	2.74	0.47	0.25	2.14	1.55	0.51	40.27	96.63	100.70	a	6.70	18.27	73.00	460.50
Tukey's HSD, P=0.05	*0.7643*	*0.7715*	*0.5752*	*0.4331*	*0.1771*	*0.8510*	*0.3268*	*0.1625*	*0.0016*		*0.9456*	*0.4576*	*0.5296*	*0.1187*

[1] Leaf samples were collected on 7/11 and sent to Brookside Labs (Ohio) for a complete nutrient analysis. A total of 10 leaves were collected per treatment replicate.

Numbers in each column with a letter in common or no letters are not significantly different from each other (Tukey's HSD, P=0.05)

Table 3. Effects of soil applied kelp on fruit nutrient content of 'Dixie Red' high tunnel tomatoes grown in Watermill, NY- 2023.

	Fruit Analysis[1]															
	Nitrogen	Phosphorous		Calcium	Magnesium	Potassium	Boron	Manganese	Copper	Zinc		Iron	Molybdenum	Sulfur	
Treatment	(%)	(ppm)		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)		(ppm)	(ppm)	(ppm)	
LI Kelp	1003.04	316.41	a	41.71	75.81	2156.70	0.75	1.09	0.58	2.39	a	3.77	0.20	78.67	a
Fertrell	1148.29	291.99	ab	46.92	73.14	1877.71	0.72	1.09	0.57	2.28	ab	3.56	0.20	78.58	a
Grower Standard	765.90	272.09	b	52.03	62.81	1740.57	0.69	1.01	0.50	2.08	b	3.39	0.20	71.01	b
(Tukey's HSD, P=0.05)	*0.0722*	*0.0326*		*0.4584*	*0.0659*	*0.1512*	*0.7117*	*0.4624*	*0.3457*	*0.0381*		*0.2309*		*0.0085*	

[1] Fruit were harvested on 7-25 and sent to Brookside Labs (Ohio) for a complete nutrient analysis of the fruit. 1 fruit per treatment replicated was used.

Numbers in each column with a letter in common or no letters are not significantly different from each other (Tukey's HSD, P=0.05)

Table 4. Pre- and post-trial soil sample results - Watermill, NY- 2023.

Pre-Trial Soil Test[1]		Metals								
	Sulfur	Arsenic	Cadmium	Lead	Phosphorus		Nitrogen	Kjeldahl N	Nitrate N	Nitrite N
Treatment	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	pH	mg/kg	mg/kg	mg/kg	mg/kg
LI Kelp	232.0	12.8	<.68	7.3	663	7	48.1	46.6	1.5	<1.2
Fertrell	277.0	13.2	<.66	7.3	658	6.1	83.3	46.7	36.6	<1.1
Grower Standard	210.0	12.4	<.69	7.3	753	6.9	67.8	60.4	7.4	<1.1

Post-Trial Soil Test[2]		Metals									
	Sulfur	Arsenic	Cadmium	Lead	Mercury	Phosphorus		Nitrogen	Kjeldahl N	Nitrate as N	Nitrite as N
Treatment	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	pH	mg/kg	mg/kg	mg/kg	mg/kg
LI Kelp	230	11.2	0.71	6.7	0.04	678	6.5	94.1	76.9	17.1	1.1
Fertrell	185	10.3	0.67	6.1	0.04	737	6.3	51.0	38.8	12.2	1.1
Grower Standard	381	10.2	0.68	6.2	0.04	910	6.6	84.8	76.5	8.1	1.1
Tukey's HSD, P=0.05	*0.2287*	*0.5709*	*0.5684*	*0.6938*	*0.4277*	*0.1051*	*0.4387*	*0.2514*	*0.2419*	*0.1265*	*0.4444*

[1] Pre-trial soil samples were collected as a composite sample from each treatment plot on 4-19 and sent to Pace Analytical Laboratories (NY).

[2] Post-trial soil samples were collected from each treatment replicate on 9-25 and sent to Pace Analytical Lab (NY).

Numbers in each column with a letter in common or no letters are not significantly different from each other (Tukey's HSD, P=0.05)

3. On-Farm Greenhouse Leafy Greens Trial: Evaluation of Growing Media-Applied Sugar Kelp in Greenhouse-Grown Potted Leafy Greens

Prepared by Nora Catlin and Kyle Smith

A. Materials and Methods

Another on-farm trial was organized to evaluate the potential impact of media-incorporated sugar kelp on plant size, nutrient uptake, and root health on basil. The sugar kelp meal used for this trial is the same sugar kelp used for the high tunnel tomato trial, and the leafy greens trial discussed above. The trial was organized as a side-by-side comparison on basil ‘Sweet Genovese’. On 16-October, half of the planting was transplanted into Lambert LM111 growing media with dried ground sugar kelp meal incorporated into the media at 1/3 c to 1 gal media and the remaining half were untreated. For this trial a higher rate than used in the lettuce trial was chosen, based on some preliminary observational and unpublished data. Each treatment had a total of 18 single plant replicates and grown in 3-inch round containers. Based on grower input on how they would most be interested in using sugar kelp, plants were not given fertilizer in other forms during the course of the trial and were irrigated only with clear water. Growing media EC and pH were collected from a random selection of 10 plants from each treatment on 26-October, 2-November, 8-November and 15-November using the pour-thru method. On 26-November, a random selection of 12 plants from each treatment were harvested at the soil line for dry weight determination. Composite samples (4) of foliage and media were created from 3 pots from each treatment and sent to Brookside Labs (New Bremen, Ohio) for nutritional analysis. Foliar and media samples were also analyzed for the heavy metals arsenic, cadmium, and lead. All data was recorded and analyzed, and statistical significance was assessed using ANOVA.

B. Results and Discussion

No significant differences in media pH were found between treatments for arugula ‘Astro’ or lettuce ‘Mesclun Mix’ on either date data were collected. Media pH was significantly lower in the sugar kelp treatment for lettuce ‘Black Seeded Simpson’ for both dates (Table 5). However, media pH of both treatments fell within the recommended pH for lettuce crops (5.5-6.5) for the duration of the trial.

Media EC was significantly higher in the sugar kelp treatments for all plants on the 20-July date, and all but lettuce ‘Black Seeded Simpson’ on the 27-July date (Table 6). The media EC for both the sugar kelp and controls decreased during the trial, demonstrating that irrigation was flushing salts and fertilizer from the growing media. Media EC was higher than the recommended EC range (~500-2000 µS) for arugula but was within the recommended range at the end of the trial. Media EC was within recommended EC range (~1300-3000 µS) for lettuce at the first data collection but was under the recommended range at the end of the trial. Additional fertilizer at the end of the crop cycle would have maintained recommended EC levels for lettuce. Higher rates of kelp meal may have resulted in media EC much higher than recommended ranges, though leaching through irrigation would have reduced the salt level over time. Further testing would be required to assess at what level sugar kelp meal would have negative impacts on plant growth and health due to high salts levels.

There were no significant treatment differences between final dry weight (foliar yield) or root health evaluations for any of the plants tested (Tables 7 and 8).

Trends in the nutritional analyses of the foliage and growing media differed by crop type (Tables 9 and 10). In some cases, the addition of sugar kelp improved nutrient levels, but this varied by plant. Further testing on specific plants would be needed to better determine specific effects of sugar kelp meal on nutrient levels in the foliage and growing media. Foliar N was significantly higher in the untreated control treatment on arugula 'Astro' but was significantly higher in the sugar kelp treatment in lettuce 'Black Seeded Simpson'. Foliar P, S, Mn, and Zn were significantly higher in the sugar kelp treatments on lettuce "Mesclun Mix' and 'Black Seeded Simpson'; there were no significant differences between treatments of these nutrients for arugula 'Astro'. Foliar Ca and B were significantly higher in the sugar kelp treatment for Lettuce 'Mesclun Mix', but there were no significant treatment differences in Ca or B for the other varieties. Foliar Cu was significantly higher for the sugar kelp treatment in Lettuce 'Black Seeded Simpson', but there were no significant treatment differences in Cu for the other varieties. Very few significant treatment effects on nutrient analyses of the growing media were found. Growing media S was significantly higher only in the sugar kelp treatment in lettuce 'Black Seeded Simpson'; no other significant differences in growing media nutrients between treatments were found.

A sample of the sugar kelp meal was sent for heavy metal analysis, testing for arsenic, cadmium, and lead. Cadmium and lead were not detected (the limit of quantitation, LOQ, for Cd was 0.5 mg/kg, and 5.0 mg/kg for Pb). However, arsenic was detected in the sample, at 34.5 mg/kg. In the growing media samples sent for analysis no arsenic or cadmium was detected, however lead was detected (Table 11); there were no significant differences between treatments. As there was no lead detected in the sample of kelp meal, the presence of lead can be attributed to some factor other than the application of sugar kelp meal. Despite arsenic detection in the sample of kelp meal, no arsenic was detected in the growing media samples sent for analysis at the end of the trial. At these application rates and under these growing conditions, the addition of sugar kelp meal did not result in detectable levels of arsenic in the growing media.

Application of sugar meal application resulted in no adverse effects nor improvements on plant growth or nutrient analyses nor improvements to arugula 'Astro'. On lettuce 'Mesclun Mix' and 'Black Seeded Simpson' no adverse effects were observed on plant growth and improvements were seen for numerous nutrients. In lettuce increased P, Mg, Ca, S, B, Mn, Cu, and Zn were observed in the sugar kelp treatments, though in some cases the differences were only significant for one of the two cultivars. Based on these trial results, the application of sugar kelp meal could benefit container-grown lettuce with increased foliar nutrients. It is possible that sugar kelp meal may have other benefits or impacts, but further study would be necessary to document.

Table 5. Media pH of Arugula 'Astro', Lettuce 'Mesclun Mix', and Lettuce 'Black Seeded Simpson' plants grown in media treated with sugar kelp meal and untreated controls.

		Media pH	
Variety	Treatment	20-July	27-July
Arugula 'Astro'	sugar kelp	5.97 a	6.50 a
	control	6.02 a	6.36 a
Lettuce 'Mesclun Mix'	sugar kelp	5.92 a	5.89 a
	control	6.07 a	6.12 a
Lettuce 'Black Seeded Simpson'	sugar kelp	5.93 b	5.69 b
	control	6.17 a	6.11 a

For each plant variety, means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 6. Media EC evaluations of Arugula 'Astro', Lettuce 'Mesclun Mix', and Lettuce 'Black Seeded Simpson' plants grown in media treated with sugar kelp meal and untreated controls.

		Media EC (µS)	
Variety	Treatment	20-July	27-July
Arugula 'Astro'	sugar kelp	3380 a	1018 a
	control	2400 b	954 a
Lettuce 'Mesclun Mix'	sugar kelp	3380 a	1736 a
	control	2282 b	762 b
Lettuce 'Black Seeded Simpson'	sugar kelp	2980 a	1080 b
	control	1422 b	494 b

For each plant variety, means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 7. Root health evaluations of Arugula 'Astro', Lettuce 'Mesclun Mix', and Lettuce 'Black Seeded Simpson' plants grown in media treated with sugar kelp meal and untreated controls.

Variety	Treatment	Root Health Evaluation
Arugula 'Astro'	sugar kelp	4.0 a
	control	4.3 a
Lettuce 'Mesclun Mix'	sugar kelp	4.1 a
	control	3.8 a
Lettuce 'Black Seeded Simpson'	sugar kelp	4.2 a
	control	4.3 a

Roots were evaluated on a scale of 1-5 scale, with 5=full, healthy root structure and 1=no visible roots in growing media
For each plant variety, means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 8. Foliar dry weight of Arugula 'Astro', Lettuce 'Mesclun Mix', and Lettuce 'Black Seeded Simpson' plants grown in media treated with sugar kelp meal and untreated controls.

Variety	Treatment	Foliar Dry Weight (g)
Arugula 'Astro'	sugar kelp	1.10 a
	control	0.87 a
Lettuce 'Mesclun Mix'	sugar kelp	0.85 a
	control	1.01 a
Lettuce 'Black Seeded Simpson'	sugar kelp	1.08 a
	control	1.02 a

For each plant variety, means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 9. Foliar nutritional analyses of Arugula 'Astro', Lettuce 'Mesclun Mix', and Lettuce 'Black Seeded Simpson' plants grown in media treated with sugar kelp meal and untreated controls.

Variety	Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
Arugula 'Astro'	sugar kelp	5.99 b	0.60 b	0.634 a	6.66 a	2.51 a	1.599 a	29.4 a	154.4 a	68.9 a	8.3 a	97.6 a	105.6 a	2804.5 a
	control	7.51 a	0.76 b	0.640 a	7.08 a	2.47 a	1.663 a	28.4 a	129.4 a	72.8 a	7.4 a	111.7 a	48.1 a	2699.1 a
Lettuce 'Mesclun Mix'	sugar kelp	5.79 a	0.88 a	0.943 a	6.64 a	2.17 a	0.449 a	20.6 a	613.3 a	172.3 a	11.9 a	96.5 a	423.4 a	6280.6 a
	control	5.76 a	0.69 b	0.726 a	6.66 a	1.69 b	0.355 b	16.9 b	359.2 a	105.4 b	8.1 a	74.2 b	236.1 a	5815.3 a
Lettuce 'Black Seeded Simpson'	sugar kelp	5.77 a	0.88 a	0.846 a	6.53 a	2.05 a	0.423 a	20.6 a	425.0 a	140.8 a	10.3 a	97.6 a	300.4 a	7295.9 a
	control	4.46 b	0.58 b	0.651 b	6.04 a	1.65 a	0.334 b	18.5 a	303.6 a	99.7 b	7.2 b	69.9 b	189.9 a	7391.7 a

For each plant variety, means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 10. Media nutritional analyses of Arugula 'Astro', Lettuce 'Mesclun Mix', and Lettuce 'Black Seeded Simpson' plants grown in media treated with sugar kelp meal and untreated controls.

Variety	Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
Arugula 'Astro'	sugar kelp	1.06 a	0.06 a	0.309 a	0.07 a	1.46 a	0.128 a	5.0 a	1391.4 a	49.0 a	18.4 a	24.9 a	931.6 a	1546.9 a
	control	0.97 a	0.05 a	0.323 a	0.07 a	1.49 a	0.128 a	4.6 a	1607.1 a	50.1 a	18.4 a	25.0 a	10.31.7 a	1434.0 a
Lettuce 'Mesclun Mix'	sugar kelp	0.96 a	0.06 a	0.352 a	0.08 a	1.56 a	0.161 a	5.6 a	1745.9 a	59.4 a	19.1 a	24.9 a	1150.2 a	1628.1 a
	control	1.04 a	0.06 a	0.367 a	0.07 a	1.62 a	0.144 a	5.1 a	1963.3 a	59.9 a	21.2 a	30.2 a	1357.0 a	1533.2 a
Lettuce 'Black Seeded Simpson'	sugar kelp	1.03 a	0.06 a	0.422a	0.06 a	1.65 a	0.154 a	5.5 a	2158.6 a	84.7 a	23.5 a	28.8 a	1442.8 a	1384.3 a
	control	1.01 a	0.05 a	0.332 a	0.05 a	1.47 a	0.122 b	5.1 a	1704.9 a	55.1 a	21.3 a	27.8 a	1355.3 a	1356.8 a

For each plant variety, means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 11. Growing media analyses for arsenic (As), cadmium (Cd), and lead (Pb) in Arugula 'Astro', Lettuce 'Mesclun Mix', and Lettuce 'Black Seeded Simpson' plants grown in media treated with sugar kelp and an untreated control.

Variety	Treatment	As (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
Arugula 'Astro'	sugar kelp	ND	ND	7.3 a
	control	ND	ND	6.4 a
Lettuce 'Mesclun Mix'	sugar kelp	ND	ND	7.2 a
	control	ND	ND	6.2 a
Lettuce 'Black Seeded Simpson'	sugar kelp	ND	ND	6.0 a
	control	ND	ND	6.2 a

ND = not detected; limit of quantitation, LOQ *for As was 2 mg/kg, Cd: 0.5 mg/kg, Pb: 5.0 mg/kg*
For each plant variety, means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

4. On Farm Greenhouse Basil Trial: Evaluation of Growing Media-Applied Sugar Kelp in Greenhouse-Grown Potted Basil

Prepared by Nora Catlin and Kyle Smith

A. Materials and Methods

Another on-farm trial was organized to evaluate the potential impact of media-incorporated sugar kelp on plant size, nutrient uptake, and root health on basil. The sugar kelp meal used for this trial is the same sugar kelp used for the high tunnel tomato trial, and the leafy greens trial discussed above. The trial was organized as a side-by-side comparison on basil 'Sweet Genovese'. On 16-October, half of the planting was transplanted into Lambert LM111 growing media with dried ground sugar kelp meal incorporated into the media at 1/3 c to 1 gal media and the remaining half were untreated. For this trial a higher rate than used in the lettuce trial was chosen, based on some preliminary observational and unpublished data. Each treatment had a total of 18 single plant replicates and grown in 3-inch round containers. Based on grower input on how they would most be interested in using sugar kelp, plants were not given fertilizer in other forms during the course of the trial and were irrigated only with clear water. Growing media EC and pH were collected from a random selection of 10 plants from each treatment on 26-October, 2-November, 8-November and 15-November using the pour-thru method. On 26-November, a random selection of 12 plants from each treatment were harvested at the soil line for dry weight determination. Composite samples (4) of foliage and media were created from 3 pots from each treatment and sent to Brookside Labs (New Bremen, Ohio) for nutritional analysis. Foliar and media samples were also analyzed for the heavy metals arsenic, cadmium, and lead. All data was recorded and analyzed, and statistical significance was assessed using ANOVA.

B. Results and Discussion

Media pH was significantly higher on all evaluation dates in the sugar kelp treatment compared to the control treatment (Table 12). Media pH was lower than the recommended range (5.8-6.2) in the control treatment, and inconsistent in the sugar kelp treatment. Despite these data, no visual effects of symptoms of high or low pH were observed.

Media EC (electrical conductivity) was also significantly higher on all evaluation dates for the sugar kelp treatments, with the exception of the last evaluation on 15-Nov (Table 13). Similar to the lettuce trial, media EC decreased over time as a result of irrigation flushing out salts and fertilizer. The recommended EC range for basil is 1300-2000 µS. The EC of the sugar kelp treatments were higher for the first 3 weeks of the crop, though corresponding effects on plant and root health were not observed (Table 14 and 15). Further testing would be necessary to determine if and at what rate of sugar kelp meal would have negative impacts on plant growth and health due to high salts levels.

Differences between treatment foliar and media analyses were clearer in the basil trial than in the leafy greens trial – in part because only one plant and cultivar was tested. Foliar K, Mn, and Zn were significantly higher in the sugar kelp treatment in basil, while foliar Ca and Mg were significantly higher in the control treatment. (Table 16). Growing media N, K, B, Cu, and Na were significantly higher in the sugar kelp treatment compared to the control treatment in basil (Table 17). Elevated Na in soils is known to compete with Ca and Mg, likely why the Ca and Mg levels were reduced in the foliar samples of the sugar kelp treatment. These results suggest that sugar kelp could have a use as a growing media amendment and could provide an increase in some plant nutrients, though the high salt levels could be a concern. Unpublished observational trials (Catlin and Smith, 2023) have demonstrated sugar kelp meal rates of 10% and higher can have negative impacts on container-grown plants. These trials have also demonstrated that a heavy leaching soon after transplanting to a sugar kelp amended media could reduce the EC by 40-50%. Further testing could better fine tune the application rates of sugar kelp meal and/or other practices, such as leaching, to better understand and mitigate any negative impacts of salt.

As mentioned above, a sample of the sugar kelp meal was sent for heavy metal analysis, in which arsenic was detected at 34.5 mg/kg, and cadmium and lead were not detected. In the basil foliage samples sent for heavy metal analysis, arsenic, lead, and cadmium were not detected (Table 18). Similar to the leafy greens trial, cadmium and lead were not detected in growing media samples, though lead was detected (Table 18). As there was no lead detected in the sample of kelp meal, the presence of lead can be attributed to some factor other than the application of sugar kelp meal. Despite arsenic detection in the sample of kelp meal, no arsenic was detected in the basil foliage samples. At these application rates, and under these specific growing conditions, the addition of sugar kelp did not affect plant uptake of arsenic in basil.

Table 12. Media pH evaluations for Basil 'Sweet Genovese' plants grown in media treated with sugar kelp meal and an untreated control.

		Media pH			
Variety	Treatment	26-Oct	2-Nov	8-Nov	15-Nov
Basil 'Sweet Genovese'	sugar kelp	6.30 a	5.78 a	5.10 a	5.74 a
	control	5.69 b	5.22 b	4.66 b	5.06 b

Means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 13. Media EC for basil 'Sweet Genovese' plants grown in media treated with sugar kelp meal and an untreated control.

		Media EC (µS)			
Variety	Treatment	26-Oct	2-Nov	8-Nov	15-Nov
Basil 'Sweet Genovese'	sugar kelp	4540 b	4680 b	3557 b	1918 a
	control	2212 a	2198 a	1652 a	1157 a

Means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 14. Mean root health evaluations of Basil 'Sweet Genovese' grown in media treated with sugar kelp and an untreated control.

Variety	Treatment	Root Health Evaluation
Basil 'Sweet Genovese'	sugar kelp	3.92 a
	control	3.92 a

All ratings on 1-5 scale, with 5=full, healthy root structure and 1=no visible roots in growing media
Means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 15. Mean foliar dry weight evaluations of Basil 'Sweet Genovese' grown in media treated with sugar kelp meal and an untreated control.

Variety	Treatment	Foliar Dry Weight (g)
Basil 'Sweet Genovese'	sugar kelp	0.96 a
	control	1.04 a

Means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 16. Mean foliar nutritional analyses of Basil 'Sweet Genovese' grown in media treated with sugar kelp and an untreated control.

Variety	Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
Basil 'Sweet Genovese'	sugar kelp	5.39 a	0.60 a	0.851 b	5.01 a	2.30 b	0.359 a	21.9 a	79.4 a	146.9 a	51.4 a	75.1 a	51.3 a	678.8 a
	control	5.51 a	0.62 a	0.963 a	4.12 b	2.55 a	0.356 a	20.4 a	79.0 a	103.9 b	64.6 a	59.5 b	86.0 a	584.5 a

Means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 17. Mean growing media nutritional analyses of Basil 'Sweet Genovese' grown in media treated with sugar kelp and an untreated control.

Variety	Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
Basil 'Sweet Genovese'	sugar kelp	1.09 a	0.08 a	0.382 a	0.28 a	1.72 a	0.233 a	11.5 a	1929.0 a	65.0 a	36.5 a	77.4 a	1074.1 a	1724.9 a
	control	0.99 b	0.07a	0.384 a	0.04 b	1.70 a	0.214 a	7.8 b	1922.3 a	64.1 a	29.8 b	74.4a	1093.5 a	947.9 b

Means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

Table 18. Foliar and media analyses for arsenic (As), cadmium (Cd), and lead (Pb) in basil 'Sweet Genovese' grown in media treated with sugar kelp and an untreated control.

		Foliar			Media		
Variety	Treatment	As (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	As (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
Basil 'Sweet Genovese'	sugar kelp	ND	ND	ND	ND	ND	9.9 a
	control	ND	ND	ND	ND	ND	9.4 a

ND = not detected; limit of quantitation, LOQ *for As was 2 mg/kg, Cd: 0.5 mg/kg, Pb: 5.0 mg/kg*
Means within a column with similar letters are not statistically significant according to ANOVA (p=0.05)

5. General Comments and Summary of On-Farm Trials

In on-farm trials with high tunnel tomato and greenhouse potted leafy greens (arugula and lettuce) and basil, little impact was observed on overall yield or plant size as a result of sugar kelp application. However, an increase in a number of plant nutrients were observed for tomato, lettuce, and basil. Given the results of these trials, we have concluded that the application of sugar kelp meal can be beneficial, improving the uptake of certain plant nutrients. Previous studies conducted on greenhouse plants at LIHREC (Menasha, Aller, and Catlin, 2020) showed increased growth and a possible effect of improved drought tolerance with application of a sugar kelp extract, though the results were not consistent in repeated trials (and Menasha, Aller, and Catlin, 2021). It is possible that sugar kelp application may result in other benefits such as improved plant growth, drought tolerance or crop resilience, but further study would be required to document.

In both the 2020 and 2021 studies at LIHREC (Menasha, Aller, and Catlin, 2020, and Menasha, Aller, and Catlin, 2021), locally harvested sugar kelp was compared to commercially available kelp products and were applied according to their label recommendations on field tomato. The commercially available kelp products were rock weed kelp based (Ascophyllum nodosum) while the local kelp applications were made using sugar kelp (Saccharina latissimi). Greater benefits of applying sugar kelp in tomato could be realized if application rate studies for sugar kelp were studied and recommended application rates for sugar kelp were developed. Different species may require different application rates for optimal performance and benefit.

In greenhouse potted crops, high levels of electrical conductivity (a measure of salt level) and growing media sodium were found in some cases. While no adverse effects on plant growth were observed in any of the greenhouse potted crops, this finding merits consideration as higher application rates may result in adverse effects on plant growth and health. In unpublished research (Catlin and Smith, 2023), negative impacts on plant growth were observed when application rates were 10% v/v or higher; though leaching soon after transplant may help to mitigate impacts. Further study should look to fine tune rates and application methods to determine the most effective and safe rates and methods for different plant types.

Despite the presence of arsenic the sugar kelp meal, an increase of arsenic was not observed in the field soil nor in the greenhouse growing media under the tested conditions, likely a result of the low rate of application. It should be noted that plant uptake of heavy metals such arsenic can vary by species and can be affected by factors such rate of application and soil or growing media pH (McBride et al., 2014, Peralta-Videa et al., 2009, Zwolak et al., 2019); these results should not be interpreted broadly.

6. REFERENCES

Battacharyya, D., Zamani Babgohari, M., Rathor, P., and Prithiviraj, B. 2015. Seaweed extracts as biostimulants in horticulture. Scientia Horticulturae 196: 39-48.

Bulgari, R., Cocetta, G., Trivellini, A., Vernieri, P., and Ferrante, A. 2014. Biostmulants and crop responses: a review. Biological Agriculture & Hortculture, 31:1-17.

Catlin, N. and Smith, K. 2023. Unpublished research, Cornell Cooperative Extension of Suffolk County.

Craigie, J.S. 2011. Seaweed extract stmuli in plant science and agriculture. J Appl Phycol 23:371–393

Kim, J.K., Kraemer, G., Yarish, C. 2019. Evaluaton of the metal content of farm grown Gracilaria tkvahiae and Saccharina latssima from Long Island Sound and New York Estuaries. Algal Research 40: 101484.

McBride, M.B., A. Shayler, H.A., Spliethoff, H.M., Mitchell, R. G., Marquez-Bravo, L.G., Ferenz, G.S., Russell-Anelli, J.M., Casey, L., and Bachman, S. 2014. Concentratons of lead, cadmium and barium in urban garden-grown vegetables: The impact of soil variables. Environmental Polluton 194: 254-261.

Menasha, S., Aller, D., and Catlin, N. 2020. Saccharina Latissima (Sugar Kelp) Fertilizer Pilot Study, New England Interstate Water Pollution Control Commission (NEIWPCC), https://neiwpcc.org/wp- content/uploads/2021/02/N-S-2020-003.pdf

Menasha, S., Aller, D., and Catlin, N. Saccharina Latissima (Sugar Kelp) Fertilizer Pilot Study Year 2, New England Interstate Water Pollution Control Commission (NEIWPCC), https://neiwpcc.org/wp- content/uploads/2022/11/Sugar-Kelp-Fertilizer-Pilot-Study-Year-2.pdf

Peralta-Videa, J.R., Lopez, M.L., Narayan, M., Saupe, G., and Gardea-Torresdey, J. 2009. The biochemistry of environmental heavy metal uptake by plants: Implicatons for the food chain. The Internatonal Journal of Biochemicstry & Cell Biology 41: 1665-1677.

Shaughnessy, B.K., Jackson, B.P. and Byrnes, J.E.K. 2023. Evidence of elevated heavy metals concentrations in wild and farmed sugar kelp (Saccharina latissima) in New England. Scientific Reports 13:17644.

Zwolak, A., Sarzynska, M., Szpyrka, E., and Stawarczyk, K. 2019. Sources of Soil Polluton by Heavy Metals and Their Accumulaton in Vegetables: a Review. Water Air Soil Pollut 230: 164

7. Photos

Figure 1. Soil applied kelp meal amendment applications in a high tunnel.

Figure 2. Long Island harvested Kelp meal amendment applied to the soil surface prior to incorporation.

Figure 3. Tomato plants four weeks after Long Island kelp meal amendments.