Saccharina Latissima (Sugar Kelp) Fertilizer Pilot Study
Final Report
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Evaluation of Soil and Foliar Applied Kelp on Field Grown Tomatoes
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Introduction:

The project was conducted to evaluate the potential for using sugar kelp harvested from Long Island waters as an amendment for local agricultural crops. Kelp and other marine plants have long been used by farmers to improve soil nutrient levels, crop yields and quality. Kelp fertilizer is valued for its ability to provide needed micronutrients to crops, as it is not a significant source of macronutrients (nitrogen (N), phosphorus (P), and potassium (K)). Additionally, numerous research studies have focused on the biostimulant effects of various types of kelp or seaweed (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"). Numerous kelp and seaweed fertilizer products are currently available to growers, but if kelp can be grown, harvested, processed, and utilized locally the sustainability of both the marine and agricultural industries on Long Island may improve. Specifically, this project investigated the impact of two different types of kelp amendments and application methods on plant and soil properties.

Materials & Methods:

On May 19th, 2020 locally harvested sugar kelp was delivered to the Long Island Horticulture Research and Extension Center (LIHREC) in Riverhead, NY. The kelp was rinsed thoroughly with fresh water and line dried in a greenhouse for 3 days (Images 1-3). The kelp was then cut off the growing lines, crushed into smaller pieces by hand into paper bags, and the paper bags were placed in a drying oven at 160 °F for 48 hours. After drying, the kelp was crushed and ground into a coarse meal using a Meadow Mills steel burr commercial grain mill (Meadow Mills, North Wilkesboro, NC). The meal was then used for soil application. To prepare the extract for foliar applications, the meal was ground into smaller particles using a handheld coffee/spice grinder. Kelp extract was prepared for each application by boiling 10g of finely ground dried kelp, in 100 ml of distilled water for 30 minutes. The solution was then pre-filtered through a cheesecloth and then filtered through #4 Whatman paper.

In June, a field trial was established to evaluate the locally produced kelp meal and extract compared to commercially available kelp products on field grown tomato yield and quality. The meal was soil applied and extract foliar applied at two application rates and different standard fertilizer rates. The experiment was arranged as a randomized complete block design with four replications in a Haven loam soil. The standard fertilizer and the kelp meal soil applications were applied prior to planting. The kelp extract foliar applications were applied four times using a CO_2 backpack sprayer and continued every two weeks until harvest. Commercially available products were applied according to label rate recommendations. A total of 10 treatments were evaluated and are listed here:

1. Sugar kelp meal at 75 lbs/A plus standard fertilizer at 1000 lbs/A (10-10-10)
2. Sugar kelp meal at 150 lbs/A plus standard fertilizer at 1000 lbs/A (10-10-10)
3. Sugar kelp meal at 75 lbs/A plus standard fertilizer at reduced rate (20% reduction) at 800 lbs/A
4. Sugar kelp meal at 150 lbs/A plus standard fertilizer at reduced rate at 800 lbs/A
5. Commercial kelp meal A at 150 lbs/A plus standard fertilizer at 1000 lbs/A
6. Commercial kelp meal B at 435 lbs/A plus standard fertilizer at 1000 lbs/A
7. Sugar kelp extract, plus standard fertilizer rate at 1/3 oz/gal plus standard fertilizer at 1000 lbs/A
8. Commercial kelp extract A at 1/3 oz/gal plus standard fertilizer at 1000 lbs/A
9. Commercial kelp extract B at 1 oz/gal plus standard fertilizer at 1000 lbs/A
10. Control; standard fertilizer rate only at 1000 lbs/A 10-10-10

Treatment plots consisted of a single row or bed of 8 tomato plants. Plants were spaced 24" apart within the bed and beds were spaced 5.67 feet apart on center. Fertilizer and kelp meal applications were made by hand onto each bed and incorporated into the top three inches of the soil. Beds were then fitted with black plastic mulch and drip irrigation. Transplants of 'BHN 589' tomato were started in the greenhouse on May 8 in 50-cell tray flats, allowed to harden prior to planting and field set on June 11. Kelp foliar applications were applied at first flower on June 29 and continued every 2 weeks. Last foliar application was made on August 10. Leaf samples were collected from each treatment plot at harvest and sent to Brookside Labs (Ohio) for % total nitrogen analysis. Tomatoes were harvested four times on August 21, 28, Sept 4 and 11. Fruit were counted, weighed, and sorted into size class (Images 4-6). Data on Brix levels (% soluble sugars) were also recorded (Image 7). Fruit from each treatment plot were also sent to Brookside Labs (Ohio) for nutrient analysis. Pre- and post-trial soil samples were collected and analyzed to evaluate differences in nutrient levels, pH, EC, and % organic matter between treatments. Soil samples were sent to Pace Analytical Laboratories (NY). All data collected from the field trial were analyzed using one-way ANOVA in SUPERANOVA.

Results and Discussion:

Yield results from the trial were not significantly different among the treatments evaluated; early and total marketable yields were comparable as well as the size distribution of the fruit (Table 1). There was also no significant difference in Brix levels among the different treatments. Fruit sulfur levels were significantly affected by treatment. Treatment 9, foliar applications of commercial kelp extract B, had significantly higher fruit sulfur levels than both the soil applied low rate of sugar kelp meal treatments, the commercial kelp meal A treatment, the sugar kelp foliar treatment and the commercial kelp extract A treatment.

No significant differences were found between treatments on soil water retention, pH, EC, % organic matter, and soil nutrient levels except for calcium (Ca). Figure 1 shows end of season soil calcium levels (mg/kg) across all ten treatments. Treatment 4, high rate of sugar kelp meal with a 20% fertilizer reduction, was higher than all other treatments. Further, end of season tomato foliar nitrogen concentrations did not differ between treatments (Figure 2). It is possible that no differences were found in soil nutrient levels, except for Ca in a single treatment, and foliar nitrogen content because of kelp application rates. Although kelp meal and extracts for the respective treatments were applied using current recommended application rates for commercial products. Additionally, as previously discussed sugar kelp has been shown to have a biostimulant effect on plant growth, thus the resiliency of the tomato plants to other potential stresses may have been improved, but quantifying these changes is difficult particularly in a field setting. Future work is needed to confirm the findings presented following this single season trial.

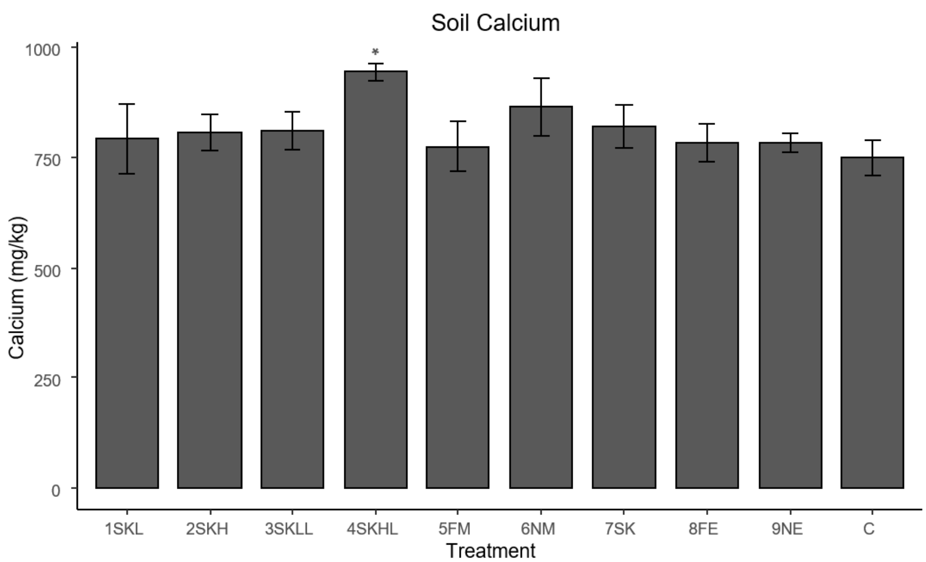

Figure 1. Soil calcium concentrations across the ten different treatments. Treatment 4, indicated by the asterisk, was higher than all other treatments. Bars are the average of four field replicates with standard error bars.

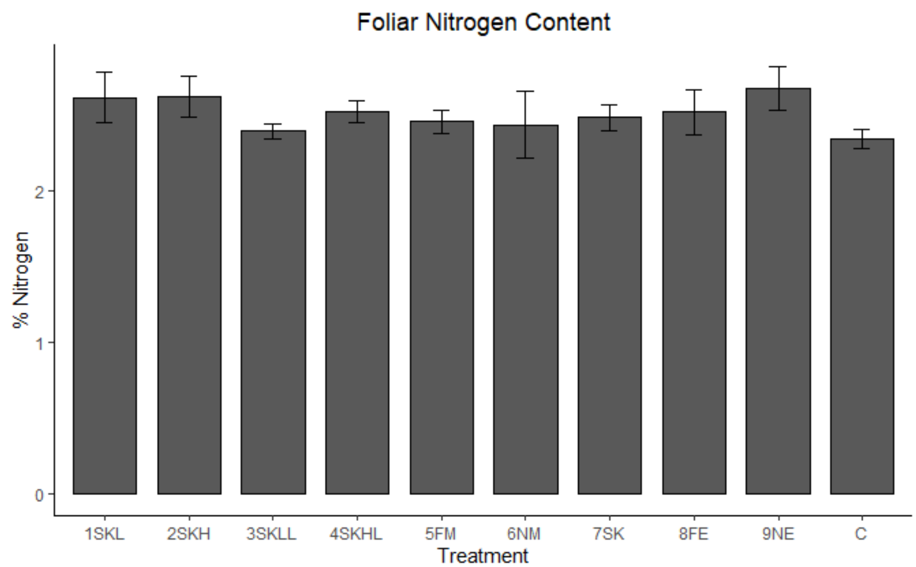

Figure 2. Percent foliar nitrogen concentration for the ten different treatments. No significant differences were found between treatments. Bars are the average of four field replicates with standard error bars.

Image 1: After arrival of the sugar kelp at the LIHREC facility it was rinsed with fresh water prior to air drying.

Image 2. Fresh sugar kelp hung to dry in a greenhouse

Image 3. Sugar kelp after 3 days drying in a greenhouse

Image 4. Harvesting tomatoes from field trial

Image 5. Sizing tomatoes into five different size classes

Image 6. Weighing all tomatoes harvesting from a particular size class

Image 7. A refractometer being us to measure the degrees Brix of a fresh tomato. Degrees Brix measures the sugar content of an aqueous solution.

Table 1. Kelp fertilizer effects on the yield of 'BHN 589' tomato grown in Riverhead, NY- 2020

			Marketable		Size Distribution					Avg.	
	10-10-10[1]	Kelp[2]	Early[3]	Total[4]	Boxes/A[5]					Wt./Fruit	Brix[6]
Treatment	lbs/A	rate/A	(boxes/A)	(boxes/A)	2"	2.5"	3"	3.5"	>3.5"	(lbs)	(%)
1	1000	75 lbs	135	1,529	1	12	130	641	745	0.66	5.3
2	1000	150 lbs	111	1,499	0	13	172	704	611	0.62	5.1
3	800	75 lbs	159	1,551	0	6	125	673	747	0.66	5.4
4	800	150 lbs	162	1,594	0	14	156	645	778	0.65	5.6
5	1000	150 lbs	176	1,517	0	9	113	596	798	0.67	5.1
6	1000	435 lbs	146	1,544	1	7	111	689	736	0.64	5.5
7	1000	1/3 oz	170	1,690	0	10	122	733	824	0.66	5.4
8	1000	1/3 oz	123	1,624	0	17	117	725	765	0.64	5.3
9	1000	1 oz	173	1,604	0	4	189	690	721	0.64	5.4
10	1000	0	143	1,493	0	6	122	677	688	0.64	5.1
Fisher's Protected LSD (0.05)			*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*
Statistical Analysis (0.05)			p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value
			0.7519	0.7924	0.5255	0.2419	0.5298	0.8204	0.5627	0.4591	0.2721

[1] Treatments received either 800 lbs/A 10-10-10 or 1000 lbs/A 10-10-10 prior to transplanting.

[2] Kelp rates reflective of treatment specifications

[3] Early marketable yields from the first harvest on 8/21 and included all fruit size distribution classes.

[4] Total marketable yields included all fruit sizes. Fruit harvested on 8/21, 8/28, 9/4 and 9/11.

[5] Box equals 25 lbs.

[6] Soluble solids; average from all 4 harvests

Table 2. Kelp fertilizer effects on fruit nutrient levels of 'BHN 589' tomato grown in Riverhead, NY- 2020

	10-10-10[1]	Kelp[2]	Ave wt	Moisture	Nitrogen	Phosphorus	Calcium	Magnesium	Potassium	Boron	Manganese	Copper	Zinc	Iron	Molybdenum	Sulfur
Treatment	lbs/A	rate/A	(g)	(%)	(%)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
1	1000	75 lbs	267.9	94.2	1178.8	287.1	50.3	115.4	2382.8	0.8	1.0	0.5	0.9	2.8	0.2	106.8
2	1000	150 lbs	234.7	94.4	1427.3	315.0	49.5	117.6	2632.0	0.7	1.0	0.5	1.0	3.0	0.2	121.0
3	800	75 lbs	265.4	94.3	1261.2	295.1	45.8	117.1	2477.8	0.7	1.0	0.5	1.0	2.7	0.2	106.3
4	800	150 lbs	275.5	94.3	1348.4	304.6	42.6	124.7	2560.3	0.7	1.0	0.5	1.0	3.0	0.2	114.9
5	1000	150 lbs	232.5	94.2	1304.6	291.1	41.7	108.9	2353.8	0.6	1.0	0.5	0.9	2.8	0.2	107.9
6	1000	435 lbs	258.4	93.7	1465.1	321.2	49.9	121.1	2741.3	0.7	1.0	0.5	1.0	3.1	0.2	121.6
7	1000	1/3 oz	253.2	94.0	1290.3	260.4	49.8	117.6	2483.5	0.8	1.0	0.5	0.9	2.7	0.2	106.3
8	1000	1/3 oz	260.0	94.4	1221.2	269.8	48.9	104.4	2299.5	0.6	1.0	0.5	0.8	2.3	0.2	98.6
9	1000	1 oz	250.5	93.9	1558.7	338.8	43.9	123.8	2735.0	0.7	1.0	0.5	1.1	3.1	0.2	126.1
10	1000	0	254.7	94.0	1369.9	306.6	37.6	130.3	2560.0	0.9	1.0	0.5	1.0	2.8	0.2	115.3
Fisher's Protected LSD (0.05)			*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(14.6)*
Statistical Analysis (0.05)			p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value
Treatment			0.8392	0.3333	0.1396	0.2101	0.2935	0.0805	0.1412	0.111	0.4635	0.4635	0.4045	0.5423	na	0.014

[1] Treatments received either 800 lbs/A 10-10-10 or 1000 lbs/A 10-10-10 prior to transplanting.

[2] Kelp rates reflective of treatment specifications

Table 3. Effects of kelp applications on tissue nitrogen of 'BHN 589' tomato grown in Riverhead, NY- 2020

Treatment	10-10-10[1] lbs/A	Kelp[2] lbs/A	Nitrogen[3] (%)
1	1000	75	2.61
2	1000	150	2.62
3	800	75	2.39
4	800	150	2.52
5	1000	150	2.46
6	1000	435	2.43
7	1000	Foliar	2.48
8	1000	Foliar	2.52
9	1000	Foliar	2.68
10	1000		2.34
Fisher's Protected LSD (0.05)			*(ns)*

Statistical Analysis (0.05)	p-value
Treatment	0.6586

[1] Treatments received either 800 lbs/A 10-10-10 or 1000 lbs/A 10-10-10 prior to transplanting.

[2] Kelp rates reflective of treatment specifications

[3] Total Nitrogen by Combustion Test, Brookside Laboratories Inc., Ohio taken on 9/11/20.

Table 4. Pre-plant soil nutrient analysis Riverhead, NY- 2020

			Soil Nutrients[3]															
Treatment	10-10-10[1] lbs/A	Kelp[2] lbs/A	Aluminium (mg/kg)	Boron (mg/kg)	Calcium (mg/kg)	Copper (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Potassium (mg/kg)	Sodium (mg/kg)	Zinc (mg/kg)	Sulfur (mg/kg)	Phosphorus (mg/kg)	Moisture (%)	pH	EC Value	Organic Matter (%)
1	1000	75	11500.0	<2.6	1010.0	27.1	10100.0	1560.0	91.7	598.0	<262	22.0	78.2	100.0	6.50	6.63	0.16	2.78
2	1000	150	10800.0	<2.6	992.0	26.4	9780.0	1490.0	87.2	574.0	<261	21.2	65.3	105.0	6.60	6.65	0.16	2.92
3	800	75	12000.0	<3.0	1080.0	28.4	10400.0	1630.0	87.9	612.0	<297	22.5	64.0	113.0	6.60	6.68	0.16	2.94
4	800	150	10900.0	<2.9	923.0	25.5	9840.0	1440.0	91.2	573.0	<287	21.5	74.2	103.0	6.80	6.33	0.16	2.93
5	1000	150	12800.0	<2.8	1040.0	28.4	11400.0	1770.0	104.0	661.0	<285	23.9	76.5	107.0	6.80	6.45	0.17	2.81
6	1000	435	12400.0	<2.8	1010.0	30.0	10900.0	1620.0	103.0	636.0	<282	23.4	79.0	116.0	7.10	6.50	0.16	3.00
7	1000	Foliar	11500.0	<2.7	982.0	28.7	10400.0	1510.0	99.3	619.0	<271	22.7	62.8	109.0	7.00	6.51	0.16	3.18
8	1000	Foliar	11000.0	<2.7	941.0	25.5	9770.0	1490.0	85.3	602.0	<273	21.1	62.3	113.0	7.00	6.53	0.16	2.72
9	1000	Foliar	10500.0	<2.7	922.0	26.0	9600.0	1390.0	87.4	542.0	<268	20.4	61.3	107.0	6.80	6.63	0.16	2.65
10	1000		11400.0	<2.6	1000.0	28.1	10000.0	1490.0	85.8	572.0	<265	21.8	76.7	109.0	6.00	6.65	0.16	2.52

[1] Treatments received either 800 lbs/A 10-10-10 or 1000 lbs/A 10-10-10 prior to transplanting.

[2] Kelp rates reflective of treatment specifications

[3] Non-replicate soil samples taken on June 10th and sent to PACE Analytical Labs (New York)

Table 5. Post-harvest soil nutrient analysis Riverhead, NY- 2020

			Soil Nutrients[3]															
Treatment	10-10-10[1] lbs/A	Kelp[2] lbs/A	Aluminum (mg/kg)	Boron (mg/kg)	Calcium (mg/kg)	Copper (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Potassium (mg/kg)	Sodium (mg/kg)	Sulfur (mg/kg)	Zinc (mg/kg)	Phosphorus (mg/kg)	Moisture (%)	pH	EC Value	Organic Matter (%)
1	1000	75	11500.0	4.9	791.8	24.8	10907.5	1367.5	95.1	518.0	492.5	83.3	22.5	1105.3	11.23	5.88	0.14	2.50
2	1000	150	11922.5	5.0	806.5	25.0	11320.0	1480.0	90.8	562.3	504.8	100.7	22.9	1101.8	10.33	5.90	0.17	2.52
3	800	75	11975.0	5.1	811.5	25.3	11245.0	1415.0	88.9	526.0	514.0	101.8	22.5	1145.0	11.08	5.95	0.16	2.84
4	800	150	10860.0	5.0	943.3	23.5	10762.5	1475.0	95.3	516.8	500.5	81.0	23.0	1097.5	9.80	6.18	0.15	2.58
5	1000	150	11495.0	5.0	773.8	24.0	10857.5	1427.5	88.5	532.5	496.5	87.6	22.0	1069.8	10.40	6.08	0.16	2.68
6	1000	435	12075.0	5.0	864.3	26.9	11350.0	1450.0	92.4	551.3	501.8	112.0	23.0	1152.5	10.43	6.08	0.16	2.80
7	1000	Foliar	11225.0	5.2	818.8	25.3	10722.5	1317.5	90.3	508.3	518.5	93.3	22.3	1205.0	11.03	6.00	0.16	2.63
8	1000	Foliar	11800.0	5.0	781.8	24.0	11050.0	1402.5	90.3	525.8	503.3	102.5	22.4	1112.5	10.40	5.88	0.18	2.66
9	1000	Foliar	11050.0	5.1	782.8	24.9	10367.5	1257.5	82.0	493.8	504.8	90.4	21.2	1132.5	11.03	6.00	0.15	2.59
10	1000		10930.0	4.9	749.0	24.2	10235.0	1278.8	79.0	484.8	488.0	93.1	21.4	1103.8	10.08	5.98	0.17	2.62
Fisher's Protected LSD (0.05)			*(ns)*	*(ns)*	*(96.2)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*	*(ns)*
Statistical Analysis (0.05)			p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value
Treatment			0.4682	0.6221	0.0187	0.4331	0.6044	0.1925	0.2570	0.4355	0.5918	0.2673	0.8226	0.7393	0.3056	0.5439	0.3900	0.4389

[1] Treatments received either 800 lbs/A 10-10-10 or 1000 lbs/A 10-10-10 prior to transplanting.

[2] Kelp rates reflective of treatment specifications

[3] Replicate soil samples taken on September 14th and sent to PACE Analytical Labs (New York)

Evaluation of Application of Sugar Kelp Extract to Greenhouse-Grown Tomato Seedlings and Petunia and Tomato Transplants

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Numerous research studies have shown benefits to the use of seaweed extracts as fertilizer amendments and/or as biostimulants. Reported benefits include effects on plant growth, increased tolerance to various plant stressors, and others. Norwegian kelp (*Ascophyllum nodosum*), or rockweed, is one of the more commonly studied and used seaweeds in horticulture, with various commercial products currently available. However, while numerous other green, brown, and red seaweeds have also been used and studied, no studies evaluating the use of sugar kelp (*Saccharina latissima*) as a fertilizer amendment or biostimulant have been reported.

Two trials were conducted on greenhouse plants to evaluate the possible effects of locally grown sugar kelp extract applied as an amendment. One trial studied the effects of sugar kelp extract on germination and seedling growth of tomato. The second trial studied the effects of kelp extract on two common greenhouse crops, tomato and petunia, grown using different fertilizer rates – a standard rate and a 50% rate.

Materials and Methods – Tomato Seedling Trial

Kelp Drying and Processing

On 19-May, locally harvested sugar kelp was delivered to the Long Island Horticulture Research and Extension Center (LIHREC) in Riverhead, NY. The kelp was rinsed thoroughly with fresh water and line dried in a greenhouse for 3 days. The kelp was then cut off the growing lines, crushed into smaller pieces by hand into paper bags, and the paper bags were placed in a drying oven at 160°F for 48 hours. After drying the kelp was crushed and ground into a coarse meal using a Meadow Mills steel burr commercial grain mill (Meadow Mills, North Wilkesboro, NC). The kelp was further ground using a coffee grinder to create a fine powder to be used to make the kelp extract.

Kelp Extract Procedure

Kelp extract was prepared for each application by boiling 5g (12-June and 22-June) or 10g (29-June, 6-July, and 13-July) of finely ground, dried kelp, in 100 ml of distilled water for 30 minutes. The solution was then filtered through #4 Whatman paper; a pre-filter through cheesecloth was used on 13-July.

Trial Procedures

Tomato 'Super Sweet' were seeded on 11-June using ProMix BX Mycorrhizae growing media. Seeds were seeded into individual cells of 105-plug trays. Trays were cut in half, creating 49 cells, and treatments were replicated over six 49-cell trays. Seedlings were irrigated with clear water for 2 weeks, until the appearance of first true leaves, after which seedlings were fertigated at each irrigation using 50 ppm N of 15-5-15 fertilizer.

Two rates of sugar kelp extract, 0.5% (5ml/L) and 1% (10ml/L), and an untreated control, were evaluated. Kelp treatments were applied weekly, using a watering can; each cell was estimated to receive 4-5 ml of solution.

Trays were monitored daily for 14 days and the day of germination for each cell was recorded. On 15-July, stem caliper diameter was measured at approximately 1 centimeter above the soil line, seedlings were harvested at the soil line for dry weight determination, and root heath and growth were rated on a scale of 1 to 5, with 5 being the best formed and healthiest root systems. After harvest, growing media was collected and a composite sample from each replicate tray was tested for pH and electrical conductivity (EC) using the 1:2 dilution method and Oakton pHTestr 30 and Oakton ECTestr 11 meters.

Data were subject to Analysis of Variance (ANOVA; JMP) and, where applicable, means were separated using Tukey's HSD (p=0.05).

Results – Tomato Seedling Trial

There were no differences between treatments for germination rate or percent germination (Table 1). However, differences were observed in final plant size (Table 2). Final stem caliper diameter and dry weight were significantly greater for the sugar kelp-extract treatments compared to the untreated control treatment. Differences were observed in root index ratings between treatments, however neither sugar kelp treatment differed from the control.

No difference in media pH was found between treatments. The 1.0% sugar kelp extract had a significantly higher EC compared to the untreated control (Table 3). The EC measurements were all lower than the recommended range of 500-1500 µS/cm (Ball Horticulture, Vegetable and Plug Growing Chart), indicating that the fertilizer rate used was less than optimal. Few significant differences found in nutritional analyses between treatment, most do not indicate clear differences between sugar kelp treatments and the untreated control treatment. (Table 4).

Materials and Methods – Tomato and Petunia Greenhouse Trials

Kelp Drying and Processing

The kelp drying and processing is as described above.

Kelp Extract Procedure

Kelp extract was prepared for each application by boiling 5g or 10g of finely ground dried kelp in 100 ml of distilled water for 30 minutes. The solution was then filtered through #4 Whatman paper; a pre-filter through cheesecloth was used on 13-July and 21-July. On 15-June and 22-June, 5g ground sugar kelp/100 ml distilled water was used to create the extract; 10g/100 ml was used on 29-June, 6-July, 13-July, and 21-July.

Trial Procedures

Tomato 'Super Sweet' and Petunia 'Pretty Grand Purple' were transplanted from 105-plug trays on 21-May into 3.5-in square containers using ProMix BX Mycorrhizae growing media.

Two rates of sugar kelp extract, 0.5% (5ml/L) and 1% (10ml/L) were evaluated under both low (75 ppm N) and standard (150 ppm N) rates of fertilizer. Additionally, the commercially available kelp extract product Stimplex (made from extract of *Ascophyllum nodosum*; 0.5%, 5ml/L) and an untreated control were evaluated under standard fertilization rates. Fertilizer (15-5-15) was applied as constant liquid feed via subirrigation using ebb and flow benches. Treatments were applied weekly, starting the week of transplant, as a drench using a watering can. Each pot received approximately 30 ml of solution. Treatments were applied to tomato on 15-June, 22-June, 29-June, and 6-July, and to petunia on 15-June, 22-June, 29-June, and 6-July, 13-July, and 21-July. Treatments were replicated across 15 single plant replicates. Media pH and electrical conductivity (EC) were measured on three of the replicates every week using the pour-thru method using Oakton pHTestr 30 and Oakton ECTestr 11 meters.

Six replicates per treatment were randomly chosen for plant growth data collection. Data collection occurred after 3 weeks, on 10-July, for tomato and after 5 weeks, 28-July, for petunia. Plant growth data collected included leaf chlorophyll index (as measured with Minolta SPAD-502 meter) taken from 3 recently matured leaves, a root index evaluation where roots were rated on a scale of 1 to 5 (5= best/healthiest), and plants were harvested at the soil line for dry weight determination. For tomato, stem caliper (diameter) was also recorded at approximately 1 centimeter above the soil line. Foliage was saved after recording dry weight to be sent for nutritional analysis (Brookside Laboratories, New Bremen, OH).

The remaining six replicates were subjected to an exploratory drought stress test. Plants were well watered and brought into a room that had an average temperature of 69°F and subjected to 24 hr of fluorescent light (providing an average of 6.75 $\mu mol/m^2/sec$ photosynthetically active radiation, as measured with Apogee Quantum Flux Meter MQ-200). Plants were not further irrigated and were evaluated daily for wilt using a 0 to 5 scale (where 1 = no wilt; 2 = slight flagging of leaves; 3 = flagging of leaves and petioles; 4 = significant flagging and wilt; 5 = total wilt). The tomato drought stress evaluation was initiated on 8-July, and the petunia drought stress evaluation was initiated on 28-July.

Results – Tomato and Petunia Greenhouse Trials

For petunia, higher dry weight was found for both sugar kelp treatments compared to the untreated treatments at the standard fertilizer rate (Table 5). Interestingly, dry weight of the two kelp treatments at the low fertilizer rate were not significantly different compared to the untreated control plants at the standard rate. No significant differences between treatments in root index ratings were found in petunia.

For tomato, at standard fertilizer rates no differences were observed in dry weight, stem caliper diameter, or root index between the sugar kelp treatments, Stimplex, and untreated controls (Table 5). No differences were observed between treatments in stem diameter. A significant reduction of dry weight and a significant increase in root index ratings were observed with the sugar kelp treatments at the low fertilizer rates compared to the untreated control at the standard fertilizer rate. Unfortunately, an untreated control was not included at the low fertilizer rate and it is uncertain if improved root growth is due to the effect of the reduced salts due to the lower fertilizer rate or the sugar kelp extract application or (Table 7).

Differences were found in the pH and EC at the low fertilizer rates compared to the standard rates, but no other significant differences found (Tables 6 and 7). Some studies have reported concerns about salt build up after repeated seaweed or seaweed extract applications; this was not observed in this trial.

No meaningful differences were observed in leaf chlorophyll index values between treatments (Table 8). Few significant different were found between treatments for the foliar analyses (Tables 9 and 10). Lower fertilizer rate affected most nutrients, but few differences were observed to be a result of kelp or seaweed application.

In the drought tolerance evaluation, some differences drought symptoms were observed between treatments, with some treatments showing improvement and a delay in drought symptoms over the control (Figures 1 and 2). As this portion of the trial was merely exploratory, it cannot be decisively concluded without further study that sugar kelp treatments significantly affected drought tolerance. Future studies should investigate this more thoroughly.

Final Comments

These trials show that there is some promise for the use of sugar kelp as an amendment. While, in this trial, tomato transplants did not show an improvement in growth with sugar kelp application, tomato seedlings in plug trays treated with sugar kelp extract did show increased plant size. Petunia transplants showed an increase in plant size for the sugar kelp treatments compared to the untreated control, as well as no reduction in growth for plants treated with sugar kelp grown at half the fertilizer rate as the untreated control. For some plants it might be possible that sugar kelp be used as amendment which allows for a reduced fertilizer rate to be applied. The mechanisms of improved plant growth where seen are not yet understood. The nutritional analyses did not clearly show that kelp application resulted in increased overall uptake; either these trial results did not elucidate differences or another mechanism is involved.

The sugar kelp application rates of 0.5% and 1.0% were chosen based on rates recommended or used for other seaweed extracts. These results did not determine which of those two rates is most beneficial, though given the plant responses seen they appear to be a good starting point, at least for petunia and tomato seedlings. Further research would be needed to better determine the most effective rates and application methods for different plants.

While this trial only conducted an exploratory drought stress evaluation, the differences observed indicate that this may be an area for further investigation. Other seaweed extracts have been reported to affect tolerance to drought stress, it would be relevant and interesting to identify whether sugar kelp has the same effects.

Other future research that would be relevant for ornamental plants could include investigating effects on other characteristics such as plant appearance and quality, effect on number of flowers, and post-harvest quality.

Tables – Greenhouse Tomato Seedling Trial

Table 1. Effect of applications of sugar kelp extract on germination rate and percent germination of tomato.

Treatment	Days to Germination	% Germination
0.5% sugar kelp extract	6.3 a	97.0 a
1.0% sugar kelp extract	6.4 a	96.3 a
Untreated Control	6.4 a	95.3 a

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

Table 2. Effect of applications of sugar kelp extract on the growth of tomato seedlings after 5 weeks growth.

Treatment	Stem Caliper (mm)	Dry Weight (g)	Root Index (0-5 scale)
0.5% sugar kelp extract	1.94 a	0.056 a	4.0 b
1.0% sugar kelp extract	1.89 b	0.055 a	4.2 a
Untreated Control	1.79 c	0.051 b	4.1 ab

Root index was evaluated on a scale of 1-5, where 5=best/healthiest
Means within a column with similar letters are not significantly different according to Tukey's HSD (p=0.05)

Table 3. Effect of applications of sugar kelp extract on tomato plug tray media pH and electrical conductivity (EC) after 5 weeks.

Treatment	pH	EC (µS/cm)
0.5% sugar kelp extract	6.80 a	240 ab
1.0% sugar kelp extract	6.80 a	287 a
Untreated Control	6.83 a	217 b

Means within a column with similar letters are not significantly different according to Tukey's HSD (p=0.05)

Table 4. Effect of applications of sugar kelp extract on final foliar nutritional analyses of tomato seedlings.

Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Iron (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
0.5% sugar kelp extract	1.77 a	0.542 a	0.444 a	4.75 a	2.20 a	0.733 a	33.6 ab	81.8 a	341 a	12.3 ab	50.6 a	36.4 a	1320 a
1.0% sugar kelp extract	1.57 a	0.485 a	0.425 a	4.58 a	2.20 a	0.661 b	34.4 a	64.9 a	334 a	11.6 b	44.2 a	34.2 a	1297 a
Untreated Control	1.77 a	0.499 a	0.449 a	4.50 a	2.25 a	0.746 a	31.0 b	56.3 a	320 a	13.0 a	46.1 a	41.4 a	1073 b

Means within a column with similar letters are not significantly different according to Tukey's HSD (p=0.05)

Tables and Figures – Greenhouse Tomato and Petunia Transplant Trials

Table 5. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on growth of petunia and tomato.

	Dry Weight (g)		Stem Caliper (mm)	Root Index (1-5 scale)	
Treatment	**Petunia**	**Tomato**	**Tomato**	**Petunia**	**Tomato**
0.5% sugar kelp extract, 150 ppm N	2.80 ab	8.62 a	5.30 a	3.7 a	3.8 b
1.0% sugar kelp extract, 150 ppm N	2.95 a	8.42 a	5.06 a	3.7 a	3.8 b
0.5% sugar kelp extract, 75 ppm N	2.22 abc	6.38 c	5.28 a	3.5 a	4.8 a
1.0% sugar kelp extract, 75 ppm N	2.30 abc	6.65 bc	5.07 a	3.5 a	5.0 a
0.5% Stimplex, 150 ppm N	2.03 bc	7.78 ab	5.22 a	3.5 a	3.8 b
Untreated control, 150 ppm N	1.85 c	8.58 a	5.08 a	3.3 a	3.8 b

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 6. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on petunia media pH and electrical conductivity (EC) as measured with the pour-thru procedure.

	pH				EC			
Treatment	**24-Jun**	**1-Jul**	**7-Jul**	**16-Jul**	**24-Jun**	**1-Jul**	**7-Jul**	**16-Jul**
0.5% sugar kelp extract, 150 ppm N	5.73 b	5.59 b	5.42 b	5.31 abc	1203 a	1190 a	1117 a	1190 a
1.0% sugar kelp extract, 150 ppm N	5.71 b	5.52 b	5.08 bc	5.13 bc	1160 a	1167 a	1200 a	1290 a
0.5% sugar kelp extract, 75 ppm N	6.01 a	5.99 a	5.95 a	5.54 ab	610 b	540 b	490 b	567 b
1.0% sugar kelp extract, 75 ppm N	6.06 a	5.95 a	6.00 a	5.69 a	620 b	563 b	457 b	537 b
0.5% Stimplex, 150 ppm N	5.73 b	5.52 b	5.26 bc	5.03 c	1187 a	1260 a	1250 a	1280 a
Untreated control, 150 ppm N	5.63 b	5.40 b	4.98 c	5.08 c	1193 a	1230 a	1183 a	1240 a

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 7. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on tomato media pH and electrical conductivity (EC) as measured with the pour-thru procedure.

	pH			EC		
Treatment	**24-Jun**	**1-Jul**	**7-Jul**	**24-Jun**	**1-Jul**	**7-Jul**
0.5% sugar kelp extract, 150 ppm N	5.70 b	5.61 a	5.31 a	1007 a	1033 a	1367 a
1.0% sugar kelp extract, 150 ppm N	5.79 b	5.67 a	5.54 a	1010 a	980 a	1040 ab
0.5% sugar kelp extract, 75 ppm N	6.22 a	5.66 a	5.47 a	413 b	503 b	413 b
1.0% sugar kelp extract, 75 ppm N	6.31 a	5.67 a	5.61 a	383 b	510 b	410 b
0.5% Stimplex, 150 ppm N	5.83 b	5.64 a	5.16 a	973 a	1017 a	1507 a
Untreated control, 150 ppm N	5.76 b	5.63 a	5.18 a	980 a	1030 a	1313 a

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 8. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on leaf chlorophyll index of petunia and tomato.

	Leaf Chlorophyll Index	
Treatment	**Petunia**	**Tomato**
0.5% sugar kelp extract, 150 ppm N	24.4 ab	49.8 ab
1.0% sugar kelp extract, 150 ppm N	25.7 a	51.9 a
0.5% sugar kelp extract, 75 ppm N	20.4 c	49.5 ab
1.0% sugar kelp extract, 75 ppm N	22.3 bc	47.1 b
0.5% Stimplex, 150 ppm N	23.4 ab	49.6 ab
Untreated control, 150 ppm N	23.9 ab	49.2 ab

Leaf chlorophyll index measured using a chlorophyll meter (Minolta SPAD-502).
Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 9. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on final foliar nutritional analyses of petunia.

Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
0.5% sugar kelp extract, 150 ppm N	6.01 ab	0.935 a	0.410 ab	8.80 a	1.91 a	0.482 b	24.0 a	215 a	219 b	11.4 b	206.5 b	122.3 a	3770 ab
1.0% sugar kelp extract, 150 ppm N	6.29 a	0.951 a	0.376 b	9.34 a	1.81 a	0.478 b	23.8 a	171 a	232 b	12.4 b	212.6 b	90.6 a	3690 ab
0.5% sugar kelp extract, 75 ppm N	4.69 c	0.983 a	0.479 a	8.87 a	1.94 a	0.619 a	21.9 ab	139 a	354 a	13.1 ab	317.0 a	101.6 a	4350 ab
1.0% sugar kelp extract, 75 ppm N	4.59 c	0.910 a	0.454 a	8.52 a	2.01 a	0.594 a	22.5 a	134 a	366 a	15.3 a	351.3 a	90.9 a	4525 a
0.5% Stimplex, 150 ppm N	5.78 b	0.986 a	0.409 ab	9.12 a	1.92 a	0.591 a	22.4 ab	180 a	244 b	12.7 ab	209.8 b	156.0 a	3795 ab
Untreated control, 150 ppm N	5.80 b	0.991 a	0.417 ab	8.73 a	1.89 a	0.547 ab	19.8 b	175 a	235 b	12.9 ab	187.0 b	93.5 a	3405 b

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Table 10. Effect of applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*) on final foliar nutritional analyses of tomato .

Treatment	N (%)	P (%)	Mg (%)	K (%)	Ca (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	Na (ppm)
0.5% sugar kelp extract, 150 ppm N	5.51 a	0.736 ab	0.533 b	5.31 a	2.34 a	0.501 a	67.7 ab	122 a	250 b	11.0 a	108.7 a	59.9 a	2010 ab
1.0% sugar kelp extract, 150 ppm N	5.54 a	0.734 ab	0.536 b	5.40 a	2.50 a	0.523 a	68.8 ab	123 a	267 b	11.4 a	105.6 a	47.0 a	2313 a
0.5% sugar kelp extract, 75 ppm N	3.76 b	0.684 b	0.643 a	4.54 b	2.40 a	0.593 a	59.0 b	104 a	348 a	10.4 a	106.5 a	38.3 a	2158 ab
1.0% sugar kelp extract, 75 ppm N	3.72 b	0.663 b	0.634 a	4.48 b	2.34 a	0.582 a	57.2 b	103 a	353 a	10.4 a	103.7 a	37.5 a	2200 ab
0.5% Stimplex, 150 ppm N	5.62 a	0.777 a	0.533 b	5.25 a	2.54 a	0.586 a	76.3 a	127 a	291 ab	12.7 a	111.0 a	62.2 a	2053 ab
Untreated control, 150 ppm N	5.79 a	0.794 a	0.540 b	5.40 a	2.62 a	0.604 a	72.3 ab	328 a	287 ab	13.4 a	115.3 a	60.8 a	1945 b

Means within a column with similar letters are not significantly different according to ANOVA and Tukey's HSD (p=0.05)

Figure 1. Drought stress evaluation of petunia plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*). Plants were irrigated on 28-July with no further irrigation and were evaluated daily for wilt using a 0 to 5 scale (1 = no wilt; 2 = slight flagging of leaves; 3 = flagging of leaves and petioles; 4 = significant flagging and wilt; 5 = total wilt).

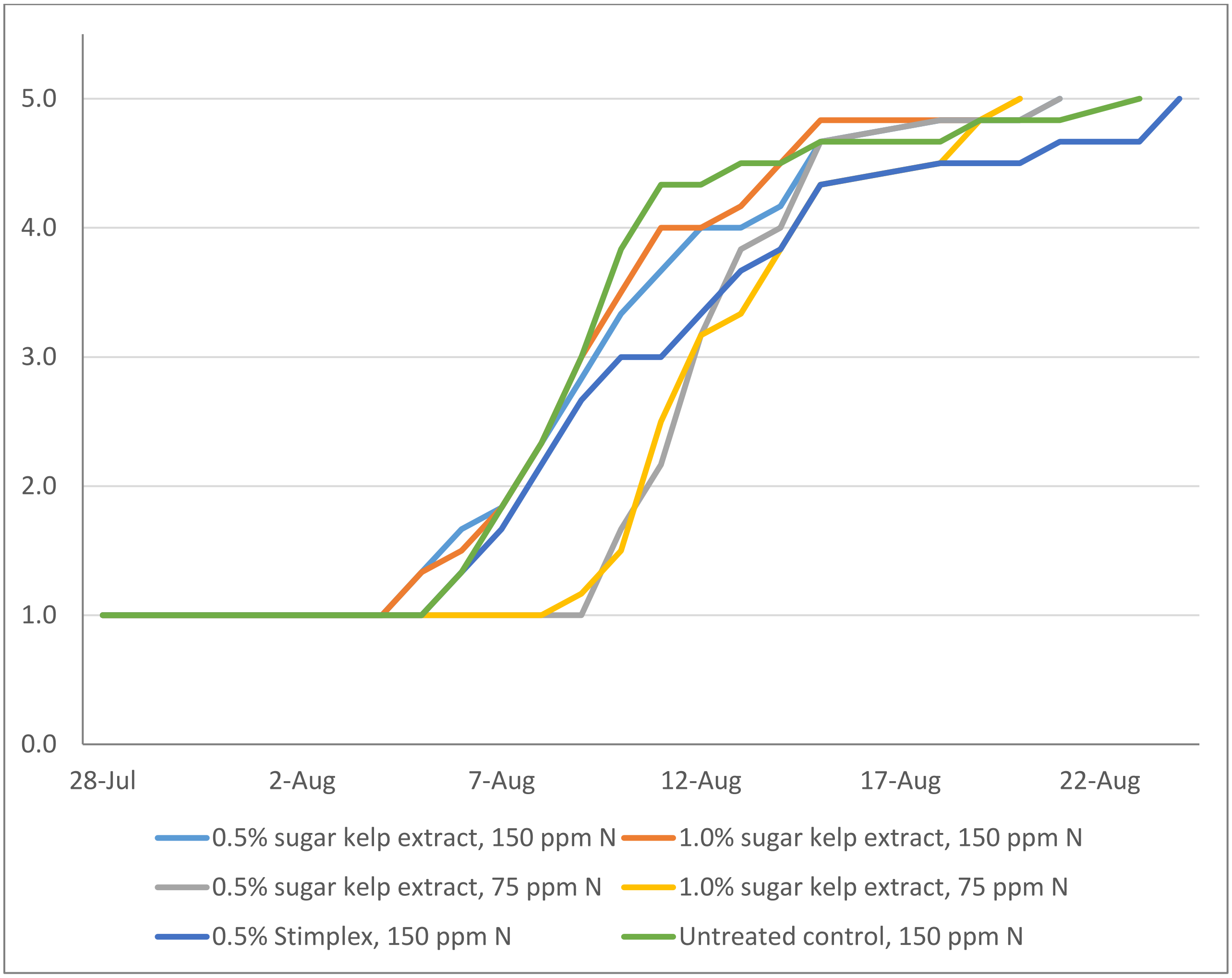
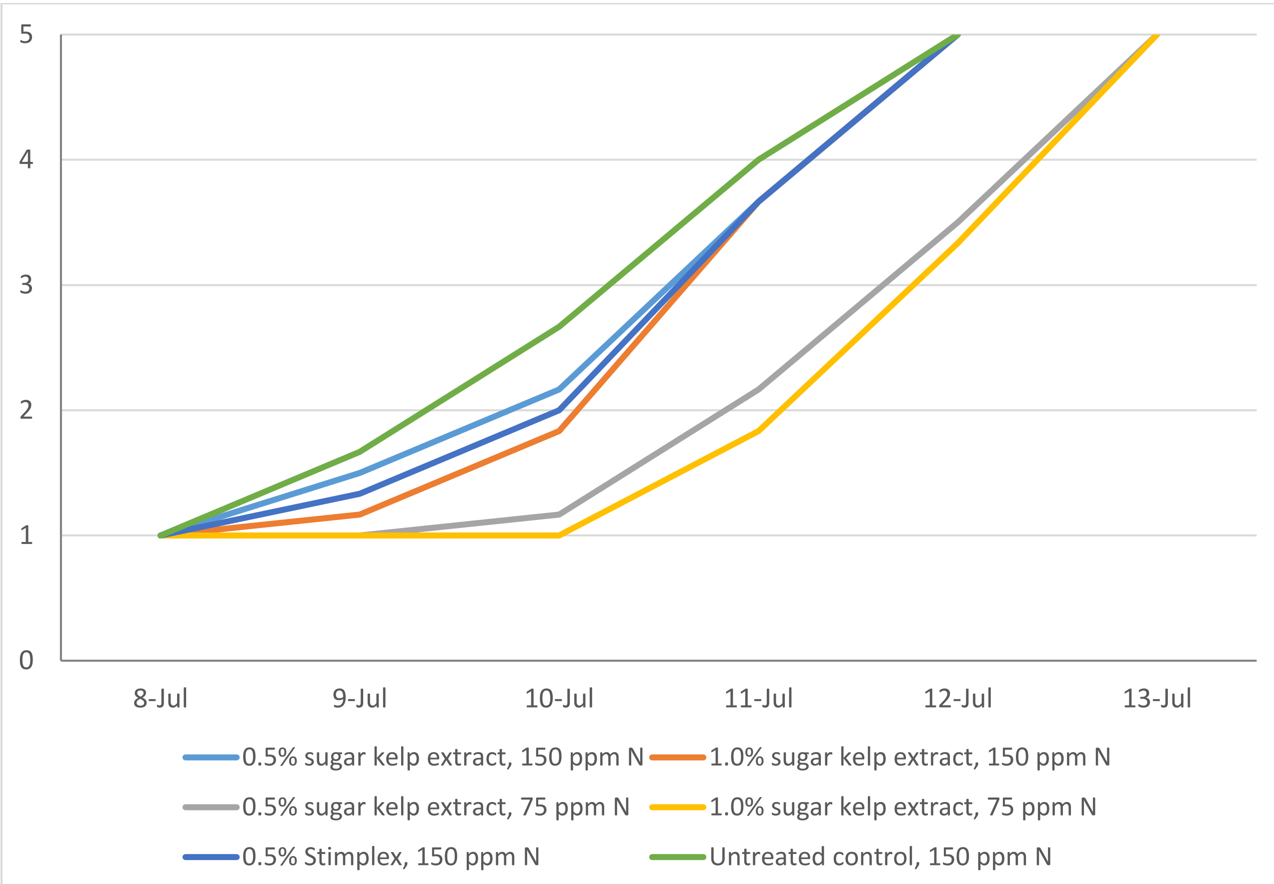


Figure 2. Drought stress evaluation of tomato plants treated with applications of sugar kelp extract and Stimplex (extract of *Ascophyllum nodosum*). Plants were irrigated on 8-July with no further irrigation and were evaluated daily for wilt using a 0 to 5 scale (1 = no wilt; 2 = slight flagging of leaves; 3 = flagging of leaves and petioles; 4 = significant flagging and wilt; 5 = total wilt).



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