

# EFFECT OF LIQUID ORGANIC FERTILIZERS AND SEAWEED EXTRACT ON *DAUCUS CAROTA* VAR. *SATIVUS* GROWTH CHARACTERISTICS

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## ABSTRACT

Common N fertilizers used in organic production are often energy intensive to produce and expensive to transport. Cyanobacteria fertilizer produced on-farm could decrease impacts on the environment as well as production costs for organic farmers. In addition, cyanobacteria fertilizer could perform similarly to products marketed to increase production via plant growth hormones such as seaweed extract. The effects of common organic fertilizers as well as organic liquid cyanobacteria fertilizer on carrot (*Daucus carota* var. *sativus*) growth and yield characteristics were tested during a field experiment at the Horticulture Field Research Center in Fort Collins, CO in 2014. Hydrolyzed and non-hydrolyzed fish emulsion, and cyanobacteria treatments were applied at 42.5 lbs N • acre<sup>-1</sup> distributed among five applications approximately 2 weeks apart. Control treatments received no supplemental N. Each treatment, including the control, was repeated with the addition of concentrated (400 ppm cytokinin as kinetin) organic seaweed extract applied foliarly. Seaweed extract was applied at the manufacturer's recommended rate of 3 applications of 1 pt • acre<sup>-1</sup>. All treatments produced carrots with similar yield, above-ground dry weight and plant height, leaf to stem ratio, sap nitrate, root branching behavior, and incidence of root cracks. Cyanobacteria treatments with and without seaweed, hydrolyzed fish treatments with and without seaweed, and non-hydrolyzed fish treatment with seaweed reduced carrot root knobs compared to non-hydrolyzed fish and the control treatments. Cyanobacteria and hydrolyzed fish treatments reduced size deformities (root is well below average length at maturity) compared to the control. Plant stress was quantified by creating a scale for observations of above-ground organs (bolting, chlorosis, leaf discoloration). Cyanobacteria plus seaweed, hydrolyzed fish, and control plus seaweed treatments decreased stress compared to both fish emulsion plus seaweed treatments. These observations may be the result of differing phytohormone levels measured in the fertilizer treatments, differing levels of micronutrients applied, and/or environmental factors such as soil conditions or soil pests.

## INTRODUCTION

Organic agriculture, like conventional agriculture, relies heavily on nitrogen (N) inputs to increase yield in food crops. Traditionally, organic farmers turn to manure, compost, and organic fertilizers such as fish emulsion to supply extra N. Purchasing and transporting fertilizers such as fish emulsion can be costly and can have a large carbon footprint, contrary to the aims of organic agriculture. Cyanobacteria are an omnipresent phylum of bacteria capable of photosynthesis and atmospheric nitrogen fixation, a talent not shared by plants. Cyanobacteria can be applied to

crops through a fertigation system, where soil microbes mineralize the N for plant use. By culturing cyanobacteria organically on-farm, organic farmers can harness the N gathering power of these prokaryotes and potentially eliminate the cost and carbon footprint of purchasing and transporting traditional organic fertilizers.

Additionally, preliminary data shows that phytohormones are present in cyanobacterial cultures as shown in Table 1. Phytohormones, also known as plant growth regulators, are marketed by manufacturers to stimulate plant growth when applied exogenously. Organic farmers can purchase products such as organic liquid seaweed extract to apply exogenous phytohormones to crop foliage or as a soil soak. Seaweed products are best known for their auxin and cytokinin contents, as these endogenous phytohormones are responsible for cell division and root and shoot elongation, respectively (Hamza and Suggars, 2001). Salicylic acid, also found in liquid cyanobacteria in this study, is known to play a role in plant response to abiotic stress (Kumar, 2014). A newly discovered plant hormone, strigolactone, interacts closely with auxin within plants and has been connected with branching behavior in peas (Gomez-Rolden et al., 2008). Changing branching behavior of food crops could increase yield and provide better weed control for organic farmers. The jury is still out on the potential impact of applying plant growth regulators for increased yield or plant health. Hamza and Suggars (2001) found that exogenously applied phytohormones improved the quality of turf grass only when used in conjunction with nitrogen fertilizers, but the combination led to higher quality grasses than nitrogen fertilizer alone. Hemphill (1981) found that only one of five vegetables tested (including carrots) produced greater yield in response to cytokinin. However, Aliyu et al. (2011) found that pre-bloom application of phytohormones increased flowering and fruiting in cashews.

The objectives of this study were to 1) evaluate liquid cyanobacteria as compared to traditional organic fertilizers in providing adequate N to increase yield in food crops, and 2) characterize the impact on vegetables of applying exogenous phytohormones from liquid cyanobacteria as compared to marketed products such as liquid seaweed.

Table 1. Fertilizer phytohormone content and application amount in field experiment.

<b>Fertilizer</b>	<b>Auxin</b>	<b>Salicylic Acid</b>	<b>Cytokinin</b>	<b>Amount Phytohormone Applied at Equal N Rate</b>
	-----ppm-----			---lb/acre---
cyanobacteria	6.500E-05	5.917E-03	n/m	0.019
hydrolyzed fish	3.970E-04	0.018	n/m	2.596E-05
non-hydrolyzed fish	1.436	0.077	n/m	1.287E-03
seaweed	0.802	48.170	400**	5.940E-07*

\* seaweed N content = 0, applied at manufacturer's recommendation

\*\* according to manufacturer

n/m – none measured

## **METHODS**

Phytohormone analysis was performed by the Colorado State University Proteomics and Metabolomics Facility in Fort Collins, CO. The assay tested for three auxin compounds, and the cytokinin zeatin. No zeatin was detected in the N fertilizer samples. The manufacturer of the liquid seaweed guarantees 400 ppm cytokinin content as kinetin.

Field experiments were conducted on certified organic land at the Colorado State University Horticultural Research Center in Fort Collins, CO. The soil in this location was described in 1980 as a fine, smectitic, mesic, Aridic Argiustoll of the Nunn series (NRCS). Soil N analysis was performed by Ward Laboratories Inc. in Kearney, NE. Pre-planting N concentration at the site of the experiment was 45.0 lbs N • acre<sup>-1</sup>. Organic Nectar carrot (*Daucus carota var. sativus*) seeds and organic seaweed extract were purchased from Johnny's Selected Seeds, and carrots were planted, then thinned, in a randomized complete block design and assigned treatments as shown in Table 2. Fish fertilizers were purchased from Fort Collins Nursery in Fort Collins, CO. Each treatment was applied to a row containing approximately 40 plants, and the center 10 plants from each row were selected for measurements. Each treatment was repeated in four replications. Daily irrigation was through a drip system, and fertilizer applications were applied through the same system by selectively closing stop valves and rinsing lines after each fertigation. Fertigation occurred five times, approximately every two weeks. Fish treatments were applied at the N rate achieved by the cyanobacteria applied for each treatment, measured on the same day. N was applied at 42.5 lbs N • acre<sup>-1</sup> over the growing season. Seaweed was applied foliarly with a backpack sprayer at a rate of 1 pt • acre<sup>-1</sup> three times over the season: immediately after appearance of seedlings, mid-growth, and 20 days before maturation.

Table 2. Description and fertilizer grade for treatments used in field experiment.

<b>Treatment</b>	<b>Fertilizer</b>
Cyanobacteria	liquid cyanobacteria
Cyanobacteria+S	liquid cyanobacteria + foliar SeacomPGR Organic Seaweed Concentrate***
Hydrolyzed fish	Neptune's Harvest Organic Fish Fertilizer**
Hydrolyzed fish+S	Neptune's Harvest Organic Fish Fertilizer** + foliar SeacomPGR Organic Seaweed Concentrate***
Non-hydrolyzed fish	Alaska Fish Fertilizer*
Non-hydrolyzed fish+S	Alaska Fish Fertilizer* + SeacomPGR Organic Seaweed Concentrate***
Control	None
Control+S	SeacomPGR Organic Seaweed Concentrate***

\*Alaska Fish Fertilizer - fertilizer grade: 5-1-1

\*\*Neptune's Harvest - fertilizer grade: 2-4-1

\*\*\*SeacomPGR Organic Seaweed Concentrate - fertilizer grade: 0-4-4

Carrots were planted on May 20<sup>th</sup>, 2014 and were harvested on September 6<sup>th</sup>, 2014. Growing season measurements included plant height and stress status which were taken every two weeks. To quantify stress a scale was created in which 1-5 points were assigned to stressed plants according to the apparent severity of the stress. Harvest measurements included yield according to weight, root length, root girth at the shoulder (widest part of the root), and root deformities. Deformities such as root knobs, root branching, root cracks, and underdeveloped root length were tallied. Any carrots roots which were well below average length when mature were considered underdeveloped. An example is depicted in Figure 1. Leaves were separated from stems of the shoot and shoot sap nitrate was measured with a LAQUAtwin Plant Sap and Soil Nitrate Meter. Leaves were dried at 120° F for 3 days. Leaves to stems ratios of dried materials were calculated to determine differences in shoot branching behavior.

Figure 1. Example of an underdeveloped root.



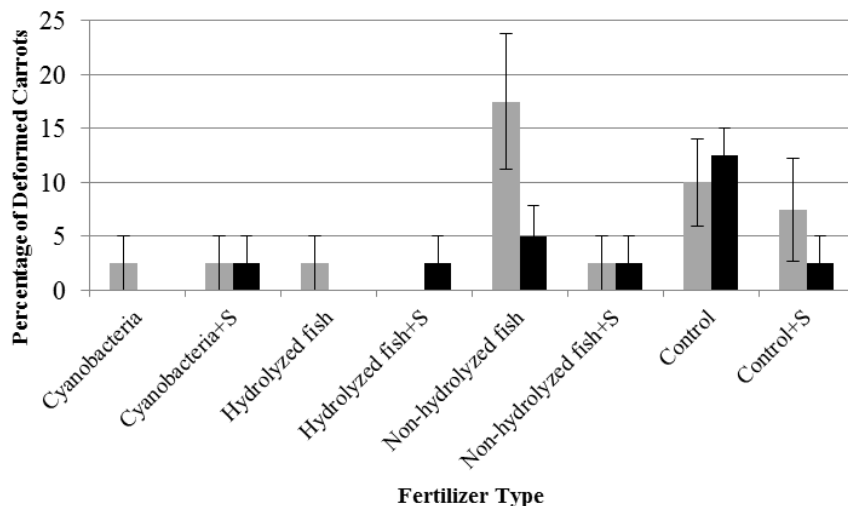
## RESULTS AND DISCUSSION

All treatments produced carrots with statistically similar yield, above-ground dry weight, plant height, and shoot sap nitrate. These conclusions, in addition to the observation that no plants showed signs of nitrogen deficiency, lead us to conclude that no plants were nitrogen deficient. Though the starting soil N content of  $45.0 \text{ lbs N} \cdot \text{acre}^{-1}$  may have been sufficient for growth, these results indicate that farm-grown liquid cyanobacteria could be competitive with other commonly used organic fertilizers for crop production. There was no significant difference in leaf to stem ratios in the shoot, root branching frequency, or incidence of root cracks, contrary to the hypothesis that additional exogenous phytohormones would impact these characteristics in carrots. Interestingly, cyanobacteria treatments with and without seaweed, hydrolyzed fish treatments with and without seaweed, and non-hydrolyzed fish treatment with seaweed reduced carrot root knobs compared to non-hydrolyzed fish and the control treatments, shown in Figure 2. Some vegetable root knobs can be caused by root-knot nematode or compacted soils (Kratochvil et al., 2004). Further experimentation is required to determine the cause of decreased occurrence of root knobs in this study, and to determine the role of exogenous phytohormones.

Cyanobacteria and hydrolyzed fish treatments reduced size deformities compared to the control (Figure 2). Again, size deformities can be caused by soil pests and soil conditions, but further experimentation will determine if application of phytohormones also affects length deformities in carrots.

Cyanobacteria plus seaweed, hydrolyzed fish, and control plus seaweed treatments decreased stress status during the growing season compared to both fish emulsion plus seaweed treatments. Salicylic acid, present in higher amounts in cyanobacteria and seaweed treatments, is known to play a role in plant resistance to biotic and abiotic stressors, and exogenous application may have influenced stress levels in this experiment. However, increased stress observed in both fish plus seaweed treatments remains unexplained, and further experiments, especially into salt contents of treatments and their potential effect on plant salt stress, are needed.

Figure 2. Frequency of carrot root deformities by treatment, root knobs in gray and underdeveloped length in black.



## SUMMARY

This work was useful in demonstrating the potential of farm-grown liquid cyanobacteria fertilizer as an option that provides competitive yields for organic farmers. However, due to high initial soil organic matter and NO<sub>3</sub>-N levels, no yield effects were seen. Initial research into the effect of phytohormones present in organic fertilizers on growth characteristics of crops seems to show promise. However, more species should be explored for changes in growth characteristics such as shoot branching and their effect on yield. Also, greater differences in fertilizer effect may be seen in a greenhouse experiment with N deficient conditions.

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**OF THE**  
WESTERN NUTRIENT  
MANAGEMENT CONFERENCE

**Volume 11**

**MARCH 5-6, 2015**  
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