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Organic farming research project report submitted to the Organic Farming Research Foundation:

Project Title:

The integration of foliar applied seaweed and fish products into the fertility management of organically grown sweet peppers

FINAL PROJECT REPORT

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SUMMARY

Seaweed extracts and fish emulsion products are commonly used by organic vegetable growers to stimulate plant growth and increase yields. The efficacy and cost-effectiveness of using these products, however, has not been conclusively determined. In these studies, we examined the use of these products for organic production of bell peppers in western North Carolina. On-farm trials and research station studies showed no response of plant growth or pepper yield to applications of one manufacturer's brand of seaweed and fish products.

INTRODUCTION

Organic vegetable growers commonly use seaweed extracts and fish emulsions that are allowed for certified organic production by the USDA National Organic Program. The advertised benefits of these products include improved crop vigor and yields; increased disease, insect, and frost resistance; and extended shelf life of produce. Growers use seaweed and fish products in different ways in many aspects of production, such as drench fertilizing during transplant production, injecting through the irrigation system early in the growing season, and as foliar sprays during all stages of plant growth.

One of the most common uses of sea-based products is as foliar fertilizers. Foliar fertilization is the application, via spraying, of nutrients to leaves and stems where they are absorbed into the plant (Alexander, 1985). Organic growers may use sea-based foliar fertilizers to supplement their soil fertilizers, either by spraying bi-weekly throughout the growing season or by spraying one-time mid-season as a nutrient boost.

Although these products are in common use, the question remains if and when seaweed and fish fertilizers are efficacious as foliar fertilizers in organic production. Researchers have reported mixed results on the effectiveness of these products. Seaweed foliar applications increased harvestable bean yields by an average of 24% (Temple, 1989), staked tomato yields by up to 99% (Csizinszky, 1984), early yield of one variety of greenhouse cucumber (Passam et al., 1995), and greenhouse tomato total fruit fresh weights by 17% (Crouch and Van Staden, 1992). Yet many other researchers have reported that applications of various seaweed products did not affect yield at all. For example, seaweed foliar sprays failed to increase yield of wheat (Miers and Perry, 1986), onions (Fiebert et al, 2003), or field tomatoes (Tourte et al., 2001).

Research on fish emulsions has been equally inconclusive. When applied as a soil drench fertilizer to greenhouse-grown plants, growth and yield in plants receiving fish soluble nutrients (FSN) were comparable to plants receiving an inorganic fertilizer (Aung and Flick, 1980, Emino 1981). Further, soil fertilization with FSN increased the mineral content of the edible organs of peas, tomatoes, lettuce, and radish above those same vegetables fertilized with standard Hoagland nutrient solution (Aung et al., 1983). When applied as a foliar spray to field-grown tomatoes and grain, though, there was no increase in yield compared to the control (Miers and Perry, 1986, Tourte et al., 2001).

The success of seaweed and fish sprays in crop production appears dependent on a number of factors, including the crop sprayed, the rate of application, the composition of the extract used, and the existing soil fertility. In the past, the adoption of foliar fertilization has been limited by the cost of the sprays, the labor for application, and inconsistent crop responses. As these products continue to grow in popularity among organic growers, growers need to know the situations in which seaweed and fish foliar fertilizers can be most beneficial and cost-effective.

OBJECTIVES

Organic vegetable growers regularly use sea-based products, such as seaweed extracts and fish emulsions, as foliar fertilizers. The effective use and the economic value of these products in organic agriculture have yet to be verified by scientific research. In these studies, we examined the effects of foliar applied seaweed and fish products on sweet bell peppers grown at three different soil fertility levels.

MATERIALS AND METHODS

On-farm Studies

During the summers of 2002 and 2003, we evaluated three foliar fertilizers on transplanted sweet bell peppers. The trials were conducted at Mountain Harvest Organics, a certified organic farm in Madison County, North Carolina, that routinely sprays their vegetable plants with seaweed extract and fish emulsion products. Carl and Julie Evans, owners of Mountain Harvest Organics, collaborated on the research.

In 2002, 'Red Knight X3R' sweet bell pepper (*Capsicum annuum* L.) (Johnny's Selected Seeds, Winslow, ME) transplants were organically grown at the farm. Prior to transplanting, the field was prepared, fertilized, and plots were laid out. The experimental design was a randomized complete block with four replications. The main plots were the spray treatments (fish, seaweed, fish/seaweed, and water) and were 10 ft long and 4 ft wide. Irrigation was provided through drip-tape laid down the center of the raised beds on the soil surface. The beds were then covered with black landscape cloth. The peppers were hand transplanted into precut holes in the landscape cloth, two rows to a bed, staggered at 18 inch spacing.

The foliar fertilizers tested were Fish Hydrolysate (2-4-1), Seaweed Plant Food (0-0-1), and Fish/Seaweed Blend Fertilizer (2-3-1) (Neptune's Harvest, Gloucester, MA). The products were diluted to the recommended rate of one ounce of concentrate to one gallon of water. Peppers were sprayed at 14-day intervals starting at transplanting. The spray was applied with a Solo 425 Backpack Sprayer (Solo, Inc., Newport News, VA) until the spray began to drip off from the foliage. Applications were made before 10:00 a.m. on application days. Control plots were sprayed with tap water.

Peppers were harvested at maturity twice. The peppers were graded according to USDA grading standards for sweet bell peppers. Number and weights were recorded for each grade from each plot.

Since many growers believe that fish and seaweed products are most effective when plants are experiencing some kind of stress, such as nutrient deficiency, in 2003, soil fertilizer treatments were added to the above study. The experimental design was a split-plot with four replications. Main plots, 40 ft long, were soil fertilizer treatments (with fertilizer and without fertilizer), and sub-plots, 10 feet long, were the spray treatments (fish emulsion, seaweed extract, fish/seaweed blend, and water). Soybean meal (Community Mill, Inc., Hendersonville, NC) was applied at 1950 lb/acre to the fertilized plots. The meal was hand broadcast on the beds and incorporated with a rotovator. The beds were covered and planted as described above.

Just prior to planting in 2003, a power outage caused the greenhouse to overheat, killing the on-farm organic pepper transplants. Since no other organic pepper transplants could be located at that time, conventionally produced 'Camelot X3R' pepper transplants were used as a substitute.

Three weeks into the study, 80% of the pepper plants were affected by *Phytophthora capsici*. Five weeks after transplanting, there was 50% mortality. The study was terminated.

Research Station Studies

Studies similar to the on-farm foliar fertilization studies were conducted during the summers of 2002 and 2003 at the Mountain Horticultural Crops Research Station in Fletcher, North Carolina. These studies were funded by a USDA-IFAFS grant project led by the University of Tennessee. We are including results from those studies here to supplement the on-farm trials supported by the Organic Farming Research Foundation.

The fields used for these studies on the research station were not certified organic, but organic practices were followed as closely as possible. Both years, the experimental design was a split-plot with 4 replications. Main plots, 125 ft long, were soil fertilizer treatments (high rate, medium rate, and a no fertilizer control), and sub-plots, 18 ft long, were the foliar spray treatments. The foliar treatments consisted of Fish Hydrolysate (2-4-1), Seaweed Plant Food (0-0-1), and Fish/Seaweed Blend Fertilizer (2-3-1) (Neptune's Harvest, Gloucester, MA); 20-20-20 (Southern Ag, Palmetto, FL); and a water control. Products were all applied at the label recommended rates. Starting at transplanting, the peppers were sprayed with a Solo backpack sprayer at 14-day intervals for a total of seven sprays.

Soybean meal was hand broadcast at a high rate, 4400 lb/acre, and a medium rate, 2200 lb/acre. No fertilizer was applied to the control treatment. Three ft wide beds, on 5 ft centers, were then machine formed and covered with black polyethylene mulch. Irrigation was by drip-tape laid in bed centers, 2 inches below the soil surface.

'X3R Camelot' sweet peppers (*Capsicum annuum* L.) (Twilley Seed Co., Hodges, South Carolina) transplants were grown at the station in 50 cell flats (Winstrip, Inc., Fletcher, NC). In 2002, eight-week old pepper plants were machine transplanted in a single row at 18 inch spacing the day following soil fertilization and bed formation. In 2003, the peppers were planted one week after soil fertilization and bed formation.

Plant tissue and soil samples were taken several times during the growing season to assess treatment differences. Peppers were harvested at maturity over two (2002) and three (2003) harvests. In 2002, foliage was harvested from each subplot (15 treatments X 4 reps = 60 samples) at the end of the growing season according to the recommended plant tissue sampling guidelines for peppers (NC Department of Agriculture and Consumer Services, 2003). The tissue was analyzed at the NC Department of Agriculture and Consumers Services (NCDA) Analytical Laboratory for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B.

Significant differences were determined using analysis of variance from the general linear model procedure (GLM) of the Statistical Analysis System 8.1 (SAS Institute, 1999) with soil and foliar fertilizer applications as sources of variation.

RESULTS

On-farm Studies

In 2002, there were no significant differences in yield or fruit grade among the foliar spray treatments (Table 1). The on-farm pepper yields were comparable to the pepper yields obtained in the research station studies. Due to high plant mortality, no yield data were collected for the 2003 on-farm study.

Research Station Studies

In 2002, peppers transplanted one day after application of both rates of soybean meal suffered severe root damage. The fertilized peppers that survived remained severely stunted throughout the growing season. While use of soybean meal affected soil and plant nutrient levels and crop yields, the foliar sprays had no effect on any variable measured (Table 2).

In 2003, all peppers planted into soil fertilized with soybean meal exhibited some initial signs of wilting, but recovered quickly. The delayed planting and the high amount of rain throughout the 2003 growing season may have contributed to the reduction in fertilizer injury compared to what occurred in 2002, which was a drought year. As in 2002, however, there were no differences in yield or fruit grade among the spray treatments (Table 3).

DISCUSSION

It would be difficult to meet the macronutrient needs of a growing plant with foliar fertilizers alone. Multiple applications would be necessary to supply a sufficient continuous supply of the nutrients. The marine derived foliar fertilizers used in this study had very low NPK values (fish 2-4-1 and seaweed 0-0-1). Even with up to seven applications during the growing season, the amount of macronutrients actually provided to the plants in this study was minimal and therefore had little effect on the plants. In the 2003 research station study, we successfully altered soil fertility levels with the SBM soil treatments. By the end of the season, pepper plants grown with the medium rate of SBM had produced 18% more peppers than the unfertilized controls. As there was no effect of the foliar treatments on pepper yield, it is likely none of the foliar treatments provided adequate macronutrients for the peppers to compensate for the lower soil fertility.

Foliar fertilization, therefore, is often most successful when used to supply an element that is lacking in the plant (Boynton, 1954). Seaweed and fish products do contain a number of micronutrients in small quantities including Mg, S, Fe, Mn, Zn, B, Cl, and Na. Plants deficient in these trace elements could respond noticeably even if only small amounts are added. As the plants in this study did not respond to foliar treatments, there was likely no micronutrient deficiency to correct.

Researchers have also found that seaweed contains a number of plant growth hormones, including cytokinins, gibberellins, abscisic acid, indoleacetic acid, and phenolic compounds (Verkleij, 1992). Research continues on the effect these externally applied organic compounds may have on plant growth. As there was no response of the peppers to foliar treatments, it is unlikely this compounds were active at levels needed to affect pepper yield.

Foliar fertilizers may work in part by being absorbed by roots when excess solution drips onto the soil. In this study, the polyethylene mulch, and to a lesser extent the landscape cloth, could have prevented this possibility, except for what ran down the plant stem into the planting hole. The success of these products may be in part through indirect soil fertilization and therefore might show a positive effect when applied to plants grown in bare ground or with an organic mulch, such as wheat straw.

Cost is one of the most important factors for growers when selecting a supplemental fertilizer. Manufacturers recommend spraying 12 gallons of fish and seaweed sprays per acre per year. At a cost of $4.25 a gallon in a 55-gallon bulk quantity, it would cost $51 per acre plus equipment and labor to apply this supplemental fertilizer. Unless the grower is gaining a noticeable benefit in crop yield and health, illustrated via on-farm studies, there appears to be little value in applying these products.

CONCLUSION

Organic vegetable growers regularly use supplementary fertilizers, including seaweed extracts and fish emulsions. The success of these products in crop production appears dependent on a number of factors, including the crop fertilized, the rate of application, the composition of the product, and the existing soil fertility. As these products continue to grow in popularity among organic growers, the growers need to know the situations in which these fertilizers can be most beneficial and cost-effective. Under the conditions in the studies reported here, sea-based foliar fertilizers were not found to have any measurable benefit to crop growth or yield.

OUTREACH

In 2002, participants at the Vegetable Field Day at the Mountain Horticultural Crops Research Station were presented with the preliminary results of the on-station research and had an opportunity to tour the field plots. We presented the results of these studies at poster sessions at the 2003 American Society for Horticultural Science annual meeting in Providence, Rhode Island, the 2003 Sustainable Agriculture Conference sponsored by the Carolina Farm Stewardship Association in Rock Hill, South Carolina, and the 2003 Southeast Vegetable and Fruit EXPO in Greensboro, North Carolina. Information on these trials can be found on the http://ncorganic.org website. In December 2003, these results were published in a Master's of Science thesis at North Carolina State University by Melissa Ann Brown entitled "The use of marine derived products and soybean meal as fertilizers in organic vegetable production. The results of these studies are also being submitted for publication in HortTechnology.

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Table 1. Total season yield by grade for 2002 on-farm pepper study.

	Fancy	No. 1	No. 2	Unclassified	Total Mkt	Total Yield
Foliar Treatment	ctns/acre	ctns/acre	ctns/acre	ctns/acre	ctns/acre	ctns/acre
Water	20	50	113	47	229	304
Fish/Seaweed Combo	16	46	99	56	218	271
Seaweed	10	35	159	82	286	359
Fish	16	27	144	64	252	315
Statistical significance	NS	NS	NS	NS	NS	NS

Table 2. Foliar analysis of 2002 research station peppers by foliar treatment.

Foliar treatment	N %	P %	K %	Ca %	Mg %	S %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
Water	6.2	0.4	5.2	1.6	0.7	0.5	143.3	52.0	66.9	27.6	36.6
Fish/seaweed	5.8	0.3	5.2	2.0	0.9	0.5	142.0	67.7	76.9	31.4	42.6
20-20-20	5.9	0.4	5.1	1.7	0.7	0.5	129.6	60.4	67.5	28.7	38.3
Fish	5.9	0.4	5.4	1.9	0.8	0.5	137.5	59.4	68.6	29.0	41.4
Seaweed	5.9	0.3	5.1	1.8	0.8	0.4	127.2	58.1	66.2	27.8	40.3
Stat. significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. 2002 and 2003 research station pepper yields with five foliar treatments.

2002 Total Season

Foliar Treatment	Fancy oz/fruit	No. 1 oz/fruit	Total Mkt oz/fruit	Fancy ctns/a	No. 1 ctns/a	Total Mkt ctns/a	Fancy %	No. 1 %	Plant Dry W gms
Water	6.84	5.59	4.94	142	116	296	32	33	229
Fish/Seaweed	6.51	5.94	4.76	79	85	197	23	36	228
20-20-20	8.13	5.83	5.42	123	125	288	33	41	273
Fish	8.15	6.00	5.55	123	131	291	33	41	273
Seaweed	7.98	5.52	5.14	109	80	223	30	30	211
LSD (0.05)	NS	NS	NS	NS	40.0	NS	NS	N 10	N 67

2003 Total Season

Foliar Treatment	Fancy oz/fruit	No. 1 oz/fruit	Total Mkt. oz/fruit	Fancy ctns/a	No. 1 ctns/a	Total Mkt. ctns/a	Fancy %	No. 1 %
Water	8.63	6.67	7.58	501	507	1014	46	47
Fish/Seaweed	8.40	6.61	7.40	512	612	1125	44	52
20-20-20	8.69	6.70	7.63	514	552	1065	48	50
Fish	8.62	6.74	7.63	446	538	985	44	51
Seaweed	8.40	6.77	7.66	444	443	887	46	46
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	N 9

Cooperating organic farmers, Carl Evans and Julie Mansfield.

Planting peppers for the research station trial.

Karen Hardy applying foliar sprays to peppers in the on-farm trial.

Melissa Brown applying foliar treatments in the research station trial.

Melissa Brown and peppers from her research on the use of foliar applied fish and seaweed products.

Melissa Brown discussing her fish and seaweed research to farmers and researchers at a field day.