Evaluation of Soil Amendments for Certified Organic Pepper Production

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Introduction

Based on the interest among organic farmers in Iowa for an unbiased analysis of the many natural soil amendment/fertilizer and compost products on the market for certified organic vegetable and herb crop production, several experiments have been conducted (Delate 1999). According to the USDA Economic Research Service, statistics on organic production in the U.S. lag far behind those complied for conventional agriculture. In the last USDA census in 1995, there were 4,050 organic farmers reporting 1.5 million acres of production (Greene 1999). The Organic Farming Research Foundation (1998) estimates that there were 10,000 U.S. organic farmers in 1998. In Iowa, 120,000 acres of organic production were reported to the Iowa Department of Agriculture and Land Stewardship (IDALS 1999). This figure reflects only acreage reported by those farmers who returned their survey; thus, more acres are believed to go unreported. This increase in organic acreage represents a doubling from the previous year, and a four-fold increase since 1993. The organic industry has been experiencing a 20% annual growth rate, with U.S. sales listed at $4.5 billion in 1998 (OTA 1998). The organic industry is a consumer-driven market based on consumers' belief that organic products are safer for human consumption and beneficial to the environment (Bourne 1999). Once the transition is complete, comparable yields to conventional systems can be obtained (NRC 1989). Organic price premiums average 57% over conventional prices (Bourne 1999), but premiums can range from 20 to 400%, depending on season and availability. Organic soybeans, for example, currently average a 250% premium price over conventional soybeans.

Certified organic producers are required to undergo third-party certification prior to reaping the premium price of organic products. Certification will verify that synthetic chemicals, including GMO seeds (genetically modified organisms), have not been used for a minimum of 36 months prior to harvest. The National Organic Program of the USDA Agricultural Marketing Service has been assigned the duty of developing national organic standards (Fernandez-Cornejo et al. 1998). Proposed rules, released in 1998, suggested including several components, currently disallowed by the private certification agencies and 15 state certification agencies. In the interim, producers must follow their state laws governing organic production. As required by law (the national Organic Farming Production Act of1990 and Iowa Code Chapter 190C), all certified organic farmers avoid the use of synthetic chemicals in their farming systems. The goal of a sustainable, organic farm is complete reduction of external inputs, using instead on-farm sources or local compost for fertilization and non-toxic (biological, mechanical and cultural) methods of pest management.

Most organic farmers rely on crop rotations, compost or manure applications, and/or cover crops to maintain soil fertility (Kelly 1990). These soil amendment products are reported to help preserve soil quality, and protect groundwater/waterways from potential nitrate contamination (Parr et al. 1986). In addition, soil amendments consisting of green and livestock waste products have been reported to mitigate vegetable disease (Zhang et al. 1996) and insect problems (Helyer et al. 1995). Weed control practices for organic farmers include cover crops, mulches (Wallace and Bellinder 1992), crop rotations, biological control, smother crops (Markey 1990), intercropping, and intensive planting.

Cover crops are the cornerstone of all organic vegetable farms (SARE 1992). Strip-tilling or conservation tillage of cover crops is one method advocated to help mitigate soil erosion. Leaving the mowed cover crop residue on the soil surface will also aid in weed management (Teasdale 1993). Research in Ohio (Creamer 1999) demonstrated comparable yields between organic tomatoes planted into a mowed cover crop (hairy vetch, rye, crimson clover, and barley) and tomatoes fertilized with synthetic fertilizer at recommended rates. Cover crop mixtures of legumes (e.g., hairy vetch) and non-legumes (e.g., rye) provide greater benefits in terms of fertility and biomass compared with a single species (Ofori and Stern 1987; Haynes 1980; Giller et al. 1991; Exner and Cruse 1993).Our research at the ISU Muscatine Island Research and Demonstration Farm (MIRDF) in 1998 demonstrated comparable yields of 'Hungarian wax' peppers treated with compost and comparable rates of conventional fertilizer (Delate 1998). In 1999, in addition to comparing organic soil amendments with conventional fertilizers, we initiated experiments at the MIRDF comparing tilled and strip-tilled cover crops as fertilizer substitutes. Second year results from these trials are presented below.

Materials and Methods

Plots previously planted to rye at the MIRDF were roto-tilled on April 7, 1999. A cover crop of hairy vetch (*Vicia villosa*) (73 lb./A) and rye (70 lb./A) was seeded in selected plots on September 23, 1998, and remained dormant throughout the winter once germination had occurred. Soil samples (a composite of 3-6 in. cores) were taken in each plot at pre-season (May 7) and in the vetch plots on June 25, after residue decomposition. The cover crop was mowed at 12-18 in. in height on May 14, 1999, in order to assist in plow-down, or create a dead mulch for the strip-tilled plots. On May 19, vetch plots were either roto-tilled to completely incorporate the residue (Treatment 5), or 15-in. strips were tilled as rows across the plot, where transplants were to be planted (Treatment 6). 'Lantern' bell pepper plants were seeded in trays on April 6 and mechanically transplanted into rows (at 18” x 42” spacing) in 15’ x 20’ plots on June 1, 1999. Four replications of seven treatments were planted within the field plots. Treatments included the following: Treatment 1 = Organic Control (no fertilization/no pesticides); Treatment 2 = Organic Compost (100 lb. N/A at planting); Treatment 3 = Organic Bio-Cal® (900 lb./A plus compost (50 lb. N/A at planting); Treatment 4 = Organic Bio-Cal® (900 lb./A) plus compost (100 lb. N/A at planting); Treatment 5 = Hairy vetch cover crop tilled completely into field before planting; Treatment 6 = Hairy vetch cover crop strip-tilled in field; Treatment 7 = Conventional Control (no fertilization/recommended pesticides); Treatment 8 = Conventional Fertilizer (conventional rates); and Treatment 9 = Conventional Fertilizer (conventional rates) and Lime (hydrated lime at 500 lb./A). Fifty-two plants were planted in each replicated plot for a total of 1,872 plants in the experiment.

The conventional fertilizer rates consisted of 14-14-14 (N-P-K) at 400 lb./A and 0-0-60 at 200 lb./A, which provided 56 lb. N, 56 lb. P and 176 lb. of K one week before planting. A side-dress of 33-0-0 at 130 lb./A provided an additional 44-lb N/A on June 25. The goal of the fertilization program was to obtain similar rates of nutrients in the organic and conventional system (•100 lb. N/A and equivalent calcium rates). Treflan® was applied at 1 pt/A on May 26, in the conventional plots. No insecticide was applied in any treatments because of low insect pressure.

An Iowa-produced compost (emphasizing the tenet of sustainable agriculture: use of locally produced inputs) was obtained for this study (Ultra-Gro®, a turkey litter product from Circle Hill Organics, Ellsworth, IA). Composition of the compost includes 2.2-2.8-1.5 N-P-K and other minor elements. The compost selected for this study had been stored for at least one year as required for certified organic production (manure must be composted for six weeks, or applied four months before harvest). The compost in Treatments 2, 3 and 4 was applied approximately one week before planting on June 25. Bio-Cal® is a locally produced bi-product of the kiln industry, consisting of 35% of various forms of calcium and the remainder in sulfur, boron and phosphorous. A subtreatment was included in the 1999 study: a mid-season application of fish emulsion (Omega Protein®, New Orleans, LA). The recommended rate of 6 gallons/acre was applied in a dilution of 4: 1, fish emulsion to water, on July 15, 1999, to half the organic plots.

Weeds were machine- or hand-cultivated throughout the season, except in vetch strip-tilled plots, where the cover crop was left as a mulch between plant rows. Irrigation was applied as needed through overhead risers. A core set of measurements was taken on 10 plants per plot (total of 40 plants per treatment) for crop plant productivity (biomass) and plant health on a June 23, July 7, and July 23, 1999. Height of plants, number of leaves, and pepper fruit were monitored, along with numbers of harmful and beneficial insects.

Peppers were harvested according to schedule on August 4, August 19, September 3, and September 16. Counts were made of culled peppers at harvest (peppers showing damage from insects or diseases). Counts were also made of number of blemishes (lesions rendering peppers unsalable) at initial weighing. Six unblemished peppers per plot (total of 216 per harvest, or 864 over four harvests) were transferred to chambers in the Horticulture Department in Ames and held at 50 degrees F in order to conduct postharvest storage-life studies. Fresh weights were taken immediately after harvest and at intervals of three weeks following harvest. All measurements were subjected to analysis of variance and Fisher's PLSD test ($P = 0.05$).

Results

Soils averaged 1.2 ppm N, 168 ppm P, and 67 ppm K with a pH of 7.4 at pre-planting. Vetch plots, sampled approximately three weeks after pepper transplanting, averaged 137 ± 17 ppm total N, and 5.9 ± 0.9 ppm nitrate-N.

At maximum growing point (July 22), mean leaf height and leaf number were significantly different among treatments. All treated plants were significantly greater in height and leaf number than the controls (ANOVA, $P = 0.05$), except for Treatment 3 (Table1). Plants chemically fertilized were significantly greater in biomass than the organically treated plants, except for the plants fertilized with the compost at 100 lb./A plus BioCal®. Plants in Treatment 4 were significantly greater in height and leaf number than the synthetic fertilizer plus lime treatment (9), but not significantly greater than plants treated with fertilizer alone (8). There were no significant differences (ANOVA, $P = 0.05$) in mean plant height and number of peppers between plants receiving a fish emulsion application and those without F.E. within organic treatments (Table 2). Control plants receiving an F.E. application were greater in height, but the difference was not statistically significant.

Table 1. Pepper plant growth parameters, MIRDF, 1999.

Treatment	**Mean Plant Height (cm)**	**S.E.**	**Mean Leaf Number**	**S.E.**
(1) Organic Control	30.03	0.34	16.63	0.54
(2) Organic Compost (100 lb./A)	35.34	0.47	25.60	0.85
(3) Organic Bio-Cal® plus compost (50 lb./A)	29.93	0.44	16.90	0.42
(4) Organic Bio-Cal® plus compost (100 lb. N/A)	38.66	0.55	28.60	0.73
(5) Hairy vetch tilled	33.63	0.66	20.80	0.68
(6) Hairy vetch strip-tilled	35.54	0.56	21.23	0.68
(7) Conventional Control	30.19	0.49	17.35	0.49
(8) Conventional Fertilizer	38.11	0.82	29.53	0.61
(9) Conventional Fertilizer and Lime	37.07	0.46	28.43	0.78
LSD (0.05)	1.53		1.82	

Table 2. Pepper plant growth parameters as affected by fish emulsion treatment, MIRDF, 1999.

Treatment	Mean Plant Height (cm)	S.E.	Mean No. of Peppers	S.E.
(1) Organic Control	30.70	0.56	3.85	0.38
(1) Organic Control-With Fish Emulsion (F.E.)	29.37	0.35	3.85	0.29
(2) Organic Compost (100 lb./A)	35.62	0.78	7.25	0.48
(2) Organic Compost (100 lb./A)-With F.E.	35.06	0.55	6.85	0.44
(3) Organic Bio-Cal® plus compost (50 lb./A)	29.92	0.53	3.25	0.40
(3) Organic Bio-Cal® plus compost (50 lb./A)-With F.E.	29.94	0.72	3.65	0.39
(4) Organic Bio-Cal® plus compost (100 lb. N/A)	38.30	0.84	5.85	0.39
(4) Organic Bio-Cal® plus compost (100 lb. N/A)-With F.E.	39.01	0.71	6.85	0.49
(5) Hairy vetch tilled	33.09	0.74	4.75	0.44
(5) Hairy vetch tilled-With F.E.	34.16	1.10	4.20	0.32
(6) Hairy vetch strip-tilled	35.92	0.84	2.85	0.35
(6) Hairy vetch strip-tilled-With F.E.	35.17	0.76	3.35	0.43

NSD between treatments of the same number (P=0.05)

Insect pests (primarily grasshoppers) and beneficial insects (ladybeetles, lacewings and spiders) were observed in low numbers in this experiment. There were no significant differences in insect populations, except at maximum growing point (July 22), mean number of beneficial insects were significantly greater in more organic plots than in conventional plots (Table 3).

Table 3. Beneficial insect populations at maximum growing point, MIRDF, July 22, 1999.

Treatment	Mean Beneficial Insects (No. x 10)	S.E.
(1) Organic Control	3.25	1.04
(2) Organic Compost (100 lb./A)	5.50	1.68
(3) Organic Bio-Cal® plus compost (50 lb./A)	2.50	0.93
(4) Organic Bio-Cal® plus compost (100 lb. N/A)	2.75	0.71
(5) Hairy vetch tilled	5.75	1.23
(6) Hairy vetch strip-tilled	2.75	0.95
(7) Conventional Control	0.75	0.42
(8) Conventional Fertilizer	3.50	1.05
(9) Conventional Fertilizer and Lime	2.00	0.73
LSD (0.05)	2.86	

As was observed with the plant growth data, all treated plants over the four harvest dates were significantly greater in harvest weight than the controls (ANOVA, P = 0.05), except for Treatment 3 (Table 4). Plants chemically fertilized produced significantly greater harvest weight than the organically treated plants, except for the plants fertilized with the compost at 100 lb./A plus BioCal®. Pepper weight from Treatment 4 was not significantly greater than from plants treated with fertilizer alone (8) or with fertilizer plus lime (9). Over the four harvest dates, among the organic treatments, harvest weight was greater from the organic plots fertilized with the F.E., but differences were not significant (Table 5). These results contrast with 1998 results where total pepper fresh weight over the five harvest periods was not significantly different among all treatments (ANOVA, P = 0.05).

We were particularly interested in the number of culled peppers in each harvest as a measure of pepper health. Although total numbers of culled peppers were not statistically different (ANOVA, P = 0.05), greater numbers of peppers were culled over all harvests due to insect or disease damage in the conventional plots compared with the organic plots (Table 4). There were significantly greater number of culled peppers in the chemically-treated plots compared with organic treatments 1, 5, and 6, but not in an overall comparison of organic vs. conventional plots. Fish emulsion application did not significantly affect the number of culled peppers (Table 5).

Table 4. Pepper harvest parameters, MIRDF, 1999.

Treatment	Mean Pepper Weight (g)	S.E.	Mean Number of Culled Peppers	S.E.
(1) Organic Control	128.75	3.98	0.91	0.23
(2) Organic Compost (100 lb./A)	142.53	5.57	1.11	0.23
(3) Organic Bio-Cal® plus compost (50 lb./A)	125.88	4.85	1.27	0.30
(4) Organic Bio-Cal® plus compost (100 lb. N/A)	152.98	6.48	1.25	0.26
(5) Hairy vetch tilled	141.20	4.95	1.02	0.23
(6) Hairy vetch strip-tilled	142.25	5.75	0.68	0.15
(7) Conventional Control	117.30	3.53	1.02	0.22
(8) Conventional Fertilizer	163.01	7.15	1.85	0.43
(9) Conventional Fertilizer and Lime	163.84	11.43	1.51	0.38
	LSD (0.05) 16.28		NSD	

Table 5. Pepper harvest parameters by fish emulsion treatment, MIRDF, 1999.

Treatment	**Mean Pepper Weight (g)**	S.E.	**Mean Number of Culled Peppers**	S.E.
(1) Organic Control	120.64	5.24	1.00	0.29
(1) Organic Control-With Fish Emulsion (F.E.)	136.35	5.43	1.08	0.43
(2) Organic Compost (100 lb./A)	136.33	9.13	1.10	0.33
(2) Organic Compost (100 lb./A)-With F.E.	148.72	6.30	1.33	0.40
(3) Organic Bio-Cal® plus compost (50 lb./A)	129.00	7.36	1.42	0.41
(3) Organic Bio-Cal® plus compost (50 lb./A)-With F.E.	122.75	6.48	1.52	0.56
(4) Organic Bio-Cal® plus compost (100 lb. N/A)	152.54	8.63	1.17	0.33
(4) Organic Bio-Cal® plus compost (100 lb. N/A)-With F.E.	153.42	9.96	1.65	0.47
(5) Hairy vetch tilled	140.68	7.41	1.27	0.37
5) Hairy vetch tilled-With F.E.	141.68	6.84	1.08	0.38
(6) Hairy vetch strip-tilled	144.22	8.37	0.83	0.23
(6) Hairy vetch strip-tilled-With F.E.	140.28	8.12	0.70	0.25

NSD between treatments of the same number (P=0.05)

We are continuing the postharvest study to determine the effect of soil amendment treatment on storage duration and pathogen development in storage. There have been no significant differences in six-week weight loss in storage among Harvest 4 treatments. The lowest rate of weight loss occurred in the vetch-strips peppers (6.64 ± 0.45%), although differences were not statistically significant.

<u>Discussion</u>

With the increasing consolidation of farms, and monopolization of farming inputs (e.g., seed and pesticide packages), farmers will succeed only if they assume more control of inputs and prices (Harl 1999). Organic producers are engaged in both strategies. Fertility and weed management are areas where farmers can cut costs. Weeds were considered the most serious problem on organic farms in several studies (Peacock and Norton 1990; OFRF 1998). Our results demonstrate the value of cover crops for both fertility and weed control.

Consistent with results from 1998, organic pepper fresh weights in 1999 were greatest from Treatment 4 plots (compost plus Bio-Cal®) (152.98 ± 6.48 g). This organic treatment was statistically equivalent to the chemically-fertilized treatments in 1999. These results contrast with the conventional treatments, where the addition of a liming product in combination with synthetic fertilizer (163.84 ± 11.43 g) did not significantly increase yields compared with fertilizer alone (163.01 ± 7.15 g). Organic farmers who rely on Bio-Cal® treatments in their system ascribe to benefits resulting from the mineral mixture in the Bio-Cal®, although no effect on yield was observed when BioCal® was not combined with the 100 lb. N/A compost application. As observed in the 1998 trial, pepper plants produced the greatest yields when provided additional nitrogen fertilization (100 lb. N/A vs. 50 lb. N/A). This is demonstrated by the weights from Treatment 3 plants (receiving 50 lb. N/A) where the average weight was 125.88 ± 4.85 g compared with peppers from Treatments 2 and 4 (receiving 100 lb. N/A) where average weights were 142.53 ± 5.57 g and 152.98 ± 6.48 g, respectively.

Despite the beneficial effect of the hairy vetch cover crop (adding an average of 137 ppm total N, with 5.9 ppm nitrate-N to the soil), yields were less in the vetch plots compared with the leading treatment of compost plus Bio-Cal®. Yields in the vetch plots (142.25 ± 5.75 g) were significantly greater than the controls, however, and equivalent to yields obtained in the compost at 100 lb. N/A (142.53 ± 5.57 g). Based on these results, vetch can supply an equivalent of 100 lb. N/A compost. This amount is a significant input for farmers who wish to avoid animal manures, and rely exclusively on cover crops. There were no significant differences between yields in plots where vetch was completely incorporated into the soil, or in plots strip-tilled. These results demonstrate the value of a minimum tillage system in preventing soil erosion, mitigating weeds, and supplying crop nutrients.

Despite less harvest weight in the organic treatments (other than the BioCal® plus compost), the greater premium obtained with organic peppers (1999 average of 70%) should offset any reduction in yields with organic systems. This experiment will be repeated at the Muscatine Island Research Farm in 2000.

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