Evaluation of Soil Amendments and Cover Crops for Certified Organic Pepper Production

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Introduction

In 1998, we began a comparison of the productivity of organic peppers compared with conventional peppers produced with synthetic agrichemicals (fertilizers and herbicides). Several experiments have been conducted around the state (Delate 2000) to evaluate natural soil amendment/fertilizer and compost products on the market for certified organic vegetable and herb crop production. In 1998 and 1999, at the ISU Muscatine Island Research and Demonstration Farm (MIRDF), organic peppers fertilized with compost at 100 lb N/A plus Bio-Cal® at 900 lb/A were not significantly different in growth and yield from conventional peppers (Delate 1998; Delate & Lawson 1999).

Certified organic producers are required to undergo third-party certification in order to obtain premium prices for 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. In order to meet certified organic requirements (IDALS 2000), a soil-building cover crop is required for at least one out of five years of horticulture production in Iowa. Beginning in 1999, our research has included the incorporation of a legume cover crop in the fertility comparison trials. 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. The same pattern was observed in Wisconsin (Stute & Posner 1995) and Maryland (Lichtenberg et al. 1994) when hairy vetch was incorporated before planting. The hairy vetch/rye cover crop in our 1999 experiments provided a 100% cover, and supplied an average of 137 ppm total N and 5.9 ppm nitrate-N to the soil. Yields in the incorporated vetch plots were significantly greater than the controls, and equivalent to yields obtained in the compost at 100 lb. N/A. Yields were less in the vetch plots compared with the leading treatment of compost plus Bio-Cal®, but there were no significant yield differences in 1999 between plots where vetch was completely incorporated into the soil versus strip-tilled. Third year soil amendment and second year vetch trial results are presented below.

Materials and Methods

Plots previously planted to rye at the MIRDF were roto-tilled on April 14, 2000. A cover crop of hairy vetch (*Vicia villosa*) (73 lb./A) and rye (*Secale cereale*) (70 lb./A) was seeded in selected plots on September 21, 1999, 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 15) and in the vetch plots on June 14, after residue decomposition. The cover crop was mowed at 12-18 in. in height on May 17, 1999, in order to assist in plow-down, or create a dead mulch for the strip-tilled plots. On May 24, 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 13 and mechanically transplanted into rows (at 18” x 42” spacing) in 15’ x 20’ plots on June 2, 2000. Four replications of seven treatments (plus two controls) 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 on May 30. A side-dress of 34-0-0 at 130 lb./A provided an additional 44-lb N/A on June 27. 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 25, in the conventional plots. No insecticide was applied in any treatments.

An Iowa-produced compost 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 on May 30, prior to transplanting on June 2. 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 2000 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 1:4, fish emulsion to water, on July 12 and August 8, 2000, 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. Because of the poor growth of the vetch cover, rye straw was applied as a mulch (3 in. deep) on May 17. 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 June 14, June 28, July 12, July 26, and August 8, 2000. 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 8 and 31, 2000. Counts were made of culled peppers at the first 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 432 over two harvests) were transferred to chambers in the Horticulture Department in

Ames and held at 50° 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

Vetch growth in Fall 1999-Spring 2000 was impacted by hot and dry weather conditions. Stands were less than 50% in 75% of the plots. At 3 wk post-tillage, nitrogen additions were limited to 2.09 and 2.30 nitrate-N in the incorporated vetch and strip-tilled plots, respectively. This level was 273% above the nitrate-N concentration at the beginning of the season, however.

At maximum growing point (August 8), mean leaf height and leaf number were significantly different among treatments. Plants chemically fertilized were significantly greater in biomass than the organically treated plants, except for number of leaves (Table 1). Leaf number in plants fertilized with the compost alone (100 lb N/A), and 50 and 100 lb N/A plus BioCal® was not significantly less than the conventional peppers. Plants grown in the vetch strips were significantly impacted by the competitiveness of the vetch, and growth was less than the controls. All conventionally treated plants were significantly greater in height and leaf number than the controls (ANOVA, P•0.05). In the organic plots, plants treated with compost alone (at 100 lb N/A) were significantly greater in height than the controls. There was no significant difference in height and leaf number in fertilizer alone versus the synthetic fertilizer plus lime treatment (Treatment 9).

Table 1. Pepper plant growth parameters, MIRDF, 2000.

Treatment	**Mean Plant Height (cm)**	**S.E.**	**Mean Leaf Number**	**S.E.**
(1) Organic Control	47.88	0.81	22.33	1.65
(2) Organic Compost (100 lb N/A)	50.60	0.56	31.45	2.51
(3) Organic Bio-Cal® plus compost (50 lb N/A)	49.90	0.74	29.64	2.40
(4) Organic Bio-Cal® plus compost (100 lb. N/A)	48.93	0.55	30.78	2.38
(5) Hairy vetch tilled	48.85	0.69	22.09	1.62
(6) Hairy vetch strip-tilled	41.70	0.64	13.33	0.78
(7) Conventional Control	45.18	0.74	19.36	1.60
(8) Conventional Fertilizer	54.59	0.74	30.41	2.48
(9) Conventional Fertilizer and Lime	52.88	0.86	30.74	2.40
LSD (0.05)	1.95		5.68	

There were no significant differences (ANOVA, P•0.05) between plants receiving a fish emulsion application and those without F.E. within organic treatments in mean plant height and number of peppers per plant (Table 2). Overall, plants receiving an F.E. application were greater in biomass, but the difference was not statistically significant.

Table 2. Pepper plant growth parameters as affected by fish emulsion treatment, MIRDF, 2000.

Treatment	**Mean Plant Height (cm)**	**S.E.**	**Mean No. of Peppers**	**S.E.**
(1) Organic Control	47.78	0.92	4.05	0.38
(1) Organic Control-With Fish Emulsion (F.E.)	48.00	1.36	3.45	0.81
(2) Organic Compost (100 lb N/A)	50.05	0.92	5.80	0.56
(2) Organic Compost (100 lb N/A)-With F.E.	51.15	0.66	5.15	0.32
(3) Organic Bio-Cal® plus compost (50 lb N/A)	50.53	0.98	4.00	0.20
(3) Organic Bio-Cal® plus compost (50 lb N/A)-With F.E.	49.27	1.12	4.67	0.35
(4) Organic Bio-Cal® plus compost (100 lb. N/A)	48.40	0.47	4.45	0.42
(4) Organic Bio-Cal® plus compost (100 lb. N/A)-With F.E.	49.45	1.00	4.80	0.86
(5) Hairy vetch tilled	50.15	0.82	4.70	0.75
(5) Hairy vetch tilled-With F.E.	47.55	1.04	3.60	0.62
(6) Hairy vetch strip-tilled	41.65	1.01	1.30	0.24
(6) Hairy vetch strip-tilled-With F.E.	41.75	0.82	1.40	0.31

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

Insect pests and beneficial insects (ladybeetles, lacewings and spiders) were recorded throughout the experiment. There were no significant differences in insect populations, including the most predominant beneficial insect, spiders (Table 3).

Table 3. Beneficial insect populations, MIRDF, 2000.

Treatment	**Mean Spider Population (No. x 100)**	**S.E.**
(1) Organic Control	1.00	0.70
(2) Organic Compost (100 lb N/A)	0.50	0.50
(3) Organic Bio-Cal® plus compost (50 lb N/A)	1.00	0.70
(4) Organic Bio-Cal® plus compost (100 lb N/A)	0.50	0.50
(5) Hairy vetch tilled	1.50	0.90
(6) Hairy vetch strip-tilled	0	0
(7) Conventional Control	1.00	0.70
(8) Conventional Fertilizer	0.50	0.50
(9) Conventional Fertilizer and Lime	0	0

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

As was observed with the plant growth data, peppers from the compost-treated plots (Treatment 2) were significantly greater in first harvest weight than the controls (ANOVA, P•0.05) (Table 4). Plants chemically fertilized produced statistically equivalent harvest weights to the organic compost treatment (at 100 lb N/A), and the compost at 50 and 100 lb N/A plus BioCal® treatments (Treatments 2, 3 and 4). Significantly greater pepper weight was obtained at the first harvest from chemically treated plants compared with organic plants from vetch plots, however. Pepper weight from plants treated with fertilizer plus lime (Treatment 9) was not significantly greater than plants treated with fertilizer alone (Treatment 8). We were particularly interested in the number of culled peppers at harvest as a measure of pepper health. There were statistically greater numbers of culled peppers due to insect or disease damage at the first harvest in the chemically fertilized plots than from the organic plots (ANOVA, P•0.05) (Table 4).

Table 4. First pepper harvest parameters, MIRDF, 2000.

Treatment	Pepper Weight per Plant (g)	S.E.	Mean Number of Culled Peppers	S.E.
(1) Organic Control	375.01	22.18	0.50	0.29
(2) Organic Compost (100 lb N/A)	576.56	42.98	1.00	0.41
(3) Organic Bio-Cal® plus compost (50 lb N/A)	489.83	24.60	0.25	0.25
(4) Organic Bio-Cal® plus compost (100 lb N/A)	500.67	51.12	0.75	0.48
(5) Hairy vetch tilled	421.97	65.97	0	0
(6) Hairy vetch strip-tilled	116.77	17.58	0	0
(7) Conventional Control	398.72	23.18	2.50	0.87
(8) Conventional Fertilizer	589.16	89.06	5.25	1.44
(9) Conventional Fertilizer and Lime	638.64	65.75	1.75	0.75
LSD (0.05)	15.15		1.91	

In the first harvest, differences were observed in pepper health, storage duration and pathogen development in storage. There were significantly greater numbers of blemishes due to insects and/or disease lesions at harvest in chemically-treated peppers (Table 5). Significant differences in discarded (unsalable) fruit after 3 weeks in storage occurred in Treatments 7 and 8 (chemical) compared with organic treatments. The lowest rate of weight loss occurred in the vetch-strips peppers (6.64 ± 0.45%), although differences were not statistically significant.

Table 5. Pepper health at first harvest, MIRDF, 2000.

Treatment	**Mean No. of Blemishes**	**S.E.**	**Mean Number Of Discards at 3 wk**	**S.E**
(1) Organic Control	6.25	1.44	0	0
(2) Organic Compost (100 lb N/A)	8.50	1.66	0	0
(3) Organic Bio-Cal® plus compost (50 lb N/A)	7.00	1.73	0	0
(4) Organic Bio-Cal® plus compost (100 lb. N/A)	4.00	0.71	0	0
(5) Hairy vetch tilled	5.25	0.25	0	0
(6) Hairy vetch strip-tilled	3.00	1.00	0	0
(7) Conventional Control	8.50	1.66	0.08	0.06
(8) Conventional Fertilizer	16.25	2.56	0.04	0.04
(9) Conventional Fertilizer and Lime	12.50	1.26	0	0
LSD (0.05)	4.66		0.07	

In the second harvest, peppers from the organic compost alone treatment (at 100 lb N/A), and the compost (100 lb N/A) plus BioCal® treatments (Treatments 2 and 4) were significantly greater in harvest weight than the controls, and the conventional fertilizer plus lime (Treatment 9) peppers (ANOVA, P•0.05) (Table 6). Plants chemically fertilized produced statistically equivalent harvest weights to the other organic plots except for the vetch strip plots, which produced the lowest harvest weight. Pepper weight and pepper number from plants treated with fertilizer plus lime (Treatment 9) were not significantly greater than plants treated with fertilizer alone (Treatment 8). There were significantly greater numbers of peppers produced in the organic Treatments 2, 3, and 4 compared with the chemically fertilized plants of Treatment 9 (Table 6). Vetch strip plots produced the lowest number of peppers.

Table 6. Second pepper harvest parameters, MIRDF, 2000.

Treatment	Pepper Weight per Plant (g)	S.E.	Mean Number of Peppers	S.E.
(1) Organic Control	528.14	44.64	3.73	0.13
(2) Organic Compost (100 lb N/A)	747.24	37.87	4.68	0.36
(3) Organic Bio-Cal® plus compost (50 lb N/A)	652.28	52.25	4.53	0.44
(4) Organic Bio-Cal® plus compost (100 lb N/A)	718.10	33.04	4.73	0.22
(5) Hairy vetch tilled	600.55	89.70	4.08	0.59
(6) Hairy vetch strip-tilled	177.92	57.58	1.50	0.42
(7) Conventional Control	522.63	89.00	3.45	0.34
(8) Conventional Fertilizer	662.00	41.63	3.80	0.19
(9) Conventional Fertilizer and Lime	539.84	72.89	3.05	0.20
LSD (0.05)	176.36		1.05	

Overall, fish emulsion application did not significantly affect pepper weight or number of culled peppers (Table 7). In the vetch strip plots, greater pepper weight was obtained from plants receiving a fish emulsion application.

Table 7. Pepper harvest parameters by fish emulsion treatment, MIRDF, 2000.

Treatment	**Mean Pepper Weight per Plant (g)**	S.E.	**Mean Number of Culled Peppers per 5 plants**	S.E.
(1) Organic Control	375.01	17.42	0	0
(1) Organic Control-With Fish Emulsion (F.E.)	375.00	45.12	0.50	0.23
(2) Organic Compost (100 N lb/A)	582.53	36.83	0.75	0.25
(2) Organic Compost (100 N lb/A)-With F.E.	570.59	61.66	0.25	0.25
(3) Organic Bio-Cal® plus compost (50 lb N/A)	454.13	25.09	0	0
(3) Organic Bio-Cal® plus compost (50 lb N/A)-With F.E.	525.55	27.83	0.25	0.25
(4) Organic Bio-Cal® plus compost (100 lb. N/A)	458.57	33.90	0.50	0.50
(4) Organic Bio-Cal® plus compost (100 lb. N/A)-With F.E.	542.57	69.38	0.25	0.25
(5) Hairy vetch tilled	448.03	69.41	0	0
5) Hairy vetch tilled-With F.E.	395.91	70.40	0	0
(6) Hairy vetch strip-tilled	95.31	25.21	0	0
(6) Hairy vetch strip-tilled-With F.E.	122.55	8.95	0	0

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

Discussion

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). Consistent with results from trials around the country (NRC 1989), we have obtained comparable organic yields to conventional systems in our vegetable systems research. As in 1998 and 1999, organic pepper fresh weights in 2000 were statistically equivalent to conventional peppers when treated with compost (at 100 lb N/A) in harvest 1 and with compost alone and compost plus Bio-Cal® in the second harvest. Contrasting with 1999 results, however, was the poor performance of organic peppers in the vetch strip plots. In 1999, yields in the vetch plots were significantly greater than the controls, and equivalent to yields obtained in the compost at 100 lb. N/A. Also in 1999, there were no significant differences in yields between plots where vetch was completely incorporated into the soil, or in plots strip-tilled. In 2000, due to poor vetch growth, peppers in vetch strip plots produced significantly less peppers and pepper weight than the controls. Based on these results, vetch can supply equivalent nitrogen from compost applications only when cover crop growth is adequate, as observed in 1999. In addition, weed management is also dependent on adequate cover crop growth prior to mowing. Supplemental irrigation may be required for adequate vetch growth if growers are relying on cover crops for their complete fertility and weed management package.

As observed in the 1998 and 1999 experiments, organic pepper plants produced greater yields when provided additional nitrogen (100 lb. N/A vs. 50 lb. N/A compost treatments), although yield differences were greater between compost alone and compost plus BioCal® treatments. Contrasting 1998 and 1999 results, pepper weight was not greater with the addition of BioCal®. The same pattern was observed in the conventional treatments, where the addition of lime did not significantly increase plant growth or yields. Despite greater height and fresh weights overall, consistent with 1999 results, plants receiving fish emulsion treatments were not significantly more productive. There were significantly greater numbers of blemished and culled peppers from the conventional plots in harvest 1 compared with the organic plots. This contrasted with 1999 results where differences were not significant, despite greater numbers of conventional culled peppers.

With 150,000 acres of organic production in Iowa (IDALS 1999), and a continued 20% annual industry growth rate (OTA, 1999), there is no indication that the market for organic products will experience any declines. 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. The greater premium obtained with organic peppers (2000 average of 70%) should offset any reduction in yields with organic systems.

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