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

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Introduction

With the implementation of consistent federal standards for products marketed as "organic" in October 2002 (USDA/AMS, 2002), organic production and consumption is expected to increase beyond current organic sales of $10 billion in 2001 (OTA, 2002). In 1999, Iowa farmers reported 150,000 acres of organic production to the Iowa Department of Agriculture and Land Stewardship survey (IDALS, 2000a), although statistics for organic horticultural crops remain underreported.

Most organic producers rely on manure or manure-based composts and nitrogen-fixing cover crops to supply their soil fertility needs (Kelly, 1990). Several research projects comparing productivity and yield for compost-fertilized and synthetic-fertilized crops have shown generally favorable results for the organic treatments. Cover crops can also be used successfully for nutrient and weed management in organic systems. In order to meet certified organic requirements in the state of Iowa (IDALS, 2000b), a soil-building cover crop is required for at least one out of every five years of horticulture production. In a national survey (Walz, 1999) and through statewide focus groups (Delate, 2002), organic farmers identified pest management and soil fertility as their most critical vegetable research needs. In response, a long-term experiment was established at the ISU Muscatine Island Research and Demonstration Farm (MIRDF) to compare pepper growth, yield, insect populations, harvest cullage and postharvest weight loss under conventional and organic management. Treatments from the first 3 years (1998 to 2000) consisted of combinations of two synthetic fertilizer and three compost-based certified organic soil amendments. In addition to the compost treatments, effects of a cover crop of hairy vetch (*Vicia villosa* Roth) and rye (*Secale cereale* L.) were evaluated in the organic system from 1999 onward. The majority of organic producers incorporate cover crops prior to planting, but others have been successful using conservation, strip-, or zone-tillage, and simply leaving the mowed cover crop on the surface to help mitigate weeds and soil erosion (Abdul-Baki & Teasdale, 1993).

Pepper growth, harvest weight and marketable fruit numbers were similar in conventional and organic production systems from 1998 to 2000 when 100 lb. N/A was applied through synthetic fertilizer or compost. Zone-tillage organic pepper production resulted in significantly reduced growth and pepper weight in two out of three years at the MIDRF, however. In 2001, a poultry litter-based organic fertilizer replaced the compost, and gypsum was used instead of Bio-Cal™, a calcium product. In our research at the MIRDF, organic pepper weight was significantly greater with the addition of calcium applications in one out of four years only. The same pattern was observed in the conventional treatments where the addition of lime did not significantly increase plant growth or yields from 1998–2001. The number of culled peppers due to insect or disease damage was greater in the synthetic fertilizer plots in 2000, but postharvest weight loss was similar in the compost and synthetic fertilizer treatments after three to nine weeks in 50° F storage.

In 2002, a second-year evaluation of the organic poultry litter-based fertilizer and gypsum soil amendment was conducted. In addition, hairy vetch cover crops were evaluated for a fourth year. Due to three years of inconsistent results with the zone-tilled hairy vetch treatment, this treatment was modified in 2002 to include a side-dress application of organic fertilizer (50 lb N/A) after plant establishment.

Materials and Methods

A cover crop of hairy vetch (*Vicia villosa*) (60 lb/A) and rye (*Secale cereale*) (90 lb/A) was seeded in selected plots at the MIRDF on September 21, 2001, and after germination, remained dormant throughout the winter. Soil samples (a composite of 5 6-in. cores) were taken in vetch incorporated, vetch strips and organic control plots at pre-season (May 28) and at the last harvest (September 19). Plots previously planted to rye in the non-vetch treatments were roto-tilled on June 8, 2002. Treatment 5 vetch plots were mowed on June 1 and roto-tilled to completely incorporate the residue on June 8. The vetch in the zone-tilled vetch plots was killed with a cultipak, followed by a disc coulter and chisel sweep acting as an undercutter, sweeping 8-10 in. under the vetch to cut roots and loosen the soil under the mulch without disturbing the soil surface. Passage of the disc coulter and chisel sweep left a 1-3 in. strip down the center of the row into which the peppers were planted. 'Red Knight' bell pepper plants were seeded in trays on April 15 and mechanically transplanted into rows (at 18" x 42" spacing) in 15' x 20' plots on June 12, 2002. Four replications of nine treatments were planted within the field plots in a randomized complete block design. Treatments included the following: Treatment 1 = Organic control (no fertilization/no pesticides); Treatment 2 = Organic fertilizer (100 lb N/A), preplant incorporated; Treatment 3 = Organic fertilizer (50 lb N/A) + gypsum (500 lb /A), preplant incorporated; Treatment 4 = Organic fertilizer (100 lb N/A) + gypsum (500 lb /A), preplant incorporated; Treatment 5 = Hairy vetch cover crop tilled completely into field before planting; Treatment 6 = Hairy vetch cover crop strip-tilled in field with an organic fertilizer side-dress application (50 lb N/A); Treatment 7 = Conventional Control (no fertilizer or lime/recommended pesticides); Treatment 8 = Conventional fertilizer (conventional rates); and Treatment 9 = Conventional fertilizer (conventional rates), lime (hydrated lime (357 lb/A) and elemental sulfur (993 lb/A). Fifty-two plants were planted in each replicated plot for a total of 1,872 plants in the experiment.

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 and sulfur rates). 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 143 lb/A provided an additional 44 lb N/A at first flower. The organic fertilizer (Midwestern Bio-Ag®, Blue Mounds, Wisconsin) was a blend of blood meal, feather meal, composted poultry litter, bone meal, sulfate of potash, borate, copper sulfate, manganese sulfate and zinc sulfate and consisted of 6-3-5 N-P-K. Organic fertilizer was applied as a 50 or 100 lb. N/A treatment prior to planting, or as a side-dress application (50 lb. N/A) after plants were established within tilled vetch strips on June 25. The gypsum contained 21% calcium and 17% sulfur. Treflan® was applied at 1 pt/A on June 8 in the conventional plots. No insecticides were applied in any treatments based on monitoring reports.

Weeds were machine or hand cultivated throughout the season in organic plots, except in vetch strip-tilled plots, where the cover crop was left as a mulch between plant rows. As a result of inadequate growth of the vetch cover, rye straw was applied as a mulch (3 in. deep) on July 11, 2002. 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 25, July 11, July 24, and August 6, 2002. Height of plants, number of leaves, and number of pepper fruit were monitored, along with numbers of harmful and beneficial insects.

Peppers were harvested according to schedule on August 15, August 28, and September 12, 2002. The number of pepper plants showing disease symptoms and removed from plots was determined at final harvest. Fresh weights were taken immediately after harvest. After blemish counts (insect or disease lesions rendering peppers unsalable) at initial weighing, 24 unblemished peppers per treatment per harvest were transferred to 50° F chambers in the Iowa State University Horticulture Department for postharvest storage-life studies. Fresh weights and visual quality of stored peppers were recorded two to six weeks after storage. Evaluations were terminated when peppers were unmarketable. All measurements were subjected to analysis of variance and Fisher's PLSD test (P•0.05) (SAS Institute, 1988).

Results and Discussion

At maximum growing point (August 6), mean leaf height and fruit number were significantly different among treatments (Table 1). The tallest plants were found in the organic fertilizer (100 lb N/A) treatment; these plants were significantly taller than all other treatments except the conventional fertilizer and conventional fertilizer plus lime treatments. The organic fertilizer (100 lb N/A) plus gypsum treatment was statistically equivalent to the conventional fertilizer treatments. Leaf number was similar in the organic fertilizer treatment (100 lb N/A), alone or with gypsum, the hairy vetch strip-tilled plus organic fertilizer (50 lb. N/A) treatment, and in the synthetically fertilized plots. Increasing N from 50 to 100 lb N/A in the gypsum treatments did not result in an increase in plant growth, contrary to previous years. Plant growth was also not increased by adding lime to the fertilizer treatment.

Plant height and leaf number in the strip-tilled vetch treatment plus 50 lb. N/A side-dress application were greater than in the completely incorporated (tilled) vetch treatment. This result contrasts with previous years where the strip-tilled treatment without the additional 50 lb N/A were significantly smaller than the other organic treatments. Fruit number was similar between the two vetch treatments in 2002, however. The greatest mean number of fruits per plant was produced in the organic fertilizer treatments of 100 lb N/A alone and with gypsum. There was no difference in fruit number between the conventional fertilizer treatments and the organic fertilizer at 50 lb N/A plus gypsum treatment.

Table 1. Pepper plant growth and insect parameters, MIRDF, 6 August 2002.

Treatment	Mean Plant Height (cm)	Mean Leaf No.	Mean Fruit No.	Mean No. Beneficial Insects	Mean No. Pest Insects
Organic Control	42.4 a	70.2 a	3.8 ab	10.02[z]	10.03[z]
Organic Fertilizer (100 lb N/A)	51.5 c	95.8 d	6.3 d	10.05	10.01
Organic Fertilizer (50 lb N/A) plus Gypsum (500 lb/A)	44.8 ab	76.8 abc	4.5 bc	10.02	10.01
Organic Fertilizer (100 lb N/A) plus Gypsum (500 lb/A)	47.6 b	88.1 cd	5.5 d	10.06	10.01
Hairy Vetch Tilled	43.6 a	72.3 ab	3.7 ab	10.12	10.02
Hairy Vetch Strip-Tilled plus organic fertilizer (50 lb. N/A)	47.0 b	92.5 d	2.8 a	10.02	10.00
Conventional Control	41.7 a	77.7 abc	2.9 a	10.03	10.02
Conventional Fertilizer	48.8 bc	92.9 d	4.1 b	10.04	10.03
Conventional Fertilizer, Lime and Sulfur	48.3 bc	85.5 bcd	4.0 b	10.00	10.01
LSD (0.05)	3.32	13.3	0.95	N.S.	N.S.

[z] Insect numbers transformed (x+10) for ANOVA, due to low population numbers.

Table 2. Pepper yield, number of peppers, mean weight per pepper (three harvests combined), and pepper quality, MIRDF, 2002.

Treatment	Mean Yield (Lb/A)	Mean No. Peppers/ Acre	Mean Weight/ Pepper (g)	Culls (%)	Blemishes/ Pepper
Organic Control	4043.8	14615.4	129.71	16.85	0.40
Organic Fertilizer (100 lb N/A)	5169.4	18343.2	137.40	16.71	0.46
Organic Fertilizer (50 lb N/A) plus Gypsum (500 lb/A)	3324.9	15461.5	131.43	14.37	0.35
Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A)	4971.3	19230.8	132.33	17.24	0.46
Hairy Vetch Tilled	4289.5	15897.4	127.91	16.88	0.46
Hairy Vetch Strip-Tilled plus Fertilizer (50 lb. N)	4497.4	15256.4	134.84	8.44	1.03
Conventional Control	3543.1	15664.3	116.71	12.10	0.94
Conventional Fertilizer	4754.5	18333.3	130.46	7.56	0.64
Conventional Fertilizer, Lime and Sulfur	6287.3	20384.6	147.14	17.76	0.38
LSD (0.05)	N.S.	N.S.	N.S.	N.S.	N.S.

Organic and conventional yields were similar in 2002 (Table 2). Although there was a trend towards greater yield, number of harvested peppers and average weight per pepper in the organic fertilizer (100 lb N/A) plus gypsum and conventional fertilizer plus lime plots, yields were not statistically different among treatments. These results compare with previous years where conventional and organic yields were similar when 100 lb N/A was provided through fertilizer or compost. From1998 through 2000, however, organic pepper plants produced greater yields when provided with additional nitrogen (100 lb. N/A vs. 50 lb. N/A compost treatments), but in 2001 and 2002, no significant differences in yield, number of peppers and mean pepper weight were found between the 50 and 100 lb N/A organic fertilizer treatments. Enhanced pepper productivity was obtained with nitrogen additions as low as 50 lb N/A from the organic fertilizer in 2002, suggesting increased nutrition from the mineral components of the organic fertilizer and/or a more rapid N mineralization rate in the poultry litter base compared to the Ultra Gro™ compost used from 1998 to 2000.

Higher yields were obtained in the vetch treatments in 2002 compared to the previous years. In 2002, vetch treatments were equivalent to conventional fertilizer treatments, compared to 2001, where strip-tilled vetch plots contained the lowest yielding peppers, and incorporated vetch yields were statistically equivalent to the organic fertilizer treatments, but significantly lower than the conventional treatments. The addition of the 50 lb N/A side-dress application greatly enhanced plant performance in the strip-tilled plots. While not statistically different, strip-tilled pepper yields were greater than yields in the completely incorporated vetch treatment. Yields in the incorporated vetch treatment were similar to the organic fertilizer (50 lb N/A) plus gypsum treatment, suggesting an N contribution of 50 lb/A from the incorporated vetch. Biomass additions from the two vetch treatments were similar (Table 3). The 2002 results are similar to research reported in Ohio, where yields were comparable between conventionally fertilized tomatoes and organic tomatoes planted into an undercut cover crop mixture of hairy vetch, rye, crimson clover (*Trifolium incarnatum* L.) and barley (*Hordeum vulgare* L) (Creamer et al., 1996).

Table 3. Hairy vetch biomass, MIRDF, May 22, 2002.

Treatment	**Dry weight (Lb/A)**
Hairy Vetch Tilled	3,549.7 ± 194.8
Hairy Vetch Strip-Tilled	3,531.7 ± 207.4
LSD 0.05	N.S.

As in 2001, there was a significantly greater number of diseased pepper plants removed from the strip-tilled vetch plots in 2002, suggesting an environment more conducive to disease development (Table 4). While not statistically significant, pepper plant removal due to disease symptoms was lowest in the gypsum plus organic fertilizer (50 lb. N/A) treatment, and the conventional fertilizer plus lime and sulfur treatments.

Table 4. Rogued pepper plants due to disease, MIRDF, July 11, 2002.

Treatment	Diseased plants (%)
Organic Control	3.37 a
Organic Fertilizer (100 lb N/A)	1.44 a
Organic Fertilizer (50 lb. N/A) plus Gypsum (500 lb/A)	0.96 a
Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A)	1.44 a
Hairy Vetch Tilled	3.85 a
Hairy Vetch Strip-Tilled plus Fertilizer (50 lb. N)	14.4 b
Conventional Control	3.85 a
Conventional Fertilizer	1.92 a
Conventional Fertilizer, Lime and Sulfur	0.96 a
LSD (0.05)	3.19

Postharvest weight loss did not differ among treatments (Table 5), similar to results obtained in the compost (100 lb N/A) and synthetic fertilizer treatments in 1999 and 2000 after three to nine weeks in 50° F storage.

Treatment	**Weight loss (%)**		
	2 weeks	**4 weeks**	**6 weeks**
Organic Control	3.15	8.61	11.75
Organic Fertilizer (100 lb N/A)	3.23	8.89	11.49
Organic Fertilizer (50 lb. N/A) plus Gypsum (500 lb/A)	3.71	9.22	12.50
Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A)	3.48	9.02	12.61
Hairy Vetch Tilled	3.37	8.74	11.73
Hairy Vetch Strip-Tilled plus Fertilizer (50 lb. N)	3.16	7.89	10.46
Conventional Control	4.00	9.33	12.23
Conventional Fertilizer	3.07	8.37	12.35
Conventional Fertilizer, Lime and Sulfur	3.50	8.74	11.24
LSD (0.05)	N.S.	N.S.	N.S.

Conclusions

With the continued 20% annual industry growth rate, organic agriculture holds much promise for vegetable producers (Clark et al., 1999). Lower yields in the transition from conventional to organic production are expected due to slower N-release from organic materials compared to synthetic fertilizers (MacRae et al., 1993). Our limited knowledge of the underlying mechanisms operating in organic farming systems (Høgh-Jensen, 1998) includes our lack of understanding of soil quality and plant productivity improvements from the interactions between beneficial microbial populations and nutrients present in manure-based organic fertilizers. Animal-based and cover crop-based fertilization has been effective in increasing soil organic matter and biological activity within organic production systems. Differences in compost maturity and fluctuating moisture content are key factors affecting N mineralization rates. While strip-tilling or conservation tillage of vegetables into cover crops can help mitigate soil erosion and aid in weed management, competition from re-growth and inadequate N contribution have limited adoption of this system for organic growers. In 2002, we increased yields in the strip-tilled vetch treatment by adding50 lb N/A from organic fertilizer, side-dressed after transplanting. We will continue evaluation of this system in 2003, and add an economic comparison with compost alone and incorporated vetch crops. Based on four years of data from the MIDRF, lower yields should be anticipated if growers rely solely on incorporated (tilled) vetch cover crops for their nitrogen source. Cost of production analysis, however, may favor crops produced with on-farm sources of cover crop seed as opposed to off-farm fertilizer inputs.

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