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

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Introduction

Organic production rose to 2.3 million acres in the U.S. in 2001 (USDA-ERS, 2002). Much of the increase has been associated with the implementation of consistent federal standards for products marketed as "organic" in October 2002 (USDA/AMS, 2002). In order to meet certified organic requirements in the state of Iowa (IDALS, 2000), a soil-building cover crop is required for at least one out of every five years of horticulture production. 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). 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 to 2002. Pepper growth, harvest weight and marketable fruit numbers were similar in conventional and organic production systems from 1998 to 2002 when 100 lb. N/A was applied through synthetic fertilizer or compost/organic fertilizer. Zone-tillage organic pepper production resulted in significantly reduced growth and pepper weight in two out of three years at the MIDRF. In 2003, a third-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. The additional side-dress application resulted in a significant increase in plant production in 2002.

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 24, 2002, 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 14) and at transplant (June 13). Plots previously planted to rye in the non-vetch treatments were roto-tilled on May 30, 2003. Treatment 5 vetch plots were mowed on June 5 and roto-tilled to completely incorporate the residue on June 7. 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 23 and mechanically transplanted into rows (at 18" x 42" spacing) in 15' x 20' plots on June 13, 2003. 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). Forty-eight plants were planted in each replicated plot for a total of 1,728 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, Cinagrow™ (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 4-3-5 N-P-K. Organic fertilizer was applied as a 50 or 100 lb. N/A treatment prior to planting on May 14, 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 May 30 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 14, 2003. 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 26, July 14, and July 28, 2003. 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 13, August 25, and September 12, 2003. Fresh weights were taken immediately after harvest and blemishes (insect or disease lesions rendering peppers unsalable) were enumerated. 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 , four and six weeks after storage. Evaluations were terminated when peppers were unmarketable. All measurements were subjected to analysis of variance and Fisher's PLSD test ($P \leq 0.05$) (SAS Institute, 1988).

Results and Discussion

At maximum growing point (July 28), mean leaf height was significantly different among treatments (Table 1). The tallest plants were found in the treatment of organic fertilizer (50 and 100 lb N/A) alone and with gypsum, and the vetch treatments. Leaf number was also greater in the organic treatments. Fruit number was similar in all treatments, except in the vetch treatments, where fruit numbers were the lowest (Table 1). Plant growth was not increased by adding lime or gypsum to the fertilizer treatments.

Plant height and leaf number in the strip-tilled vetch treatment plus 50 lb. N/A side-dress application were equivalent to 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. Insect populations were low overall, and insect pests and beneficial insects were not significantly different among treatments (Table 1).

Organic and conventional yields were similar in 2002 (Table 2). Although there was a trend towards greater yield in the organic fertilizer (100 lb N/A), the vetch tilled, and conventional fertilizer 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, compost or cover crops. 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, 2002, and 2003, 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 2003, suggesting a more rapid N mineralization rate in the poultry litter based fertilizer compared to the Ultra Gro™ compost used from 1998 to 2000.

Higher yields were obtained in the tilled vetch treatments in 2003 compared to 1999-2001 results, similar to 2002 results. In 2002 and 2003, 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 enhanced plant growth in the strip-tilled plots but fruit production was more limited than in 2002. Although vetch biomass production and nitrogen content (2%) was similar between treatments (Table 3), the cooling effect of the vetch strips may have lowered temperatures in the rooting zone of strip-tilled pepper plants, slowing fruit set and pepper fruit growth in this treatment. There were no differences in average pepper weight and percentage of blemished peppers among treatments. Postharvest weight loss was not consistent across treatments, with the conventional and organic control fruit having the greatest weight loss after 2–6 weeks in storage (Table 4).

Table 1. Pepper plant growth and insect parameters, MIRDF, 28 July 2003.

Treatment	Mean Plant Height (cm)	Mean Plant Leaf No.	Mean Plant Fruit No.	Mean No. Beneficial Insects	Mean No. Pest Insects
Organic Control	35.05 b	53.28 b	2.25 ab	1.50	0.33
Organic Fertilizer (100 lb N/A)	38.15 c	59.73 bc	2.25 ab	1.42	1.00
Organic Fertilizer (50 lb N/A) plus Gypsum (500 lb/A)	37.65 c	61.75 c	2.68 b	0.62	0.54
Organic Fertilizer (100 lb N/A) plus Gypsum (500 lb/A)	38.05 c	59.93 bc	2.35 ab	0.83	1.83
Hairy Vetch Tilled	36.95 bc	56.38 bc	1.45 a	1.25	0.58
Hairy Vetch Strip-Tilled plus organic fertilizer (50 lb. N/A)	38.18 c	61.50 c	1.45 a	0.92	0.67
Conventional Control	29.45 a	49.10 a	2.78 b	0.58	1.33
Conventional Fertilizer	31.20 a	46.53 a	2.15 ab	0.42	0.83
Conventional Fertilizer, Lime and Sulfur	30.13 a	44.45 a	2.50 ab	0.50	1.25
LSD (0.05)	2.28	7.80	1.01	NS	NS

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

Table 2. Pepper yield, number of peppers, mean weight per pepper, and pepper quality, MIRDF, 13 Aug 2003.

Treatment	Mean Yield (lb/A)	Mean No. Peppers/ Acre	Mean Weight/ Pepper (g)	Blemished Peppers (%)
Organic Control	2664.2	10892.9	117.01	0.0
Organic Fertilizer (100 lb N/A)	3461.6	10714.3	149.49	1.47
Organic Fertilizer (50 lb N/A) plus Gypsum (500 lb/A)	3049.9	10892.9	160.86	5.42
Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A)	2708.2	7500.0	130.16	2.50
Hairy Vetch Tilled	3107.9	10178.6	154.32	0.0
Hairy Vetch Strip-Tilled plus Fertilizer (50 lb. N)	1731.6	5000.0	113.78	4.54
Conventional Control	2478.2	8928.6	237.45	11.92
Conventional Fertilizer	3191.6	10000.0	141.08	1.32
Conventional Fertilizer, Lime and Sulfur	2785.8	8750.0	148.81	1.47
LSD (0.05)	NS	NS	NS	NS

Table 3. Hairy vetch biomass, MIRDF, May 14, 2003.

Treatment	Dry weight (Lb/A)	Percent Nitrogen	Percent Dry Matter
Hairy Vetch Tilled	8950.71	2.00	18.67
Hairy Vetch Strip-Tilled	10771.52	2.34	24.31
LSD 0.05	NS	NS	NS

Table 4. Pepper postharvest weight loss after 2 to 6 weeks in 50°F storage, 2003.

Treatment	Weight loss (%)		
	2 weeks	4 weeks	6 weeks
Organic Control	2.0	3.9	6.2
Organic Fertilizer (100 lb N/A)	1.7	3.4	5.4
Organic Fertilizer (50 lb. N/A) plus Gypsum (500 lb/A)	1.7	3.5	5.4
Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A)	1.7	3.2	5.0
Hairy Vetch Tilled	1.7	3.4	7.5
Hairy Vetch Strip-Tilled plus Fertilizer (50 lb. N)	1.5	3.1	5.2
Conventional Control	1.9	3.7	5.8
Conventional Fertilizer	1.8	3.6	5.5
Conventional Fertilizer, Lime and Sulfur	1.7	3.5	5.7
LSD (0.05)	.002	.003	.018

Conclusions

With the continued 20% annual industry growth rate, organic agriculture holds much promise for vegetable producers (USDA-ERS, 2002). 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, inadequate N mineralization and potential cooling of soil surrounding plants may limit the adoption of this system for organic growers. In 2004, we will evaluate the effect of maintaining a cover crop for an entire growing season on soil properties and on subsequent vegetable crop yields.

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