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

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## *Introduction*

In 1998, Iowa producers identified the need for research on soil amendments and cover crops for certified organic horticultural operations (Delate and DeWitt, 1998). Significant growth in the organic food industry, particularly in Western countries (Lampkin and Padel, 1994), has attracted many Iowa producers. The U.S. organic industry continues to grow at a rate of 20% annually (Greene, 2000), with organic sales reaching $8 billion in 2000 (OTA, 2001). Sales are expected to increase with the implementation of consistent federal standards for products marketed as “organic” by October 2002 (USDA-NOP, 2000). In 1999, Iowa farmers reported 150,000 acres of organic production to the Iowa Department of Agriculture and Land Stewardship survey (IDALS, 2000).

Organic vegetable farmers routinely apply compost and calcium products to their soil, but there is limited research on the effects of these products. Because nitrogen in synthetic fertilizers is rapidly mobile and available in the early phase of the growing season, slow-release organic amendments provide additional challenges for organic farmers. In 1998 and 1999, we compared the productivity of organic peppers with conventional peppers produced with synthetic agrichemicals 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).

Beginning in 1999, our research has included the incorporation of a legume cover crop in the fertility comparison trials. 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. 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. In the 2000 season, however, vetch growth in the fall of 1999 and spring of 2000 was impacted by hot, dry weather conditions and stands were less than 50% in 75% of plots. Vetch strip plots produced significantly less peppers and significantly lower pepper weight than the controls (Delate & Lawson, 2000), although organic peppers produced equivalent yields to conventional when fertilized with 100 lb. N/A from compost.

In 2001, we continued this research with some treatment modification.  As a result of changes in supply, the compost was replaced by an organic poultry litter based fertilizer and Bio-cal® was replaced with gypsum. Fourth year soil amendment and third year vetch trial results are presented below.

## *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 on September 12, 2000, and after germination, remained dormant throughout the winter.  Soil samples (a composite of 5 6-in. cores) were taken in each plot at pre-season (May 8) and at the last harvest (September 11).  Plots previously planted to rye at the MIRDF were roto-tilled on May 29, 2001.  Vetch plots (Treatment 5) were mowed on May 21 and roto-tilled to completely incorporate the residue (May 30). The vetch in the strip-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 11 and mechanically transplanted into rows (at 18” x 42” spacing) in 15’ x 20’ plots on June 1, 2001.  Four replications of nine treatments  were planted within the field plots. 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; 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 at 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 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 23.  A side-dress of 34-0-0 at 143 lb/A provided an additional 44 lb N/A at first flower**.**  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).  Treflan® was applied at 1 pt/A on May 30 in the conventional plots.  No insecticide was applied in any treatments. 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.  The gypsum applied contained 21% calcium and 17% sulfur.

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.  As a result of inadequate growth of the vetch cover, rye straw was applied as a mulch (3 in. deep) on July 16, 2001**.**  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 18, July 2, July 19, and August 2, 2001.  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 2, August 14, August 28 and September 11, 2001. The number of pepper plants showing disease symptoms and removed from plots was determined at final harvest. Fresh weights were taken immediately after harvest.  All measurements were subjected to analysis of variance and Fisher's PLSD test (P•0.05).

***Results***

At maximum growing point (August 2), mean leaf height and fruit number was significantly different among treatments (Table 1). The organic fertilizer (100 lb N/A) treatment produced the tallest plants, significantly taller than all treatments except the organic fertilizer (100 lb N/A) plus gypsum and the conventional fertilizer treatment. Plant height in the strip-tilled vetch treatment was significantly greater than in the organic control. However, fruit number was impacted by poor vetch growth and vetch treatments produced significantly less fruit than all other treatments, including controls. The greatest numbers of fruit were produced in the organic fertilizer treatment of 100 lb N/A and the organic fertilizer treatment of 50 lb N/A plus gypsum. There was no significant differences in fruit number between the organic fertilizer at 50 lb N/A plus gypsum and the organic fertilizer at 100 lb N/A plus gypsum.

Table 1. Pepper plant growth parameters, MIRDF, 2 August 2001.

| **Treatment** | **Mean Plant Height (cm) ±S.E.** | **Mean Fruit No. ±S.E.** |
|---|---|---|
| Organic Control | 45.49±0.57 | 5.45±0.27 |
| Organic Fertilizer (100 lb N/A) | 52.47±1.22 | 6.32±0.27 |
| Organic Fertilizer (50 lb. N/A) plus Gypsum (500 lb/A) | 48.81±0.75 | 6.35±0.35 |
| Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A) | 49.92±1.04 | 6.05±0.26 |
| Hairy vetch tilled | 46.21±1.38 | 4.95±0.32 |
| Hairy vetch strip-tilled | 50.52±0.87 | 4.35±0.30 |
| Conventional Control | 46.24±0.99 | 5.17±0.29 |
| Conventional Fertilizer | 50.59±0.84 | 5.22±0.23 |
| Conventional Fertilizer, Lime and Sulfur | 49.01±1.06 | 5.70±0.30 |
| LSD (0.05) | 2.77 | 0.80 |

Insect pests (primarily aphids and lepidopterous larvae) and beneficial insects (primarily ladybeetles, lacewings, and spiders) were recorded throughout the experiment. The strip-tilled vetch plots contained the greatest number of beneficial insects and was statistically equivalent to the organic control. The conventional control plots contained the greatest numbers of insect pests compared with all other treatments, but these populations were statistically equivalent to the organic control (Table 2).

Table 2. Mean number of beneficial and insect pests, MIRDF, 2001.

| **Treatment** | **Mean No. of Beneficials ±S.E.** | **Mean No. of Pests ± S.E.** |
|---|---|---|
| Organic Control | 1.40±0.24 | 1.33±0.21 |
| Organic Fertilizer (100 lb N/A) | 1.10±0.10 | 1.00±0.00 |
| Organic Fertilizer (50 lb. N/A) plus Gypsum (500 lb/A) | 1.17±0.17 | 1.00±0.00 |
| Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A) | 1.00±0.00 | 1.00±0.00 |
| Hairy vetch tilled | 1.14±0.14 | 1.20±0.13 |
| Hairy vetch strip-tilled | 2.00±0.00 | 1.25±0.25 |
| Conventional Control | 1.00±0.00 | 2.00±1.00 |
| Conventional Fertilizer | 1.00±0.00 | 1.00±0.00 |
| Conventional Fertilizer, Lime and Sulfur | 1.14±0.14 | 1.00±0.00 |
| LSD (0.05) | 0.37 | 0.66 |

Table 3. Pepper yield, number of peppers, and mean weight per pepper (four harvests combined), MIRDF, 2001.

| **Treatment** | **Mean Yield (g)** | **S.E.** | **Mean Number of Peppers** | **S.E.** | **Mean Weight per Pepper (g)** | **S.E.** |
|---|---|---|---|---|---|---|
| Organic Control | 2784.96 | 336.80 | 22.81 | 2.64 | 123.73 | 7.10 |
| Organic Fertilizer (100 lb N/A) | 3788.25 | 383.85 | 22.93 | 2.70 | 171.58 | 6.85 |
| Organic Fertilizer (50 lb N/A) plus Gypsum (500 lb/A) | 3584.26 | 257.53 | 24.83 | 1.79 | 146.17 | 4.93 |
| Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A) | 3736.55 | 331.03 | 25.00 | 2.24 | 150.99 | 4.67 |
| Hairy vetch tilled | 3050.52 | 287.22 | 22.00 | 2.65 | 147.36 | 7.59 |
| Hairy vetch strip-tilled | 2258.91 | 275.08 | 18.40 | 2.11 | 127.70 | 10.45 |
| Conventional Control | 2429.51 | 214.70 | 18.06 | 1.34 | 133.46 | 3.93 |
| Conventional Fertilizer | 3967.62 | 386.15 | 25.27 | 2.33 | 155.62 | 4.25 |
| Conventional Fertilizer, Lime and Sulfur | 4426.84 | 224.40 | 30.59 | 1.85 | 147.27 | 4.99 |
| LSD (0.05) | 820.79 | | 6.03 | | 17.24 | |

Organic and conventional yields were similar in plots where organic fertilizer at 50 lb N/A plus gypsum and the organic fertilizer at 100 lb N/A plus gypsum were applied (Table 3). Mean pepper weight in the organic fertilizer (100 lb N/A) treatment was equivalent to the conventional fertilizer treatment and significantly greater than all other treatments. Strip-tilled vetch plots contained the lowest yielding peppers, although yields were not significantly less than the controls, as was observed in 2000. Mean pepper weights were significantly less than all other treatments and equivalent to the organic control. Where vetch was incorporated, yields were statistically equivalent to the organic fertilizer treatments but significantly lower than the conventional treatments.

Table 4. Post harvest weight loss for all harvests combined, MIRDF, 2001.

| **Treatment** | **Weight loss after 3 weeks (%) ± S.E.** | **Weight loss after 6 weeks (%) ± S.E.** | **Weight loss after 9 weeks (%) ± S.E.** |
|---|---|---|---|
| Organic Control | 4.88 ± 0.13 | 14.62 ± 2.39 | 6.62 ± 1.74 |
| Organic Fertilizer (100 lb N/A) | 4.12 ± 0.13 | 8.22 ± 0.47 | 4.58 ± 1.84 |
| Organic Fertilizer (50 lb. N/A) plus Gypsum (500 lb/A) | 4.35 ± 0.14 | 8.52 ± 0.25 | 3.14 ± 0.65 |
| Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A) | 4.27 ± 0.14 | 8.27 ± 0.27 | 5.25 ± 1.28 |
| Hairy vetch tilled | 4.33 ± 0.17 | 8.34 ± 0.28 | 8.51 ± 1.72 |
| Hairy vetch strip-tilled | 4.41 ± 0.14 | 7.41 ± 0.32 | 4.01 ± 1.20 |
| Conventional Control | 4.36 ± 0.15 | 8.19 ± 0.34 | 5.75 ± 1.60 |
| Conventional Fertilizer | 4.06 ± 0.16 | 7.81 ± 0.31 | 5.08 ± 0.65 |
| Conventional Fertilizer, Lime and Sulfur | 3.84 ± 0.13 | 7.55 ± 0.23 | 11.21 ± 2.31 |
| LSD (0.05) | 0.39 | 2.29 | 4.22 |

There were a significantly greater number of diseased pepper plants removed from the strip-tilled vetch and the conventional control treatments compared with other treatments (Table 5). Pepper plant removal due to disease symptoms was lowest in the organic fertilizer (100 lb. N/A) treatment.

Table 5. Mean number of pepper plants removed from each treatment, MIRDF, 2001.

| **Treatment** | **Mean number of diseased plants removed from plots** | **S.E.** |
|---|---|---|
| Organic Control | 1.75 | 1.03 |
| Organic Fertilizer (100 lb N/A) | 0.50 | 0.50 |
| Organic Fertilizer (50 lb. N/A) plus Gypsum (500 lb/A) | 2.50 | 0.87 |
| Organic Fertilizer (100 lb N/A) plus Gypsum (500lb/A) | 1.00 | 0.58 |
| Hairy vetch tilled | 3.40 | 0.51 |
| Hairy vetch strip-tilled | 7.25 | 3.01 |
| Conventional Control | 4.25 | 1.25 |
| Conventional Fertilizer | 1.67 | 0.88 |
| Conventional Fertilizer, Lime and Sulfur | 0.75 | 0.75 |
| LSD (0.05) | 3.53 | |

***Discussion***

With 150,000 acres of organic production in Iowa (IDALS, 2000), and a continued 20% annual industry growth rate (OTA, 2001), there is no indication that the market for organic products will experience any declines. As was observed in 1998-2000, organic and conventional pepper yields in 2001 were equivalent when plants were provided organic fertilizer. In 2001, an organic fertilizer and gypsum were substituted for the organic compost and Biocal® applied in 1998-2000. In 1998 through 2000, organic pepper plants produced greater yields when provided with 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. In 2001, no significant differences in yield, number of peppers and mean pepper weight were found between the organic fertilizer (100 lb N/A), organic fertilizer (50 lb N/A) plus gypsum treatment, and the organic fertilizer (100 lb N/A) plus gypsum treatment. Only in one out of four years was organic pepper weight significantly greater with the addition of calcium applications. The same pattern was observed in the conventional treatments where the addition of lime did not significantly increase plant growth or yields.

Strip-tilling or conservation tillage of cover crops is one method advocated to help mitigate soil erosion and 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. For a leguminous cover crop to supply nitrogen equivalent to compost applications and to play a role in weed management, however, cover crop growth must be adequate. Pepper yields were lowest in the vetch strip-tilled plots for the second consecutive year, although not significantly lower than the controls, as was observed in 2000. The yields in the 2001 strip-tilled plots were significantly lower than the three organic fertilizer treatments and the two conventional treatments. Mean pepper weight was equivalent to the organic control and significantly lower than all the other treatments. Incorporated vetch plots performed better, with yields equivalent to the organic fertilizer treatments. The poor performance in vetch-strip plots in 2000 was attributed to dry weather conditions in late fall of 1999 and spring of 2000 and a resultant poor stand of vetch. In addition, competition between vetch plants and pepper plants occurred. Even with a wetter spring and timely irrigation allowing for a good stand of vetch in 2001, vetch strip plot performance was inferior to vetch incorporated plots. Timing of incorporation of the tilled vetch strips may be important in insuring decomposition and timely nutrient release. Preventing competition through continued vetch strip management is key. In addition, significantly more diseased plants were removed from the strip-tilled vetch plots and the conventional control, suggesting a pathogen-crop interaction with the vetch strips. We will investigate this additional potential constraint in 2002, in addition to fine-tuning the undercutting of the vetch strips.

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