# Improving Soil Health and Increasing Rotation Options for Organic High Tunnel Vegetable Production

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UNIVERSITY OF MINNESOTA EXTENSION

## INTRODUCTION

High tunnels are plastic covered, low-energy use structures that appear similar to greenhouses, but differ from conventional greenhouses in major ways, one being significantly lower construction and operating costs. High tunnels are capable of extending the growing season earlier in the spring and later in the fall, increasing the availability and amount of locally grown food. High tunnels are an intermediary between full environmental risk-taking of outdoor production, and the controlled conditions and relatively high energy use of a conventional greenhouse.

High tunnels can be successfully used in organic production by offering a more controlled environment offering protection from weather conditions such as heavy rain and wind; constant wet foliage which can lead to disease problems; may provide a safe haven for predatory insects; and generally provide plants with a less stressful growing environment.

Organic high tunnel research has been conducted at the University of Minnesota Southwest Research and Outreach Center (SWROC), located in Lamberton, MN since 2009. The SWROC has three 30' x 48' high tunnels, certified by the Midwest Organic Services Association (MOSA).

## OBJECTIVES

This research was conducted to:

- Select a wider number of economically viable vegetable crops species to incorporate in a rotation to improve soil health;
- Provide high tunnel producers with information on how to remediate soil nutrient imbalance to maintain sustainability;
- and determine the nutrient value of plant compost compared with beef manure compost.

## MATERIALS AND METHOD

### Soil fertility treatments:

1. Beef manure compost applied at 112 kg available N/ha
2. Alfalfa tissue compost applied at 112 kg available N/ha
3. Turkey manure compost applied at 112 kg available N/ha
4. No fertility control treatment

### Vegetable crop varieties:

1. Cucumber - Socrates
2. Determinate tomato – Scarlet Red
3. Green Pepper – Ace
4. Potato – Dark Red Norland, Yukon Gold
5. Sweet Potato – Beauregard, Georgia Jet
6. Round Red Beets – Red Ace
7. Cauliflower - Skywalker
8. Broccoli – Belstar
9. Brussels Sprouts - Nautic


### High tunnel setup:

- Three gothic style 9 x 15m high tunnels oriented east-west for optimal solar radiation.
- Certified organic land, in close proximity to windbreaks for protection.
- Five 12 x 0.6m raised beds (7.6 cm) per tunnel, centered 1.6m apart, and divided into four soil fertility subplots.
- After construction each bed had an application of 137 kg/m$^2$ of sand.
- Each tunnel has electric and water lines installed, and automatic thermostatic controlled side roll ups for temperature control.
- Two 2.54 cm flatube tapes, spaced 28 cm apart provide water to each bed, black plastic mulch is used for moisture retention and weed control.
- Soil moisture monitored with tensiometers and electronic sensors
- Air, and soil temperatures monitored with electronic sensors.

### Procedures:

- Vegetable seedlings were started in the greenhouse in March (tomatoes and peppers March 4, cucumbers March 19, 2013.
- Hairy vetch (planted October 10, 2012 at a rate of 39 kg/ha) was incorporated into beds April 9, 2013. Compost was applied (112 kg/ha) and incorporated April 10, 2013.

### Procedures continued:

- Cucumber seedlings were transplanted 43 cm apart into the high tunnels on April 26, 2013. Potatoes were planted 30 cm apart on April 29, 2013. Peppers were also planted on April 29, 2013 43 cm apart. Tomatoes were planted 43 cm apart on May 6, 2013, and sweet potatoes slips originally planted April 30, 2013 (30 cm apart) were replanted May 13, 2013.
- Cucumbers were trellised for support; determinate varieties were supported with cages.
- Disease and insect control were managed through use of OMRI approved methods only.
- Harvest began in June for cucumbers and July for tomatoes and peppers and finished in late October for all three crops. Potatoes were harvested July 29, 2013 and sweet potatoes August 9, 2013.
- Round red beets (7.6 cm spacing) and cauliflower (43 cm spacing) were planted July 30, 2013 after potato harvest. Broccoli and Brussels sprouts were planted (43 cm spacing) August 12, 2013 after sweet potato harvest.
- Round red beets were harvested October 14, 2013. Cauliflower, broccoli and Brussels sprouts biomass was collected November 25, 2013.
- Soil samples (0-15cm, 15-30cm, 30-60cm) were collected on May 22, 2013, midseason following potato and sweet potato harvest and at the end of the season on November 11, 2013.


## RESULTS AND DISCUSSION

**Table 1. Growing Degree Days**

| | 2013 GDD | |
|---|---|---|
| Date | High Tunnel | Outdoor |
| May | 416 | 273 |
| June | 604 | 525 |
| July | 742 | 672 |
| August | 701 | 612 |
| September | 501 | 483 |
| October | 181 | 169 |
| November | 32 | 22 |
| Total | 3177 | 2756 |

+GDD = (Tmax +Tmin)/2 – Tbase. Where Tmax is maximum daily temperature and is set equal to 86°F when temperatures exceed 86°F,Tmin is the minimum daily temperature and is set equal to 50°F when temperatures fall below 50°F, Tbase is the base temperature.

**Table 2. 2013 Yield – Total Season Weight by Soil Fertility Treatment**

| Soil Fertility | Cucumber t/ha | Tomato t/ha | Pepper t/ha |
|---|---|---|---|
| Alfalfa Compost | 149 a | 267 ab | 97 ab |
| Beef Compost | 142 a | 278 a | 113 a |
| Turkey compost | 119 a | 230 b | 82 b |
| No-fertility | 123 a | 265 ab | 99 a |

+Means followed by the same letter by column are not significantly different at the 0.05 probability level.

**Table 3. 2013 Potato and Sweet Potato Yield – Total Season Weight by Soil Fertility Trt.**

| Soil Fertility | Potato Grade | D. Red Norland t/ha | Yukon Gold t/ha | Sweet Potato Grade | Beauregard t/ha | G. Jet t/ha |
|---|---|---|---|---|---|---|
| Alf. compost | A | 10 a | 46 b | 1 | 4 a | 20 b |
| Beef compost | A | 12 a | 56 a | 1 | 5 a | 28 a |
| Turkey compost | A | 9 a | 28 d | 1 | 6 a | 11 c |
| No-fertility | A | 7 a | 37 c | 1 | 6 a | 12 c |
| Alf. compost | B | 6 a | 12 ab | 2 | 9 a | 9 a |
| Beef compost | B | 5 a | 14 a | 2 | 8 a | 10 a |
| Turkey compost | B | 7 a | 10 c | 2 | 8 a | 9 a |
| No-fertility | B | 13 a | 11 bc | 2 | 8 a | 10 a |
| Alf. compost | C | 2 a | 6 a | | | |
| Beef compost | C | 2 a | 4 b | | | |
| Turkey compost | C | 3 a | 4 b | | | |
| No-fertility | C | 4 a | 3 c | | | |

+Means followed by the same letter within column and grade are not significantly different at the 0.05 probability level. Potato grade A equal or greater than 6.4 cm diameter, grade B 4.4 cm to 6.4 cm diameter, grade C tubers diameter less than 4.4 cm. Sweet potato grade 1 4.4 cm to 10cm diameter, grade 2 root diameter 2.5 cm to 4.4 cm.

**Table 4. Second Crop Yield/Biomass – Total Season Weight by Soil Fertility Trt.**

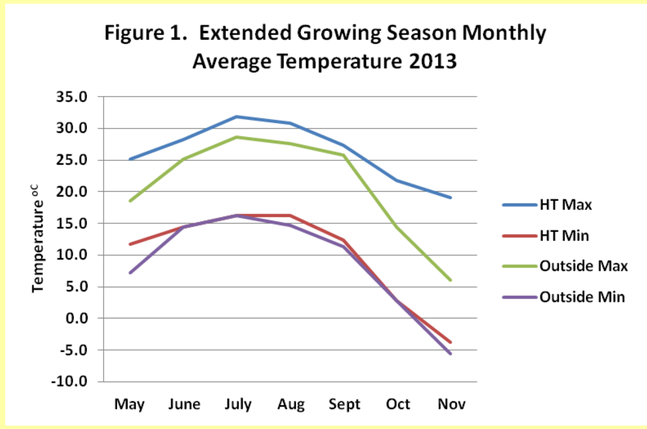
| Soil Fertility | Red Beets Yield t/ha | Cauliflower Biomass t/ha | Broccoli Biomass t/ha | Brussels Sprouts Biomass t/ha |
|---|---|---|---|---|
| Alfalfa Compost | 34 a | 65 a | 45 a | 22 a |
| Beef Compost | 37 a | 61 a | 43 a | 21 a |
| Turkey compost | 31 a | 49 a | 34 a | 25 a |
| No-fertility | 33 a | 49 a | 31 a | 21 a |

+Means followed by the same letter by column are not significantly different at the 0.05 probability level.

**Table 5. Fall 2012 High Tunnel P and K levels versus Soil Test P and K Interpretation Category for Vegetables (ppm)**

| Nutrient | Very Low | Low | Optimum | High | Very High | 2012 Levels |
|---|---|---|---|---|---|---|
| Phosphorus (P) | < 15 | 15-30 | 31-45 | 46-75 | >75 | 210 |
| Potassium (K) | < 60 | 60-120 | 121-180 | 181-200 | >200 | 675 |

+Source




## Discussion

- Maximum and minimum air temperatures are shown in Figure 1. During the 2013 growing season the maximum monthly air temperature in the high tunnels averaged 3.5°C higher than the outside maximum temperature. In addition, high tunnel minimum air temperatures were 1.4°C warmer than the outside minimum temperatures.
- Growing degree days (GDD) is a method to evaluate the effect of temperatures on plant growth. Long-term GDD values for Lamberton average 2528. In 2013 (Table 1) outside GDD totals were 2756 compared to 3177 in the high tunnels.
- There was no significant yield difference in cucumber yield (Table 2).
- Tomato and pepper yields were greatest in the beef compost treatment (Table 2).
- Yukon Gold potato yields were significantly higher in the beef compost treatment in grade A, alfalfa and beef compost treatments yielded significantly higher grade B yellow potatoes, and alfalfa compost yielded the greatest potato grade C (Table 3).
- Sweet potato yields varied by variety and grade (Table 3). Georgia Jet yields were greater than Beauregard, with beef compost yielding significantly higher grade 1 sweet potatoes, and no significant differences among treatments in yields in grade 2 (Table 3).
- Of the double crops planted only the Round red beets yielded any produce (Table 4), there was no significant treatment difference. Cauliflower, broccoli and Brussels sprouts produced large amounts of biomass, but no vegetable yields (Table 4).
- Soil nitrogen levels decreased after potato harvest, 88 kg/ha to 45 kg/ha (Figure 2) and 71 kg/ha to 27 kg/ha after sweet potato harvest (Figure 5).
- Phosphorus (Figure 3 and 6) and potassium (Figure 4 and 7) did not decrease suggesting the potato and sweet potato crop was able to remove the phosphorus and potassium nutrients that were applied and did not use the nutrients in reserve.

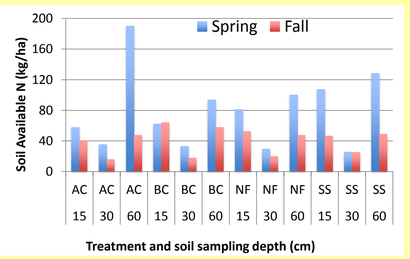



Figure 2. Soil available N for soil samples collected in the spring and fall (after potato harvest) of the 2013 growing season. AC: alfalfa compost, BC: beef manure compost, NF: control, and SS: Sustane®.

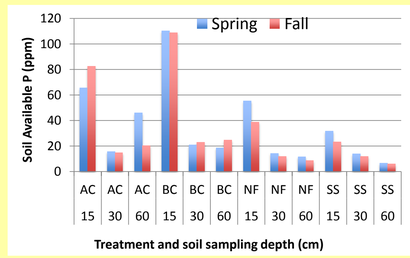



Figure 3. Soil available P for soil samples collected in the spring and fall (after potato harvest) of the 2013 growing season.

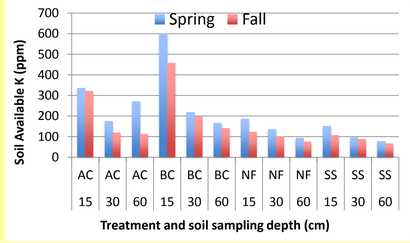



Figure 4. Soil available K for soil samples collected in the spring and fall (after potato harvest) of the 2013 growing season.

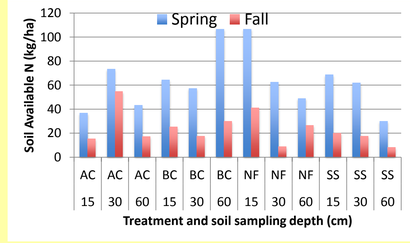



Figure 5. Soil available N for soil samples collected in the spring and fall (after sweet potato harvest) of the 2013 growing season.

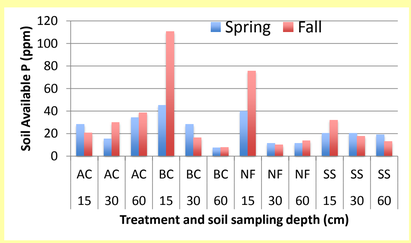



Figure 6. Soil available P for soil samples collected in the spring and fall (after sweet potato harvest) of the 2013 growing season.

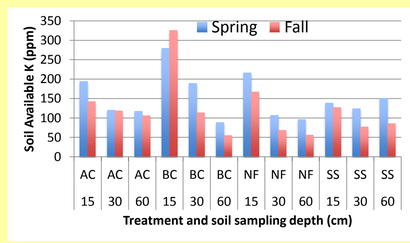



Figure 7. Soil available K for soil samples collected in the spring and fall (after sweet potato harvest) of the 2013 growing season.

## CONCLUSIONS

- All soil fertility treatments tested provided similar amounts of nutrients for optimum production. Generally alfalfa and beef compost had greater yields regardless of the crop species.
- Soil nutrient levels did not decrease as it was expected except for nitrate levels. It is possible that the soil tests taken at the end of the double crop might show a decrease in P and K as there should have been large amounts of these nutrients taken up in the biomass produced by the double crop.
- More research needs to be conducted on the use of double crops. In 2013 the only double crop that produced yield was round red beets. Earlier starting of crops in the greenhouse may help produce yield, or trying other crop species may be necessary .
- In summary, the research conducted showed that different nutrient sources and crop species can be used to manage soil fertility in high tunnel organic cropping species.

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