# Final Report

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

Paulo Pagliari, Soil Scientist

Carl Rosen, Soil Scientist

Lee Klossner, Research Fellow

University of Minnesota, Southwest Research and Outreach Center

March 31, 2016

## Introduction

The University of Minnesota Southwest Research and Outreach Center (SWROC) near Lamberton, MN, built three organic high tunnels in 2010 that have been used for research and outreach programs. The experiments conducted in these three tunnels focused on variety trials and soil fertility and plant nutrition, with manure compost and green manure being the main source of nutrients. The research conducted was very successful and generated results that have helped local organic growers to improve management of their high tunnels. However, the research results also showed that the nutrient management philosophy of using manure compost to supply a crop's requirement for nitrogen (N) has the potential to negatively affect the sustainability of the tunnels and lead to soil health problems. The high amount of soluble salts present in manure compost, can lead to salt build up in the soil to levels that are limiting to production of most vegetable crops. The very high concentration of nutrients that can be found in soils from repeated manure and compost application as the main source of nutrients can also cause an imbalance of nutrient uptake by plants leading to physiological disorders and yield reduction. Therefore, being able to maintain soil health is the key to maintain soil productivity and sustainability. Crop rotation can be used as a remedy for soil salinity and high nutrient levels, if the correct plant species and adequate rotations are used. For example, crops such as potato and sweet potato can export a large amount of nutrients from soils; and in combination with other vegetables can provide the tools to improve soil health in tunnels that are starting to become or already are problematic.

The use of high tunnels to extend the growing season is increasing in Southwest MN; however, there is a lack of research that provides information on productivity of a diverse number of crop species that could be used in rotation to help improve and maintain soil health. Therefore, our objectives are: 1) continue the current research and identify a wider number of economically viable vegetable crop species to incorporate in a rotation that improve soil health; 2) provide high tunnel producers with information on how to remediate soil nutrient imbalance to maintain sustainability; 3) determine the nutrient value of cover crops and plant compost compared with beef manure compost; and 4) provide organic growers information on how to improve and maintain sustainability of vegetable production in organic high tunnel in Southwest MN and other regions.

**Field Operations and Challenges During the Three Years**

*2013*

Summer crops of peppers, tomatoes, and cucumbers were started in the SWROC greenhouse and transplanted into beds in the high tunnels; while potatoes and sweet potatoes were planted directly into beds in the high tunnels. Cucumbers (hybrid Socrates) were transplanted on April 26; peppers (hybrid Ace) were transplanted on April 29; potatoes (Dark Norland and Yukon Gold) were planted on April 29; tomatoes (cultivar Scarlet Red) were transplanted on May 6; sweet potatoes (Beaugard and Georgia Jet) were planted on May 13.

The cold spring delayed transplanting/planting of the crops by at least two weeks, which also pushed initial produce production back by at least two weeks than it was expected. The delayed start of the vegetables also affected the double cropping of beds that were planted to potatoes and sweet potatoes. The colder temperatures of the early spring kept the potatoes and sweet potatoes from growing, which also delayed their harvest. Our initial goal was to have the potatoes and sweet potatoes harvest by the first week of July; however harvest did not happen until the last day of July and early August. After potato harvest, table red beets (Red Ace) and cauliflower (Skywalker) were transplanted to the high tunnels on July 30. After the sweet potato harvest brussels sprouts (Nautic) and broccoli (Belstar) were transplanted to the high tunnels on Augut 12.

There were four experimental treatments that were evaluated in this research. There was a control treatment which did not receive any fertilizer level, there was an alfalfa compost treatment, a beef manure compost, and a Sustane® treatment. The three nutrient sources were applied to provide 100 lb N/acre, which should provide enough fertility for maximum crop production. The treatments and crops planted were replicated three times (once in each of the three high tunnels) for each of the 9 crops. Each of the three high tunnels had five beds that were two feet wide by 40 feet long (5 x 80 squared feet). Each bed was planted to one crop and the bed was separated into four sections of 20 squared feet. One of the four fertility treatments was randomly assigned to each 20 square feet section for each crop. In each bed, tomatoes, peppers, cucumbers, cauliflowers, brussel sprouts, and broccolis were transplanted one foot apart; potatoes were planted one foot apart and 6” deep; sweet potatoes were transplanted 8” apart, and table beets were planted 6” apart. During the growing season water was supplied as needed for optimum growth using drip irrigation.

*2014*

Summer crops of peppers, tomatoes, and cucumbers were started in the SWROC greenhouse and transplanted into beds in the high tunnels; while potatoes and sweet potatoes were planted directly into beds in the high tunnels. Cucumbers (hybrid Socrates) were transplanted on April 28; peppers (hybrid Ace) were transplanted on April 29; potatoes (Dark Norland and Yukon Gold) were planted on April 29; tomatoes (cultivar Scarlet Red) were transplanted on May 6; sweet potatoes (Beaugard and Georgia Jet) were planted on May 13.

The 2014 season had a better start and production went well throughout the whole year. Much of the challenges observed in 2013 were overcome in this season and much better yields were observed as it will be discussed in the next section.

*2015*

Summer crops of peppers, tomatoes, and cucumbers were started in the SWROC greenhouse and transplanted into beds in the high tunnels; while potatoes and sweet potatoes were planted directly into beds in the high tunnels. Cucumbers (hybrid Socrates) were transplanted on April 21; peppers (hybrid Ace) were transplanted on April 28; potatoes (Dark Norland and Yukon Gold) were planted on April 28; tomatoes (cultivar Scarlet Red) were transplanted on May 4; sweet potatoes (Beaugard and Georgia Jet) were planted on May 8. As observed for the 2014 season, there were very little challenges during this season and production was also kept at its best throughout the season.

## Vegetable Production Summaries

In this section we will present the yield for each vegetable in each season:

*2013 Cucumber Production*

We had many challenges trying to have a good crop of cucumber since the start of our high tunnel research in 2010. However, this year we had the best crop of the past four years. To achieve such good yields, it was required that pyganic was sprayed on regular basis, as much as three times a week. In previous years, the cucumber beetle brought disease (bacterial wilt) that killed all of the cucumber plants within a few weeks after first detection (by June or July). However, this year the plants looked healthy and produced all summer. In previous years cucumber production averaged about 1,250 lbs per 1,000 square feet, this year the highest yield recorded was above 3,000 lbs per 1,000 square feet. Cucumber harvest in 2013 started on June 14 and they are still being harvested.

Although there was no statistical significance among the different fertility treatments, Cucumber yields and total fruit produced were numerically greater for alfalfa compost and beef manure compost than for the control and Sustane ® (Table 1). The numerically higher number of fruits in the alfalfa and beef manure composts could be economically important if the fruits are sold in a unit bases and not in a weight basis. In addition, the fact that the control treatment yielded as much as the fertility treatments show how the fertility from a previous crop can carry on to the next crop.

Table 1. Average cucumber yield in lbs per 1000 square feet (lb/1,000 sf) and number of fruits produced per 1,000 square feet.

| **CUCUMBERS** | | | | |
|---|---|---|---|---|
| **Treatment** | lb/1,000 sf | | Number of fruits/1,000 sq ft | |
| **Alfalfa Compost** | 3,062 | a | 5,900 | a |
| **Beef Manure Compost** | 2,910 | a | 5,800 | a |
| **Sustane®** | 2,442 | a | 4,900 | a |
| **No Fertility** | 2,537 | a | 4,850 | a |

Within a column, means followed by different letters are statistically different.

<u>*2014 Cucumber Production*</u>

The 2014 season was another year of poor crop performance compared with the 2013 crop. Cucumber was harvested from June 18 to August 4 when most plants had died from bacterial wilt. As in the previous years, the cucumber beetle brought the disease (bacterial wilt) that killed all of the cucumber plants within a few weeks after first detection (by the end of July-beginning of August). The average cucumber yield in was around 2,000 lbs per 1,000 square feet among all four treatments, which is less than 1,000 lbs per 1,000 square feet compared to the best treatment in 2013.

Although there was no statistical significance among the different fertility treatments, Cucumber yields and total fruit produced were numerically greater for no fertility and beef manure compost treatments than for the alfalfa compost and Sustane® (Table 2). The numerically higher number of fruits could be economically important if the fruits are sold in a unit bases and not in a weight basis. In addition, the fact that the control treatment yielded as much as the fertility treatments show how the fertility from a previous crop can carry on to the next crop.

Table 2. Average cucumber yield in lbs per 1000 square feet (lb/1,000 sf) and number of fruits produced per 1,000 square feet.

| **CUCUMBERS** | | | | |
|---|---|---|---|---|
| **Treatment** | lb/1,000 sf | | Number of fruits/1,000 sq ft | |
| **Alfalfa Compost** | 1,824 | a | 3,883 | a |
| **Beef Manure Compost** | 2,184 | a | 4,517 | a |
| **Sustane®** | 1,959 | a | 4,033 | a |
| **No Fertility** | 2,253 | a | 4,733 | a |

Within a column, means followed by different letters are statistically different.

*2015 Cucumber Production*

We have had many challenges trying to have a good crop of cucumber since the start of our high tunnel research in 2010. This year was the best year we have had for cucumbers as we were able to maintain harvest until October 26, which had never happened before. The success of the cucumber this year was mainly due to early spraying of organic approved insecticides, in addition to clay to avoid the cucumber beetle from transmitting diseases. In addition, we replaced plants when they died from bacterial wilt.

Cucumber was harvested from June 10 to October 26, which was a week earlier than last year and lasted for two months longer than in 2014. The yield observed in 2015 was considerably higher compared with the previous two seasons. Although we have not run any statistical analysis yet, the beef manure compost (4,014 lbs / 1,000 sqft) and alfalfa compost (3,815 lbs / 1,000 sqft) had much greater yield than the Sustane (2,000 lbs / 1,000 sqft) and control (2,755 lbs / 1,000 sqft) treatments (Table 3). The number of fruits followed the same trend as yield, being greatest for the beef manure compost, followed by alfalfa, control, and Sustane had the lowest number of fruits (Table 3).

Table 3. Average cucumber yield in lbs per 1000 square feet (lb/1,000 sqft) and number of fruits produced per 1,000 sqft.

| **CUCUMBERS** | | |
|---|---|---|
| **Treatment** | lb/1,000 sqft | Number of fruits/1,000 sq ft |
| **Alfalfa Compost** | 3,815 | 9,500 |
| **Beef Manure Compost** | 4,014 | 8,400 |
| **Sustane®** | 2,500 | 5,800 |
| **No Fertility** | 2,755 | 6,783 |

*2013 Tomato Production*

Tomato at the SWROC high tunnels has always been a high production crop. For comparison, tomato production in 2012 was about 7,000 lbs per 1,000 square feet. In 2013 we harvested well over 5,700 lbs per 1,000 square feet for some treatments. The 2013 cropping season was better than 2012 as it produced healthier fruits. In 2012, during the last week of June and first two weeks of July the tomatoes were suffering from a physiological disorder, blossom-end rot. In 2013, the physiological disorder also occurred but was not as severe and also did not last as long. We attributed the better control of the disorder to a better watering pattern and also to a better nutrient management.

There were significant differences in tomato yield among the fertility treatments tested (Table 4). The beef manure compost had the greatest yields while the Sustane® had the lowest, with the alfalfa compost and control treatments ranking between the beef manure compost and Sustane®. The number of fruits per plant was also greatest in the beef manure compost and lowest in the Sustane® treatment (Table 4).

Table 4. Average tomato yield in lbs per 1000 square feet (lb/1,000 sf) and number of fruits produced per 1,000 square feet.

| **TOMATOES** | | |
|---|---|---|
| **Treatment** | lb/1,000 sf | Number of fruits/1,000 sq ft |
| **Alfalfa Compost** | 5,475 ab | 8,500 ab |
| **Beef Manure Compost** | 5,695 a | 8,600 a |
| **Sustane®** | 4,710 b | 7,300 b |
| **No Fertility** | 5,430 ab | 8,350 ab |

Within a column, means followed by different letters are statistically different.

*2014 Tomato Production*

2014 was another great year for tomato production and as much as 6,243 lbs per 1,000 square feet was observed for the best treatment. The 2014 cropping season was healthier than the previous cropping seasons as there was very little physiological disorder. In 2014, the physiological disorder occurred but was not severe and also did not last as long. We attributed the better control of the disorder to a better watering pattern and also to a better nutrient management. There were no significant differences in tomato yield among the fertility treatments tested (Table 5). However, there was a trend for tomato yield be higher with alfalfa and manure compost than with the other treatments.

Table 5. Average tomato yield in lbs per 1000 square feet (lb/1,000 sf) and number of fruits produced per 1,000 square feet.

| **TOMATOES** | | |
|---|---|---|
| **Treatment** | lb/1,000 sf | Number of fruits/1,000 sq ft |
| **Alfalfa Compost** | 5,999 a | 9,100 a |
| **Beef Manure Compost** | 6,243 a | 9,683 a |
| **Sustane®** | 5,505 a | 9,100 a |
| **No Fertility** | 5,329 a | 8,633 a |

Within a column, means followed by different letters are statistically different.

*2015 Tomato Production*

Tomato yield in 2015 year we had the highest yields ever recorded for tomatoes during the research. The total tomato yield in the high tunnel averaged 7,580 lbs per 1,000 square feet for the best treatment. The 2015 cropping season was better than the previous cropping seasons for a few reasons, little physiological disorder, high air humidity, and longer season. In 2015, the physiological disorder occurred but was not severe and also did not last as long. As in the other years, the better control of the disorder as probably due to a better watering pattern and also to a better nutrient management. However, there were no significant differences in tomato yield during the 2015 season (Table 6).

Table 6. Average tomato yield in lbs per 1000 square feet (lb/1,000 sqft) and number of fruits produced per 1,000 sqft.

| TOMATOES | | |
|---|---|---|
| **Treatment** | lb/1,000 sf | Number of fruits/1,000 sq ft |
| **Alfalfa Compost** | 7,658 | 17,433 |
| **Beef Manure Compost** | 7,322 | 15,717 |
| **Sustane®** | 7,521 | 16,733 |
| **No Fertility** | 7,819 | 17,667 |

Within a column, means followed by different letters are statistically different.

*2013 Pepper Production*

As for tomato, green bell peppers at the SWROC high tunnels was a high production crop. Green peppers production in 2012 was about 1,700 lbs per 1,000 square feet and in 2013 we harvested more than 2,000 lbs per 1,000 square feet for most of the treatments tested. As it was observed for the tomatoes, the late start for produce production did not have any effect on the crops maximum productivity even though it was a shorter growing season. The peppers yield was greatest for beef manure compost and no fertility treatments and lowest for the Sustane® treatment (Table 7). The same trend was observed for the number of fruits produced per 1,000 square feet (Table 7) as for total yield. Beef manure compost had the highest number of fruits while Sustane® had the lowest number of fruits.

Table 7. Average pepper yield in pounds per 1,000 square feet (lb/1,000 sf) and number of fruits produced per 1,000 square feet.

| PEPPERS | | |
|---|---|---|
| **Treatment** | lb/1,000 sf | Number of fruits/1,000 sq ft |
| **Alfalfa Compost** | 1,982 ab | 6,500 a |
| **Beef Manure Compost** | 2,309 a | 7,550 a |
| **Sustane®** | 1,679 b | 5,300 b |
| **No Fertility** | 2,036 a | 6,250 ab |

Within a column, means followed by different letters are statistically different.

*2014 Pepper Production*

The 2014 season resulted in more than 3,000 lbs per 1,000 square feet for the two highest yielding treatments tested. There were significant treatment effects for the peppers yield. The treatment with the highest yields were alfalfa compost and beef manure compost, while the lowest yields were observed for the no fertility and for the Sustane® treatments (Table 8). The same trend was observed for the number of fruits produced per 1,000 square feet (Table 8) as for total yield. Alfalfa compost and beef manure compost while the no fertility and Sustane® had the lowest number of fruits. This result also shows that the control plots had a significant amount of nutrient left from the previous research and was able to supply all of the nutrients needed for maximum plant production.

Table 8. Average pepper yield in pounds per 1,000 square feet (lb/1,000 sf) and number of fruits produced per 1,000 square feet.

| **PEPPERS** | | |
|---|---|---|
| **Treatment** | lb/1,000 sf | Number of fruits/1,000 sq ft |
| **Alfalfa Compost** | 3,440 a | 11,150 a |
| **Beef Manure Compost** | 3,270 a | 10,450 a |
| **Sustane®** | 2,527 b | 8,567 b |
| **No Fertility** | 2,443 b | 7,933 b |

Within a column, means followed by different letters are statistically different.

*2015 Pepper Production*

Green peppers production in 2013 was well over 1,700 lbs per 1,000 square feet. In 2014, yield totaled more than 3,000 lbs per 1,000 square feet for the two highest yielding treatments tested, and in 2015 green peppers yields broke our previous records. The beef manure compost had the greatest yields at over 5,000 lbs per 1,000 sqft, alfalfa compost yield was 4,615 lbs per 1,000 sqft, Sustane yield was 4,134 lbs per 1,000 sqft, and the control was 3,766 lbs per sqft (Table 9).

Table 9. Average pepper yield in lbs per 1000 square feet (lb/1,000 sqft) and number of fruits produced per 1,000 sqft.

| **PEPPERS** | | |
|---|---|---|
| **Treatment** | lb/1,000 sf | Number of fruits/1,000 sq ft |
| **Alfalfa Compost** | 5,010 a | 22,967 a |
| **Beef Manure Compost** | 4,615 ab | 22,033 a |
| **Sustane®** | 4,134 bc | 19,900 b |
| **No Fertility** | 3,766 c | 18,567 b |

*2013 Potato and Sweet Potato Production*

Potatoes and sweet potatoes have not been grown on organic high tunnels in southwest MN; however, this research shows a great potential for potato and sweet potato production under organic high tunnels. Potatoes and Sweet potatoes when grown in high tunnels might allow for the grower to have up to two crops in the tunnel per growing season. That is because the higher growing degree days inside the tunnel compared with the outside makes it ideal for a rapid potato and sweet potato growth and development, which can lead to an early crop harvest. With the early crop harvest the organic high tunnel growers can have produce available faster than conventional growers and may also be able to get a premium price for delivering produce in a time when high demand. In addition, the early harvest allows the organic high tunnel growers to use the space for a second crop, and cold season vegetables make for an ideal second crop following potato and sweet potato. However, there is still a lot of research and information that needs to be acquired before this practice becomes profitable for the organic grower. For example, the use of heat might be required early in the spring and also later in the summer; the choice of variety seems to also be very important; and also the source of fertility seems to be an important factor controlling final potato and sweet potato yield inside the tunnels.

In 2013, the potatoes yield varied greatly by treatment and variety planted. In addition there was a high variability among the three tunnels used in the research. The potatoes harvested were graded into three different classes by tuber size, grade A were tubers with diameter equal to or greater than 2.5", grade B were tubers with diameter ranging between 1.75 - 2.5", and grade C were tubers with diameter less than 1.75" (creamer). On average, the Red Norlands had the lowest yields and the Yukon Gold had the greatest yields (Table 10). Within each variety, no significant differences due to fertility treatments were observed for potato yields for the Red Norland (Table 10). However, beef manure compost and alfalfa compost had the greatest yields for all potato grades and Sustane® and the control had the lowest (Table 10). The total yields for the beef manure compost and alfalfa compost were equivalent to over 600 hundredweight (600 cwt), which is an excellent yield for potato. In contrast, the Sustane® treatment yields were equivalent to 372 cwt and the control treatment yields were equivalent to 458 cwt. As it has been observed for the other crops, the control treatment had enough fertility left form previous years that it supplied a significant amount of nutrients for potato production.

Table 10. Average potato yield in lbs per 1,000 square feet.

| Grade | Treatment | lbs / 1,000 square feet | | | |
|---|---|---|---|---|---|
| | | Red Norland | | Yukon Gold | |
| **A** | Alfalfa Compost | 209 | a | 943 | b |
| **A** | Beef Manure Compost | 239 | a | 1,150 | a |
| **A** | Sustane® | 185 | a | 575 | d |
| **A** | No Fertility | 148 | a | 763 | c |
| **B** | Alfalfa Compost | 120 | a | 252 | ab |
| **B** | Beef Manure Compost | 96 | a | 286 | a |
| **B** | Sustane® | 150 | a | 199 | c |
| **B** | No Fertility | 256 | a | 229 | bc |
| **C** | Alfalfa Compost | 35 | a | 128 | a |
| **C** | Beef Manure Compost | 42 | a | 80 | b |
| **C** | Sustane® | 56 | a | 82 | b |
| **C** | No Fertility | 71 | a | 59 | c |

Potato grade: A equal or greater than 2.5" diameter, B tubers ranging between 1.75 - 2.5" diameter, C tubers ranging less than 1.75" (creamer). Within a column and potato grade, means followed by different letters are statistically different.

Sweet potato yields varied by variety, treatment, and also by high tunnel (Table 11). The Georgia Jet yielded the highest and the Beauregard yielded the lowest (Table 11). There were no significant differences for the Beauregard regardless of grade. In contrast, for the Geogia Jet grade 1, the beef manure compost had the greatest yield, alfalfa compost the second greatest, and the Sustane® and the control had the same yield (Table 11). On average, the sweet potato yields for the alfalfa and beef manure compost treatments were equivalent to 295 cwt, and for the Sustane® and control the yields were equivalent to 190 cwt. Sweet potato yields around 200 cwt are considered good yields, and above 250 cwt are considered high yields.

Table 11. Average sweet potato yield in lbs per 1,000 square feet.

| Grade | Treatment | lbs / 1,000 square feet | |
|---|---|---|---|
| | | Beauregard | Georgia Jet |
| **1** | Alfalfa Compost | 82 a | 401 b |
| **1** | Beef Manure Compost | 105 a | 568 a |
| **1** | Sustane® | 116 a | 235 c |
| **1** | No Fertility | 128 a | 250 c |
| **2** | Alfalfa Compost | 187 a | 178 a |
| **2** | Beef Manure Compost | 166 a | 211 a |
| **2** | Sustane® | 154 a | 182 a |
| **2** | No Fertility | 168 a | 203 a |

Sweet potato grade: grade 1 roots diameter ranging from 1.75 to 4"; grade 2: root diameter ranging from 1 to 1.75". Within a column and sweet potato grade, means followed by different letters are statistically different.

*2014 Potato and Sweet Potato Production*

In 2013, the potatoes yield varied greatly by treatment and variety planted and in 2014 the same treatment effects were observed in the potatoes yield (Table 12). In addition, there was a high variability among the three tunnels used in the research. The potatoes harvested were graded into three different classes by tuber size, grade A were tubers with diameter equal to or greater than 2.5", grade B were tubers with diameter ranging between 1.75 - 2.5", and grade C were tubers with diameter less than 1.75" (creamer). In contrast to 2013, both varieties of potatoes had great yields. When summed over all treatments, the Red Norlands yielded 4,993 lbs per 1,000 square feet and the Yukon Gold yielded 4,696 lbs per 1,000 square feet (Table 12). The results of this research also showed significant difference between treatments for both varieties (Table 12). For the Red Norland, yields were highest with Sustane and beef manure compost and lowest in the no fertility and alfalfa compost. For the Yukon Gold different results were observed and the alfalfa compost had the greatest yields and the Sustane had the lowes, with the beef manure compost and no fertility ranging in the middle.

Table 12. Average potato yield in lbs per 1,000 square feet.

| Treatment | lbs / 1,000 square feet | | | |
|---|---|---|---|---|
| | Red Norland | | Yukon Gold | |
| **Alfalfa Compost** | 896 | b | 1,999 | a |
| **Beef Manure Compost** | 1,414 | a | 1,200 | b |
| **Sustane®** | 1,649 | a | 627 | c |
| **No Fertility** | 1,034 | b | 870 | c |

| Grade | Yield lbs / 1,000 square feet | |
|---|---|---|
| **A** | 6,537 | a |
| **B** | 2,336 | b |
| **C** | 816 | c |

Potato grade: A equal or greater than 2.5" diameter, B tubers ranging between 1.75 - 2.5" diameter, C tubers ranging less than 1.75" (creamer). Within a column and potato grade, means followed by different letters are statistically different.

Sweet potato yields were significant different by variety and grade, but no treatment effects were observed (Table 13). The Georgia Jet yielded the highest and the Beauregard yielded the lowest (Table 13). Sweet potato yields around 200 cwt are considered good yields, and above 250 cwt are considered high yields. The sweet potatoes yield for the control shows that this crop requires little addition of fertility when there was adequate amounts of nutrients in the soil.

Table 13. Average sweet potato yield in lbs per 1,000 square feet.

| Grade | Treatment | lbs / 1,000 square feet | | | |
|---|---|---|---|---|---|
| | | Beauregard | | Georgia Jet | |
| **1** | Alfalfa Compost | 245 | a | 608 | a |
| **1** | Beef Manure Compost | 334 | a | 514 | a |
| **1** | Sustane® | 276 | a | 440 | a |
| **1** | No Fertility | 301 | a | 526 | a |

| Grade | Yield lbs / 1,000 square feet | |
|---|---|---|
| **1** | 940 | b |
| **2** | 1882 | a |
| **3** | 422 | c |

Sweet potato grade: grade 1 roots diameter ranging from 1.75 to 4”; grade 2: root diameter ranging from 1 to 1.75”, and 3 less than 1”. Within a column and sweet potato grade, means followed by different letters are statistically different.

The initial two years were proven challenging for potato growth, however, in 2015 a much better and uniform crop was observed. In the previous years, the Red Norland had better yields than the Yukon Gold, but in 2015 yields were similar between the two cultivars (Table 14). As with the other crops no statistical analysis has been performed yet, but there seems to be clear differences among treatments. Beef manure compost had the greatest yields followed by alfalfa compost, control, and Sustane had the lowest yields.

Table 14. Average potato yield in lbs per 1,000 square feet.

| **Treatment** | **lbs / 1,000 square feet** | |
|---|---|---|
| | Red Norland | Yukon Gold |
| **Alfalfa Compost** | 692 | 675 |
| **Beef Manure Compost** | 807 | 805 |
| **Sustane®** | 661 | 547 |
| **No Fertility** | 715 | 487 |

As observed in the previous years, the Georgia Jet yielded the highest and the Beauregard yielded the lowest (Table 15). Although no statistical differences were observed, there appears to be some trends due to treatment application for the Geogia Jets. The yields observed for the control treatments are much lower than those observed for the beef manure compost, alfalfa compost, and Sustane (Table 15).

Table 15. Average sweet potato yield in lbs per 1,000 square feet.

| **Grade** | **Treatment** | **lbs / 1,000 square feet** | |
|---|---|---|---|
| | | Beauregard | Georgia Jet |
| **1** | Alfalfa Compost | 324 | 394 |
| **1** | Beef Manure Compost | 289 | 447 |
| **1** | Sustane® | 302 | 374 |
| **1** | No Fertility | 265 | 277 |

*Table Beets Production*

Cropping table beets as a second crop is proving to be a great way to use up nutrient left overs after the first crop. Table beets production in 2013 and 2014 was around 330 lbs per 1,000 square feet for the two highest yielding treatments tested. While in the 2015, yield was much lower at only around 50 lbs per 1,000 square feet. The reasons for the lower yields are not yet know but could have been due to the lower fertility, as potato yields were higher in 2014 and

2015 then in 2013. There were no significant treatment effects for the table beet yields (Table 16).

Table 16. Average beets yield in pounds per 1,000 square feet (lb/1,000 sf).

| BEETS | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|
| **Treatment** | lb/1,000 sf | | | | | |
| **Alfalfa Compost** | 330 | a | 337 | a | 44 | a |
| **Beef Manure Compost** | 338 | a | 342 | a | 40 | a |
| **Sustane®** | 295 | a | 293 | a | 53 | a |
| **No Fertility** | 314 | a | 261 | a | 39 | a |

Within a column, means followed by different letters are statistically different.

For the broccoli, cauliflower, and Brussels sprouts, yields were lower than we expected every year. There was a significant amount of biomass growth, however, there were no harvestable produces. Although those crops have short growing degree days, it is likely the amount of day light needed is much greater than what is achievable during the months of August to November when the second crop was grown. The results from the table beets, however, indicates that it is possible to double crop in high tunnels but further studies are needed to identify which crops would be successful.

**Extension and Outreach Activities**

*2013*

This year as in the past, we responded to a number of calls, emails, and visits by interested people thinking of or planning to put up their own high tunnels. We were invited to present the results of the past three years of research at the Top Crop presentation held in Fairmont, MN, on March 11, 2013. The SWROC high tunnels were highlighted as a stop during four summer events: Organic Field Day tour (about 50 participants, July 9, 2013), Lamberton horticulture group tour (about 25 participants, July 11, 2013), ITQ teacher tour (about 35 participants, July 11, 2013), and University on the prairie tour (about 60 participants).

The produce harvested from the high tunnel was used by the SWROC kitchen for events during the summer and fall in 2013. A great amount of produce was donated to area food shelved in seven surrounding counties. This brought much positive feedback to this project and the SWROC organic research. Many compliments were given to the high quality of our organic and locally grown food.

*2014*

In 2014 we had the first Season Extension Field day funded by the Ceres Trust during the current program. The event took place on March 12. Speakers included Robin and Doug Trott, speaking about cut flowers for high tunnels; Karl Foord, speaking about the profitability of high tunnels; Andew Petran, speaking about strawberry production under low tunnels; Courtney Tchida, speaking about the student organic farm from the St Paul campus; LaMoine Nickel, speaking about composting; and Paulo Pagliari, speaking about the current research on high tunnels at the SWROC.

In 2014 we responded to a number of calls, emails, and visits by interested people thinking of or planning to put up their own high tunnels. The SWROC high tunnels were highlighted as a stop during four summer events: Organic Field Day tour (about 60 participants, July 16, 2014), ITQ teacher tour (about 35 participants, July 11, 2014), and University on the prairie tours (about 180 participants), in addition to other events that took place at the SWROC throughout the year.

The produce harvested from the high tunnel was used by the SWROC kitchen for events during the summer and fall in 2014. A great amount of produce was donated to area food shelved in seven surrounding counties. This brought much positive feedback to this project and the SWROC organic research. Many compliments were given to the high quality of our organic and locally grown food.

*2015*

In 2015 we had the second Season Extension Field day funded by the Ceres Trust. The event took place on March 4. Speakers included Nathan Harder, local organic grower speaking about their farming experiences; Angela Orshinsky, speaking about pest management; Terri Nennich, speaking about pruning and plant spacing; Thomas Halbach, speaking about composting; and Paulo Pagliari, speaking about the current research on high tunnels at the SWROC. This year as in the past, we responded to a number of calls, emails, and visits by interested people thinking of or planning to put up their own high tunnels. The SWROC high tunnels were highlighted as a stop during four summer events: Organic Field Day tour (about 80 participants, July 16, 2014), ITQ teacher tour (about 35 participants, July 15, 2015). A great amount of produce was donated to area food shelved in seven surrounding counties. This brought much positive feedback to this project and the SWROC organic research. Many compliments were given to the high quality of our organic and locally grown food.

## Conclusions

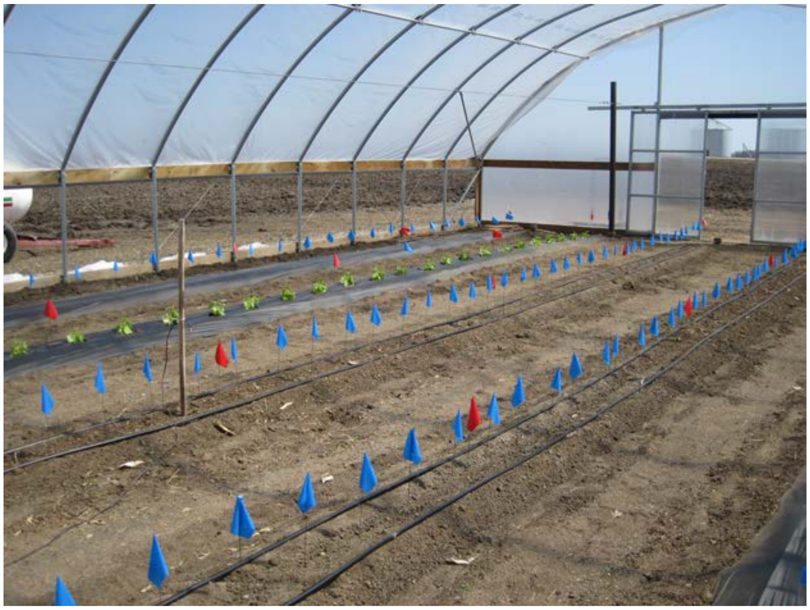
Although there were no statistical differences in tomato yield in much of the treatment tested there could have been significant economical effects. For example, in many cases organic produce is sold on a number of fruit basis as opposed to on a weight basis. Then treatments with numerical higher number of fruits would also have a much higher net return to investment. Therefore, caution should be taken when interpreting the results of this research and a more economical perspective should be used to reevaluate the results.

Significant differences in some crops were observed in the study and in general the beef manure compost and alfalfa compost were the treatments with the best yield. This was probably due to the fact that the amount of nutrients in those two treatments were readily available for plant uptake, while that of Sustane® needed further breakdown by the soil microorganisms before the plant could use.

However, the combination of soil tests with compost nutrient testing was the best approach to maintain crop production in the high tunnels at its maximum potential and also maintain sustainability of the tunnels by keeping the production at its best.

Double cropping in high tunnels has high potential, however, more research is needed to identify which crops are ideal to be cropped during the months of August to November.

2013 Pictures




10/14/2013


11/11/2013

2014 Pictures




07/15/2014


08/11/2014


08/11/2014


08/11/2014


08/19/2014


08/29/2014


10/23/2014


10/31/2014


11/06/2014


11/13/2014

2015 Pictures



06/08/2015


07/02/2015


07/02/2015