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

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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.

2013 Vegetable Production Planting and Challenges

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 treatments 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.

2013 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. 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 ucumber 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.

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. This year we have already harvest as much as 5,700 lbs per 1,000 square feet for some treatments. Considering that there is still at least three more weeks of harvest, we expect that the tomatoes yields will be closer, if not greater than what yields were last year even though 2013 had a much later planting date compared with 2012. 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 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 2). 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 2).

Table 2. 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.

2013 Pepper Production

As for tomato, green bell peppers at the SWROC high tunnels has always been a high production crop. Green peppers production in 2012 was about 1,700 lbs per 1,000 square feet. This year we have already harvested more than 1,700 lbs per 1,000 square feet for most of the treatments tested. Considering that there is still at least three more weeks of harvest, we expect that the pepper yields will be much higher than they were last year as well. 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 were greatest for beef manure compost and no fertility treatments and lowest for the Sustane® treatment (Table 3). The same trend was observed for the number of fruits produced per 1,000 square feet (Table 3) as for total yield. Beef manure compost had the highest number of fruits while Sustane® had the lowest number of fruits. This result also shows that the control plots had a significant amount of nutrient left from previous years research and was able to supply all of the nutrients needed for maximum plant production.

Table 3. 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.

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 4). Within each variety, no significant differences due to fertility treatments were observed for potato yields for the Red Norland (Table 4). However, beef manure compost and alfalfa compost had the greatest yields for all potato grades and Sustane® and the control had the lowest (Table 4). 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 4. 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 5). The Georgia Jet yielded the highest and the Beauregard yielded the lowest (Table 5). 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, alfala compost the second greatest, and the Sustane® and the control had the same yield (Table 5). 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 5. Avereage 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.

Soil Fertility

Soil samples were collected in the spring 2013 from all beds and also in the summer after potato and sweet potato harvest. Samples were collected from 0-6”, 6-12”, and 12-24” depth increments. This sampling strategy should allow us to assess how much nutrient were used by the potato and sweet potato plants and also how much fertility was left for the second crops.

The levels of nitrogen (N) in the soil cropped to potatoes decreased in all depths for all treatments except for the beef manure compost at the 6” depth and Sustane® at the 12” depth (figure 1). The greatest reduced in the soil N levels was observed for the deeper sample (24”) that was amended with alfalfa compost (figure 1). On average, the soil N in the spring was 79 lb N per acre and in the fall it had dropped to 40 lbs N per acre (almost 50% reduction in N levels). This shows the high potential for potato to remove N from the soils.

In contrast to soil N levels, soil phosphorus (P) levels tended to remain the same in most treatments (figure 2). A significant reduction in soil P levels was observed for plots treated with alfalfa compost at 24” depth and control at 6” depth (figure 2). There was a significant increase in soil P levels for the alfalfa compost at the 6” depth (figure 2).

The levels of potassium (K) in the soil followed a similar pattern as that observed for P, where there little reduction on K levels following potato growth (figure 3). There was only significant decrease in K levels for the alfalfa compost at the 24” depth and beef manure compost at the 6” depth (figure 3).

The sweet potatoes also used a significant amount of N from the soil (figure 4). Soil N levels decreased in all plots cropped with sweet potato and the greatest reductions were observed for the control and beef manure compost treatments (figure 4). On average the soil N level dropped from 63 lbs of N per acre at the beginning on the study to 24 lbs of N per acre after the sweet potato harvest, a reduction of 62% in soil N following sweet potato.

The levels of P in the soil after sweet potato harvest tended to either increase or remained the same with only a significant reduction for the plots treated with alfalfa compost at the 6” depth (figure 5). For potassium, there was a significant increase in K levels after beef manure compost addition at the 6” depth, and for the remainder treatments, K levels tended to slightly decrease or remained the same (figure 6).

The fact that N levels in the soil decreased after potato and sweet potato harvest shows that those crops took up more than the N that was applied with the treatment sources. In contrast the fact that P and K levels did not decrease after potato growth suggests that the crop was able to remove what was applied and did not need to use the reserve in the soil. It is likely that the nutrients that remained in the soil after potato and sweet potato harvest would be available for the second crop that was planted following their harvest. Although we have not harvested the second crop, it is likely that there was in fact plant of nutrients for the crop following the potato and sweet potato as they look, visually, to be doing well and have produced a very high amount of above ground biomass. See pictures section for beets, cauliflower, broccolis, and brussel sprouts at the end of the report.

Outreach

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.

We are now planning for our third Extending the Season Field Day to be held sometime between mid February – early March at the SWROC. In this event, we will share what we have been doing for organic research in the high tunnels and also invite expert from around the state, and also researchers and producers from other states within the Midwest to speak about research and organic agriculture production under high tunnels.

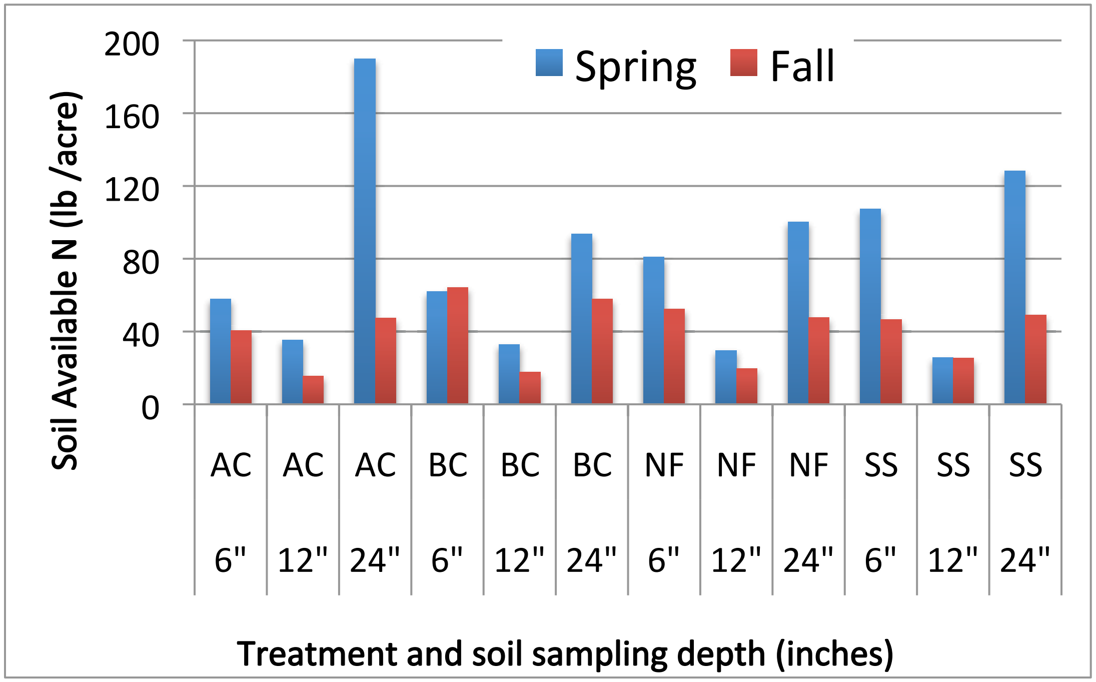

Figure 1. Soil available N for soil samples collected in the spring and fall (after potato harvest) of the 2013 growing season. AC: alfalfa compost, BC: beef manure compost, NF: control, and SS: Sustane®.

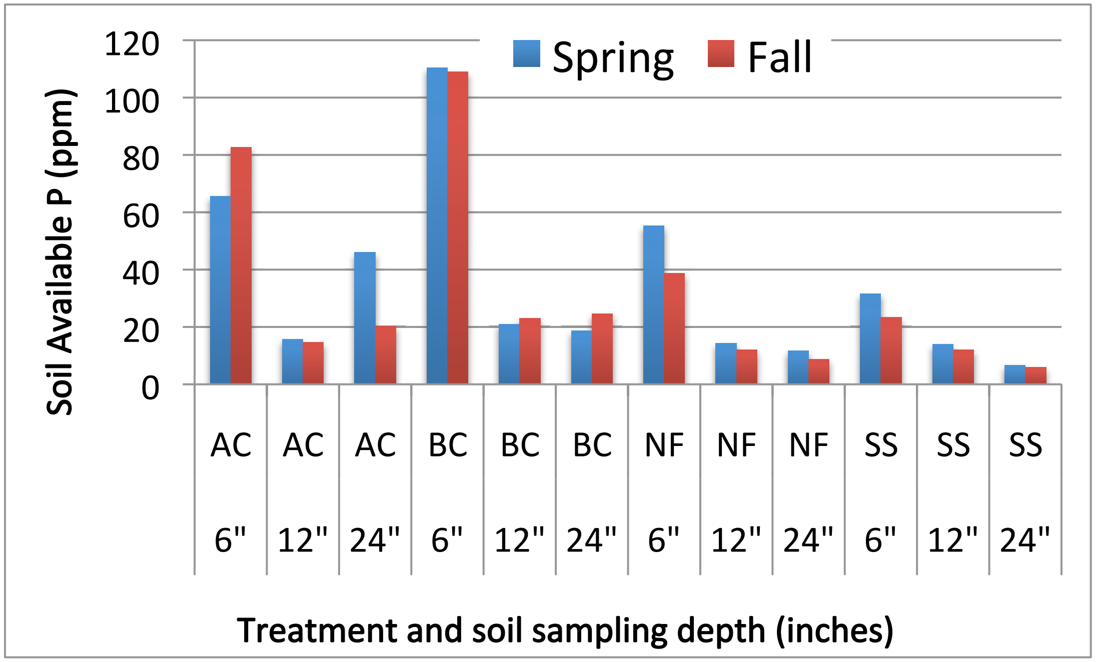

Figure 2. Soil available P for soil samples collected in the spring and fall (after potato harvest) of the 2013 growing season. AC: alfalfa compost, BC: beef manure compost, NF: control, and SS: Sustane®.

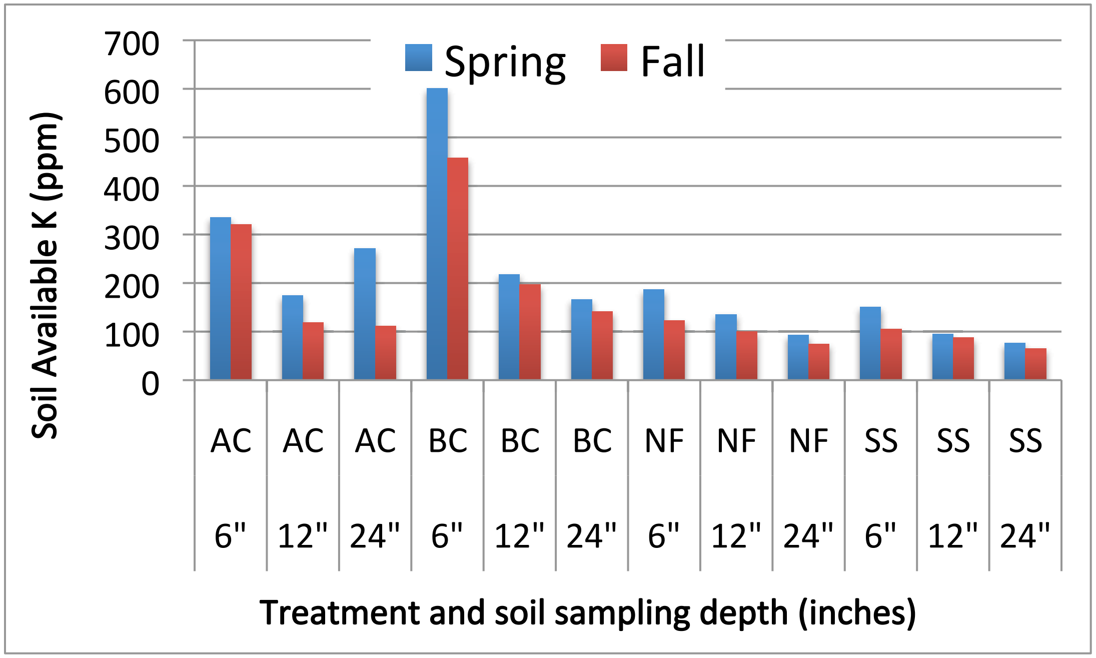

Figure 3. Soil available K for soil samples collected in the spring and fall (after potato harvest) of the 2013 growing season. AC: alfalfa compost, BC: beef manure compost, NF: control, and SS: Sustane®.

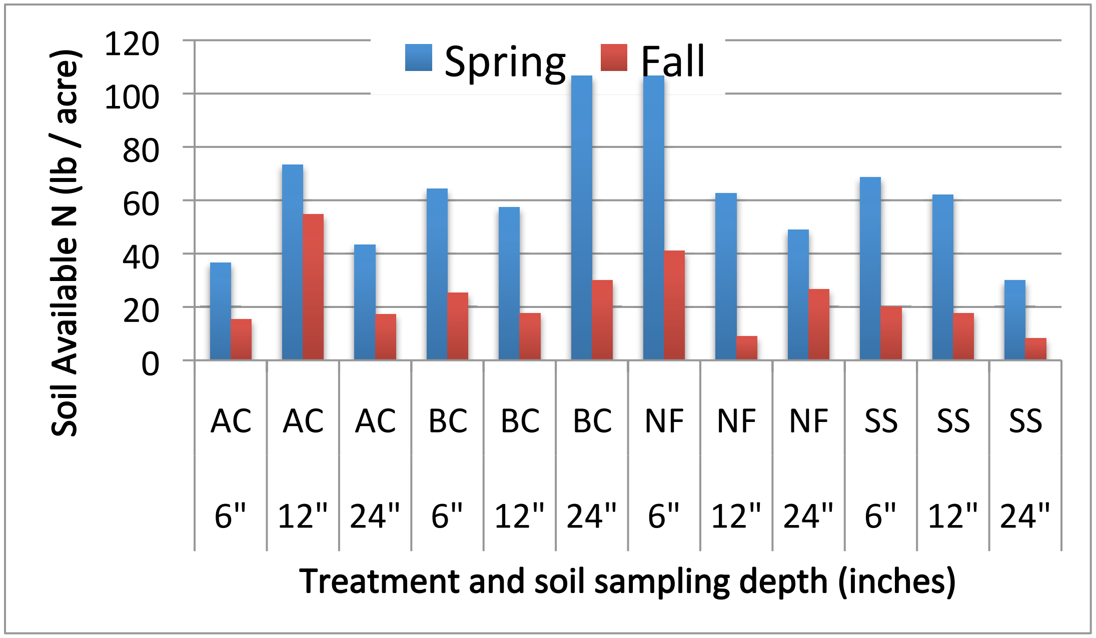

Figure 4. Soil available N for soil samples collected in the spring and fall (after sweet potato harvest) of the 2013 growing season. AC: alfalfa compost, BC: beef manure compost, NF: control, and SS: Sustane®.

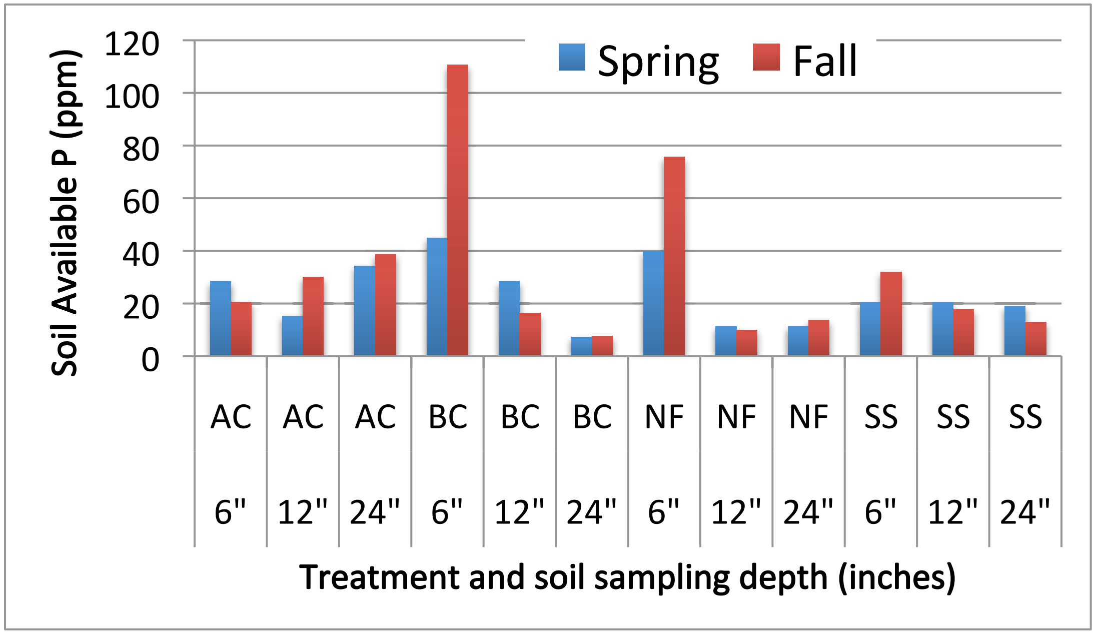

Figure 5. Soil available P for soil samples collected in the spring and fall (after sweet potato harvest) of the 2013 growing season. AC: alfalfa compost, BC: beef manure compost, NF: control, and SS: Sustane®.

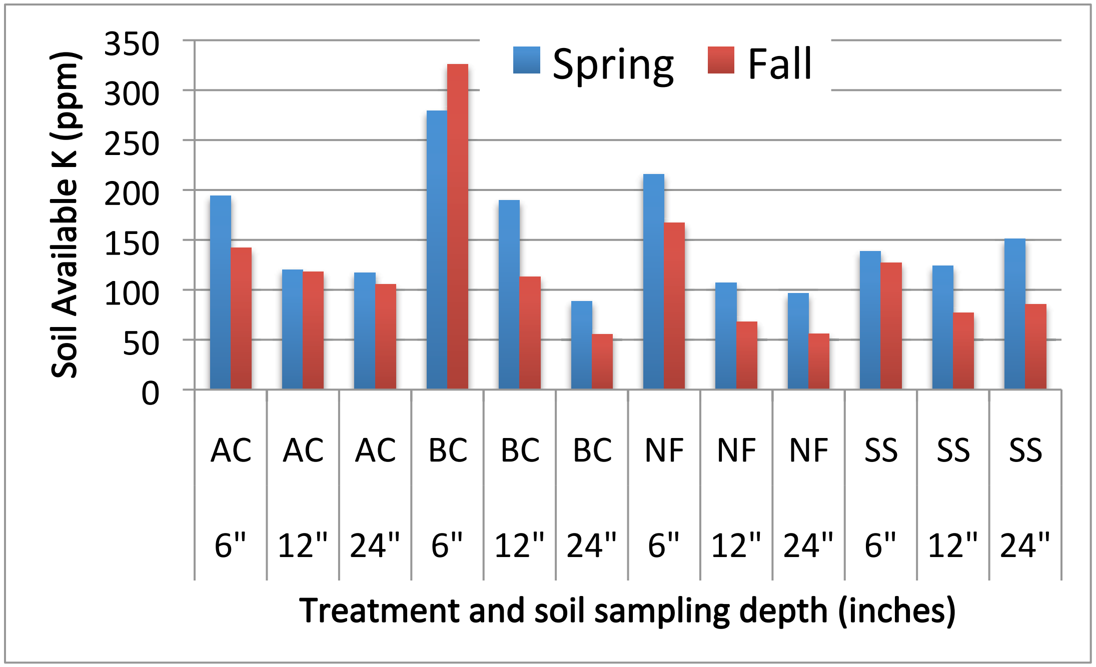

Figure 6. Soil available K for soil samples collected in the spring and fall (after sweet potato harvest) of the 2013 growing season. AC: alfalfa compost, BC: beef manure compost, NF: control, and SS: Sustane®.

PHOTOS

High tunnels at the University of Minnesota, Southwest Research and Outreach Center near Lamberton.

Table beets

Table beet, brussel sprouts, cauliflower, broccolis, tomatoes


Sweet potatoes, potatoes


Tomatoes

Bell peppers.