Penn State **Extension**

Filling Soil Health Prescriptions with Targeted Cover Crop Options - Pennsylvania Final Report

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Every farm has a field that just does not perform up to expectations. Nine farms in Southeastern PA used the Cornell Soil Health Test in 2009 and 2010 to learn more about which soil properties might be holding back poor performing fields on their farms. The soil health tests yielded interesting results. Some results confirmed farmer expectations and provided a catalyst for change. For example, "This is what I might have guessed for that field," said one farmer, "It is nice to have the experts confirm my suspicions." Other tests revealed unseen below-ground problems. For all who participated, the project provided a valuable learning tool. One grower stated, "I can honestly say that the Soil Health Study has taught me more than any other class or workshop." Six of nine farmers acted on their Soil Health results, planting cover crops and monitoring possible benefits. At the remaining three farms Soil Health test results indicated few problems and/or cover crop attempts were thwarted by environmental conditions.

Compost or Cover Crops?

Mushroom soil is cheap and accessible in SE PA. Growers, organic and conventional alike, looking for organic matter often apply it with the 'more is better' adage. The debate is not out, but the results of a soil health test at one small farm in SE PA showed surprising results.

Figure 1 "I've tried spinach, cabbage, and tomatoes – very little seems to grow" in this area.

Red Cat Farm in Germansville, PA is a two-acre farm specializing in lettuce mix and bedding plants. The farm's production is generally bountiful. But, in one small section nothing did well. Teena had tried everything: cabbage, lettuce, tomatoes, and peppers. Suspecting that large applications of mushroom compost and past burning of raspberry canes might have contributed to the problem, Teena took a soil health test.

The soil health test came back with two red flags: high phosphorus and low active carbon. High phosphorus was not a surprise with large mushroom soil applications the likely culprit. Although the sites is small with no nearby streams, there is a concern that at high levels the soil will no longer sorb the P and it could be leached into water sources. With total soil organic matter (SOM) above seven, low active carbon came as a surprise.

Crops Grown: LET				Date Sampled: 5/6/2009
	Indicators	Value	Rating	Constraint
PHYSICAL	Aggregate Stability (%)	30	40	
	Available Water Capacity (m/m)	0.25	[illegible]	
	Surface Hardness (psi)	98	[illegible]	
	Subsurface Hardness (psi)	209	[illegible]	
BIOLOGICAL	Organic Matter (%)	7.3	[illegible]	
	Active Carbon (ppm) (Permanganate Oxidizable)	399	13	Soil Biological Activity
	Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week)	31.9	[illegible]	
	Root Health Rating (1-9)	5.0	50	
CHEMICAL	*pH	7.0	[illegible]	
	*Extractable Phosphorus (ppm) [Value <3.5 or >21.5 are downscored]	144.5	0	<3.5:Plant P Availability, >21.5: Env. Loss Potential
	*Extractable Potassium (ppm)	233	[illegible]	
	*Minor Elements		[illegible]	
	OVERALL QUALITY SCORE (OUT OF 100)		71.7	High
Measured Soil Textural Class:===> silt loam				
	SAND (%): 36.1		*SILT (%): 52.2*	*CLAY (%): 11.8*
Location (GPS): Latitude=> 0 Longitude=> 0				

* See Cornell Nutrient Analysis Laboratory report for recommendations

Figure 2 Active carbon – the major food source for microbes is low. Phosphorus is five times the level recommended for vegetables.

Active carbon is the carbon that changes quickly when we input organic matter and is easily eaten by soil microbes. It is the fuel for the soil food web – bacteria, fungi, insects, and earthworms. It measures the simple carbohydrates, amino acids, and sugars in soil carbon that are easily hydrolyzed and oxidized making them easily accessible by microbial communities. Active carbon is critical because it is the primary food source for microbes, insects, and earthworms in the soil. Without it the numbers of these groups decrease. Without the good soil microbes we don't have the services they give us, like nitrogen mineralization and competition with pathogens. In comparison the carbon from mushroom soil is likely very stable and not accessible to soil microbes as food.

To improve soil active carbon and remove excess P from the soil we chose to grow a cover crop of rye. This grass has a thick mat of roots which will break down near the surface and provide an energy source in the soil. Rye also needs a lot of P. When the grass is removed as hay or forage it is known to draw down soil P levels.

The rye cover crop did not establish well on the site due to impressive deer grazing the first year. Teena tried again the following fall with better success. In fall 2011 we took a soil test and P levels were still above optimum. This is likely because the rye was still too small, less than a foot tall and had not removed significant amounts of P into plant biomass. But try, try again, Teena plans to let the rye grow this spring and remove more P.

Figure 3 Teena has become a cover crop enthusiast, putting land aside on her little farm to 'feed the soil'. Shown here with luscious clover and wheat cover crops in fall 2011.

Teena says, "I honestly have to say that the Soil Health Study has taught me more about soil health than probably any other class or workshop that I have taken. A few reasons why are: it dealt with our own soil so there is motivation to learn exactly what was occurring, because more aspects of soil health other than just the nutrient components were addressed, it made more sense, and the format and detailed explanations of the whole testing and evaluating process gave reasons to some of the soil's problems."

The Compaction Question

Compaction might be the silent killer on vegetable farms in Pennsylvania. After another rainy spring where farmers know they have been out in their fields when they should not, I measured soil compaction on 80% of the farms I visited. Armed with my handy dandy soil penetrometer farmers were able to see for themselves where hardpans were keeping roots short and shallow. Heavy rains pool on deep hardpans, drowning roots; or wash right over surface hardpans creating run-off. We all know compaction is a problem. Knowing 'WE' have the problem is the first step to alleviating it.

At DE Lichtenwalner Farms, Macungie PA when asked to find a poor field for soil health testing, Mark immediately pointed to a field on the far ridge. The field had not done well in years. The really bad patches tended to be circular and worse toward the edge of the field. The field had been in continuous no-till corn for a number of years. As the farm became surrounded by houses they couldn't grow potatoes or other vegetables in that area. Wheat followed by clover, which used to be a good option, just does not have the price margin any more.

Because the texture of the field is so clay based Mark was not surprised that the organic matter was low and that the soil had become hard and compacted. Years like 2009 did not help. It was hard to stay out of the field when it was wet. "This is what I might have guessed for that field," said Mark, "It is nice to have the experts confirm my suspicions."

	Indicators	Value	Rating	Constraint
PHYSICAL	Aggregate Stability (%)	52	[illegible]	
	Available Water Capacity (m/m)	0.16	47	
	Surface Hardness (psi)	257	16	rooting, water transmission
	Subsurface Hardness (psi)	282	54	
BIOLOGICAL	Organic Matter (%)	2.9	32	
	Active Carbon (ppm) (Permanganate Oxidizable)	581	43	
	Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week)	13.7	98	
	Root Health Rating (1-9)	4.0	63	
CHEMICAL	*pH	7.1	[illegible]	
	*Extractable Phosphorus (ppm) (Value <3.5 or >21.5 are downscored)	16.5	[illegible]	
	*Extractable Potassium (ppm)	248	[illegible]	
	*Minor Elements		[illegible]	
	OVERALL QUALITY SCORE (OUT OF 100):		69.4	Medium

Measured Soil Textural Class:—> *loam*
SAND (%): 41.7 *SILT (%): 47.4* *CLAY (%): 10.9*
Location (GPS): Latitude=> 0 Longitude=> 0
* See Cornell Nutrient Analysis Laboratory report for recommendations

Figure 4 Using a soil penetrometer we found a compaction layer at a four and a half inch depth.

Mark thought that in addition to breaking up the hard layers he wanted to do something to put more organic matter in the soil. There is a lot of corn stubble that goes in every year. But with no till it is concentrating on the top. In another field he planted rye cover crops in 2008, mowed it off and planted corn. No-tilling into that cold soil looked awful at first, especially since they did not get the nitrogen on until late. But once they finally got it on, it was hard to believe how fast it caught up. That was "some of the best looking corn on that field." Seeing fields like that helped Mark think it would be good to use more cover crops.

April 23, 2010 Mark planted an oat/radish cover crop designed to add organic matter and bio-drill the hard pan. Radish was spun on at 5 lb per acre and followed up with oats drilled at 1.5 bu per acre. We decided a spring planting was the best niche because corn was harvested too late in the fall to allow time for a cover crop. Spring oats and radish come on fast and could be double cropped with soybeans. We planted in three strips with and three without cover crop in the field so we could compare the soybeans that followed.

Figure 5 Oat and radish cover crop left. No cover crop control right was infested with thistle.

There were no differences that could be eyeballed in the following soybeans. Overall Mark felt the field did improve, perhaps due to a year of soybeans.

Figure 6 Tillage radish (right) at Lichtenwalner Farm. Prominent thistles (left) with large tap roots may have also contributed to breaking up hard pans.

"It was good to confirm my suspicion about the compaction layer," said Mark. "I had tried both shallow and deep tillage, but there's nothing like a deep rooted crop to bring the soil profile back in shape. From a study standpoint, it showed there's certainly much more to fertility than just N-P-K."

<u>Striving to meet optimum potential</u>

A no-till enthusiast, Forest Wesner rarely has bare ground on his farm. Long rotations including perennials like alfalfa and rye cover crops help him build soil and prevent erosion. But if you have ever farmed in shale, you know that it is hard to build organic matter and that organic matter is much needed in soil that is well drained to say the least. The opportunity to use the soil health test to identify restrictions and further improve his soil fit well with Forest's long term soil building goals for his farm.

	Indicators	Value	Rating	Constraint
PHYSICAL	Aggregate Stability (%)	35	51	
	Available Water Capacity (m/m)	0.19	[illegible]	
	Surface Hardness (psi)	205	35	
	Subsurface Hardness (psi)	350	36	
BIOLOGICAL	Organic Matter (%)	3.2	53	
	Active Carbon (ppm) (Permanganate Oxidizable)	519	44	
	Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week)	19.5	100	
	Root Health Rating (1-9)	6.3	38	
CHEMICAL	*pH	6.9	100	
	*Extractable Phosphorus (ppm) [Value <3.5 or >21.5 are downscored]	17.0	100	
	*Extractable Potassium (ppm)	180	100	
	*Minor Elements		100	
OVERALL QUALITY SCORE (OUT OF 100):			70.0	Medium
Measured Soil Textural Class: ---> *sandy loam*				
	SAND (%): 56.7		*SILT (%): 39.7*	*CLAY (%): 3.6*
Location (GPS): Latitude=> 0 Longitude=> 0				

* See Cornell Nutrient Analysis Laboratory report for recommendations

We chose a field that is far from terrible. But, because it is one of the flatter fields with nicer soil, it is one of the fields they count on for their bread and butter. Because it did not seem to be reaching its full potential, it was important to the Wesners to take a look and see if they could improve it further.

The field was in alfalfa at the time of sampling and had been for two years. Before that it was wheat, before that potatoes and before that rye. The only tillage that the site had seen was for potatoes. There had not been any deep ripping. The soil is a loam but reasonably shaly, typical for the area. They usually have a four year rotation but have been considering tightening it up and going to a two year, which they have on some sites.

The soil health report found no major concerns. However six indicators were in the yellow zone leaving room for improvement: compaction, root health, active carbon and aggregate stability.

Penetrometer readings showed a hardpan between 10 and 16 inches. It was deeper on the end of the field closest to the farm road. The problem with the penetrometer readings on shale soil is they are not always accurate. However, I have found a subsurface hardpan very common in situations where folks are tilling to a consistent depth over time. We thought it may be very beneficial to either grow a cover crop with a tuberous root system that can help drill through this hardpan or do some deeper ripping.

Another concern was the root health rating. They use beans to rate for root rot like Fusarium, Pythium, Rhizoctonia, and Thielaviopsis and root knot nematode. The rating of 6.3 means between 25 and 50% of root tissue had lesions.

Aggregate stability was also below optimum. Aggregate stability is a measure of the extent to which soil aggregates resist falling apart when wetted and hit by rain drops. This is important because it indicates the soil's physical quality with regard to its capacity to sustain its structure during most impactful conditions: a heavy rain storm after surface drying weather. Soils with low aggregate stability can constrict crops because they form crusts and often have low biological activity.

Below optimum aggregate stability goes hand in hand with active carbon. The simple carbohydrates like amino acids and sugars in soil carbon feed the soil food web. Bacteria and fungi in turn create aggregates by binding them together with sticky substances from bacteria and fungal hyphae.

When considering management options Forest thought about ripping. The problem is a lack of equipment. He has a smaller John Deere which is big enough to pull his moldboard and other equipment and likes to keep it that way in order to minimize the weight of equipment on his land. He has seen horrible compaction problems in fields where folks are bringing hog manure out on to the farm and the trucks compact the soil. When they were harvesting potatoes after this happened, huge lumps were coming up over the harvester and of course the potatoes were small.

From a cover crop standpoint a radish-oats (5 lb per acre and 40 lbs per acre) cover crop sounded optimal. The radish is known to break up soil hardpans and provide readily available food for microbes early in spring. While grasses like oats provide many fine roots which turn over and feed microbes as well as organic matter inputs.

Radishes have received considerable hype in our area due to our close proximity to Steve Groff, distributor of the 'Tillage Radish'. Potato growers have reported better yields and better quality after radish. In order to meet soil health goals and investigate the supposed advantages of radish we chose to work with radishes. Diakon radishes were established in five strips alternating with rye cover crop controls. Small no-cover crop control check plots were sprayed out with round up in the rye plots. Radish cover crops averaged 1.9 T/A dry matter.

Potatoes were planted after cover crops. At the end of the season in 2011 we harvested two twenty-foot sections in rye and radish plots and one twenty-foot section in check plots. We graded the potatoes and weighed for yield measurements.

Figure 9 Radishes formed large macropores where taproots decomposed.

Surprisingly there were no significant differences between cover cropped plots compared to no-cover crop controls. See Figure 10. We should not be surprised since cover crop benefits are known to be accumulative. However, we had hoped that some trends would be visible.

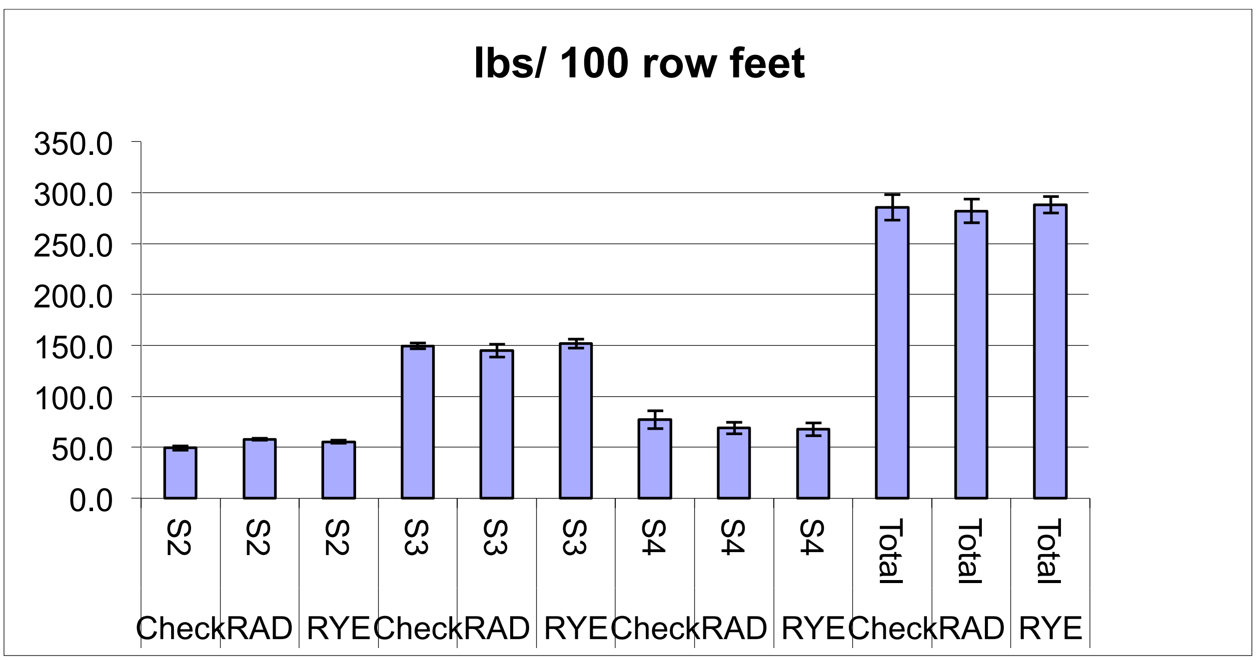

Figure 10 Potato yield after radish and rye cover crops. No significant differences were detected in any size class.

Managing for Multiple Goals

Vegetable production is often hard on soil health. Under organic management we not only till to make a good seed bed but also for multiple cultivations every year. Planting multiple successions per year to get the most per acre from expensive vegetable land makes it hard to incorporate the cover crops and rest that our vegetable fields often need. At Reeder Farms in Easton PA, Russ and Naydene Reeder chose one field to focus their rejuvenation efforts on.

	Indicators	Value	Rating	Constraint
PHYSICAL	Aggregate Stability (%)	8	8	aeration, infiltration, rooting
	Available Water Capacity (m/m)	0.24	94	
	Surface Hardness (psi)	314	5	rooting, water transmission
	Subsurface Hardness (psi)	400	13	Subsurface Pan/Deep Compaction
BIOLOGICAL	Organic Matter (%)	2.7	27	energy storage, C sequestration, water retention
	Active Carbon (ppm) [Permanganate Oxidizable]	641	56	
	Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week)	13.7	96	
	Root Health Rating (1-9)	5.3	50	
CHEMICAL	*pH	7.7	0	Toxicity, Nutrient Availability (for crop specific guide, see CNAL report)
	*Extractable Phosphorus (ppm) [Value <3.5 or >21.5 are downscored]	7.0	100	
	*Extractable Potassium (ppm)	205	100	
	*Minor Elements		100	

Soil health tests taken in spring 2009 indicated that low aggregate stability, surface and subsurface compaction, low organic matter and high pH could all be improved (figure 11). This came as no surprise to the Reeder's who had noted the lack of tilth in this field. The soil tends to crust (see figure 12). With high rainfall they have seen the water run off this relatively flat field, creating a wash in a recent pumpkin field.

Multiple indicators pointing to one problem.

Low aggregate stability, low organic matter and compaction are all inter-related. Organic matter of 2.7 is average for this area of PA. However, organic matter inputs may be the key to improving all three factors.

Aggregate stability measures how well the small clumps of soil we call aggregates stick together when wet and hit with rain drops. The more stable a soil's aggregates, the more likely the soil will retain its structure during a large rainstorm and water will continue to infiltrate. Without good aggregates the soil will crust. A soil with low aggregate stability often has low biological activity. Aggregates are formed in part by exudates from bacteria, entanglement of soil particles in fungal hyphae and digestion by earthworms. Low biological activity means reduced mineral cycling and competition with pest organisms.

Organic matter is important because it acts like a sponge retaining water and nutrients. It also contributes to soil tilth and aggregate formation. Organic materials are the primary food source for the soil microbes that stick together the soil into *t 15, 2010. Photo April 26, 2011.*

aggregates. Without enough organic matter food for soil organisms they do not help form stable soil aggregates. Interestingly these soil aggregates often also protect organic matter from breaking down.

Compaction can critically restrict plant growth. When a soil penetrometer reading shows soil compaction over 300 PSI, roots cannot penetrate the soil. Compaction not only directly affects root growth, it also reduces the amount of air filled pores and thus oxygen in the soil. The increase in CO_2 in relation to oxygen can be toxic. Deep ripping with tillage or deep rooted tap roots is necessary to break up compaction layers. But without sufficient soil organic matter the soil will re-settle and is likely to be compacted again.

Figure 13 Russell Reeder using a soil penetrometer to measure compaction.

The goal: Breaking up soil compaction and adding organic matter were the goals for this field. Like many vegetable farms, the planting window for cover crops was narrow. Tillage radish, the compaction alleviating cover crop many growers choose, should to be planted in August to do its job. We chose to use Bonar rapeseed and winter rye for our mid September planting date. The rapeseed was broadcast at 5 lbs per acre and the rye at 1.5 bu per acre in the fall of 2010.

On April 26, 2011 the rye looked good, about 18 inches tall. The rapeseed was small but investigation with a shovel showed the taproot had likely done its job (see figure 16). The cover crops were likely nutrient limited. A small patch where the turkey coop was located was tall and lush. The cover crop was sickle bar mowed and incorporated the following day.

Short and long term benefits. The question is always: "Did the cover crop benefit yields, soil health and the environment?" Generally, cover crop benefits accumulate over time. But we stubbornly tried to track the benefits just one year later. We chose to follow the cover crop with sweet corn, a crop relatively easy to monitor. Our answer to the question did cover crops improve yield: maybe. Where there was a cover crop there were more (but not statistically more) ears per plant (see figure 17).

Figure 16 Rapeseed cover crop has deep taproots known to break up soil hardpans.

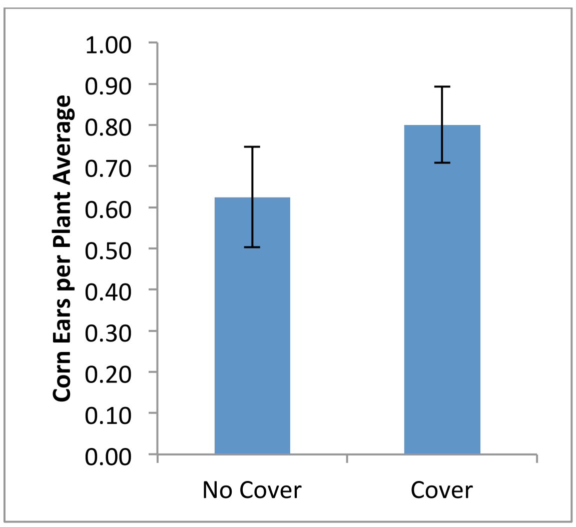

Figure 17 Where there was a cover crop there were more ears per plant. However the difference was not statistically significant.

The Cover Crop Timing Challenge

Timing is often the number one challenge to using cover crops on vegetable farms. After the last harvest of tomatoes or winter squash it is just too late for most cover crops. Winter rye is the one exception. But when planted late even rye does less work sopping up left over nutrients and holding the soil in place than we might like. Two participants in the SARE funded study "Filling Soil Health Prescriptions with Targeted Cover Crop Options" learned from this timing challenge.

rm. A no cover crop strip was left so we could compare rformance of the following crop.

killed oat and radish. Photo March 2011.

Suyandalla Farm, Coplay PA, grows a wide variety of vegetables and field crops and raises sheep. Manure, cover crops and crop residue have kept their soils in pretty good shape (see Soil Health Test figure 17 i.e. organic matter 5%). But recently the main vegetable field has been worked hard. Proximity to the greenhouse and barn as well as irrigation access have made it a prime location for vegetables. This left little space for cover crops or manure application. Low active carbon and low nitrogen supply capacity are likely as a result (see figure 17).

	Indicators	Value	Rating	Constraint
PHYSICAL	Aggregate Stability (%)	25.1	30	
	Available Water Capacity (m/m)	0.17	60	
	Surface Hardness (psi)	140	65	
	Subsurface Hardness (psi)	230	74	
BIOLOGICAL	Organic Matter (%)	4.9	85	
	Active Carbon (ppm) [Permanganate Oxidizable]	449	19	Soil Biological Activity
	Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week)	6.8	3	N Supply Capacity
	Root Health Rating (1-9)	4.0	63	
CHEMICAL	pH (see Nutrient Analysis Report)	7.5	67	
	Extractable Phosphorus (see Nutrient Analysis Report)	24.0	[illegible]	
	[illegible] (see Nutrient Analysis Report)	239.5	100	
	Minor Elements (see Nutrient Analysis Report)		100	
	OVERALL QUALITY SCORE (OUT OF 100):		63.8	Medium

Soil Textural Class:==> loam

SAND (%): 38.6 SILT (%): 47.9 CLAY (%): 13.4

Figure 18 Soil Health test Suyandalla Farms indicating low biological activity and nitrogen supply.

To feed the soil microbes and add nitrogen to the soil pool, Heather, Suyandalla Farm, chose to plant a mix of oats, radishes and clover. The winter killed covers (oats and radishes) would feed soil microbes with root exudates during the fall and then break down quickly in spring providing an influx of organic material. The clover would fix nitrogen to add to the soil organic nitrogen supply.

But with the realities of farming, the cover crop did not get planted until September 22, 2010. Rates were oats (52 lbs/A), radish (4 lb/A), rapeseed (3 lb/A) and clover (15 lb/A). Oats were five inches tall when they winter killed, but radish and rapeseed were never really present (see figure 19). This is likely due to more than a week of dry weather after planting in September. Monitoring of the proximate cauliflower and broccoli crop showed only small differences in performance between cover crop and no-cover crop plots. Heather felt that it “Made some difference. . .The broccoli looks a little smaller where there was no cover crop.”

At Cherry Valley CSA in Stroudsburg, PA soil health tests showed the soil was in good shape (see figure 20). Subsurface hardness was rated fair. But grower Heidi Secord felt it was an area to address. Penetrometer readings of 320 pounds per square inch (PSI) surpassed the level where scientists say roots cannot penetrate (300 PSI). If roots are constricted to upper layers, plants have less access to nutrients and water. Excessive rainfall might even puddle in the root zone, drowning roots.

	Indicators	Value	Rating	Constraint
PHYSICAL	Aggregate Stability (%)	60	91	
	Available Water Capacity (m/m)	0.18	78	
	Surface Hardness (psi)	157	58	
	Subsurface Hardness (psi)	319	49	
BIOLOGICAL	Organic Matter (%)	3.6	63	
	Active Carbon (ppm) [Permanganate Oxidizable]	494	40	
	Potentially Mineralizable Nitrogen (μgN/ gdwsoil/week)	14.8	100	
	Root Health Rating (1-9)	5.0	50	
CHEMICAL	*pH	6.1	67	
	*Extractable Phosphorus (ppm) [Value <3.5 or >21.5 are downscored]	11.0	100	
	*Extractable Potassium (ppm)	70	72	
	*Minor Elements		100	
	OVERALL QUALITY SCORE (OUT OF 100):		72.2	High
	Measured Soil Textural Class:==> sandy loam			
	SAND (%): 60.4	*SILT (%): 36.7*		*CLAY (%): 2.8*
	Location (GPS): Latitude=> 0 Longitude=> 0			

* See Cornell Nutrient Analysis Laboratory report for recommendations

Heidi decided to trial radish and rapeseed. Both are known for their long taproots that pierce through soil hardpans. When the roots decay they leave tunnels that crop roots can use to penetrate to deeper soil layers.

In September we spun on covers in strips with oats as a non-biodrilling cover crop control. In December covers were thick. Discoloration showed possible nutrient stress (see Figure 21). We had spun on covers with a walk on spinner-spreader. Although we had attempted to calibrate it can be difficult to maintain walking speed for accurate seeding rates.

It is tempting to just throw on a cover crop at the end of the season. But you might want to think of it more like a crop. We learned that they need to be seeded at the right time; a week or two can make a big difference as the growing degree days drop off quickly at the end of the season. Sufficient nutrients and correct spacing can also make a big difference to cover crop success. It seems hard to justify fertilizing a cover crop. But since the cover crop will recycle the nutrients for your next crop, those dollars spent should do double duty.

Figure 22 Rapeseed, radish and oat cover crops strips at Cherry Valley CSA with farmer Heidi Secord. Photo December 12, 2010.

Soil Health Project Conclusions

Healthy soil is much more than a medium to hold plants up with enough nutrients to make crops grow. It teams with life. Abundant, diverse soil biology competes with pathogens limiting their negative impact; forms soil aggregates that keep soil from crusting and allow water to penetrate; and cycle nutrients making them available for plants. A healthy soil has good tilth and sufficient depth. Organic matter is critical to these biological and physical properties of soil. The Soil Health test provides an insightful way to explore the complex and dynamic properties of soils on our farms. Critical to a useful tool it also simplifies the multifaceted properties of our soils into indicators we can understand and use to improve our soil.

As one participant said, " It showed there's certainly much more to fertility than just N-P-K." The test allowed him to focus on the most critical yield constricting property to address, and the process of working with cover crops helped him form a plan to address it. "It was good to confirm my suspicion about the compaction layer. I had tried both shallow and deep tillage, but there's nothing like a deep rooted crop to bring the soil profile back in shape."

For Extension Educators, like myself, the Soil Health test provides a wonderful tool to use out on farms with growers. Through on-farm testing we learn together both about the properties of soils and also how to improve them within the constraints of working farms.

Thank you to all Farmer Participants in this study:

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Sincerely,

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