



What's Cropping Up?



A NEWSLETTER FOR NEW YORK FIELD CROPS & SOILS

VOLUME 28, NUMBER 5 Nov./Dec. 2018

“Deja Vu all over again”: Organic soybeans in a soybean-wheat/red clover-corn rotation come in at 55 bushels/acre but high input conventional beans come in at 62 bushels/acre

Bill Cox¹, Eric Sandsted¹, Phil Atkins², and Wes Baum³

¹Soil and Crop Sciences Section - School of Integrative Plant Science, ²New York Seed Improvement Project, Plant Breeding and Genetics Section, ³Cornell University Agricultural Experiment Station

We initiated a 4-year study at the Aurora Research Farm in 2015 to compare different sequences of the corn-soybean-wheat/red clover rotation in conventional and organic cropping systems under recommended and high input management during the transition period (and beyond) to an organic cropping system. Unfortunately, we were unable to plant wheat after soybean in the fall of 2016 because green stem in soybean, compounded with very wet conditions in October and early November, delayed soybean harvest until November 9, too late for wheat planting. Consequently, soybean followed corn as well as wheat/red cover in 2018 so we are now comparing different sequences of the corn-soybean-wheat/red clover rotation with a corn-soybean rotation (Table 1). This article will focus on soybean yields in 2018 in both rotations.

The fields were plowed on May 17 and then cultimulched on the morning of May 18, the day of planting. We used the White Air Seeder to plant the treated (insecticide/fungicide) GMO soybean variety, P22T41R2, and the non-treated non-GMO variety, P21A20, at two seeding rates, ~150,000 (recommended input) and ~200,000 seeds/acre (high input). P21A20 is a not an isolate of P22T41R2 so only the maturity of the two varieties and not the genetics are similar between the two cropping systems. We treated the non-GMO, P21A20, in the seed hopper with the organic seed treatment, Sabrex, in the high input treatment (high seeding rate). We used the typical 15” row spacing in conventional soybean and the typical 30” row spacing (for cultivation of weeds) in organic soybean. Consequently, the

soybean comparison is not as robust as the corn or wheat comparisons in this study because of the different row spacing and genetics between the two cropping systems.

We applied Roundup on June 20 for weed control in conventional soybean (V4 stage) under both recommended and high input treatments. The high input soybean treatment in the conventional cropping system also received a fungicide, Priaxor, on August 2, the R3 stage. We used the rotary hoe to control weeds

Field Crop Production

“Deja Vu all over again”: Organic soybeans in a soybean-wheat/red clover-corn rotation comes in at 55 bushels/acre but high input conventional beans come in at 62 bushels/acre 73 - 75

High Seeding Rates, Fall Herbicide Application, Split-Application of N, and a Timely Fungicide Application Did Not Increase Spike Number, Kernels/Spike, Kernel Weight, nor Yield in 2018 Conventional Wheat ... 76 - 78

Soil Health

Survey of Farmers in New York Reveals Challenges and Opportunities in Soil Health 79 - 80

Nutrient Management

Adapt-N tool leads to reduced nitrate leaching compared to Corn N Calculator 81 - 83

Research

Feasibility Assessment of Dairy Biochar as a Value-Added Potting Mix in Horticulture and Ornamental Gardening 84 - 88

Field Crop Production

Table 1. Amended crop rotations in a 4-year crop rotation study at the Aurora Research Farm because of the inability to plant wheat after soybean in the fall of 2016 (green stem in soybean compounded with excessively wet conditions in October and early November prevented a timely soybean harvest and wheat planting). Consequently, we will now compare a corn-soybean-wheat/red clover (RC) rotation (without wheat in the first transition year, 2015) to a corn-soybean rotation in conventional and organic cropping systems in fields that had a spring grain, corn, or soybean as the last conventional crops in 2014.

	CROP ROTATIONS		
2015	RED CLOVER (RC)	CORN	SOYBEAN
2016	CORN	SOYBEAN	WHEAT/RC
2017	SOYBEAN	CORN	CORN
2018	WHEAT/RC	SOYBEAN	SOYBEAN

in the row in recommended and high input organic soybean at the V1 stage (May 29). We then cultivated close to the soybean row in both recommended and high input organic treatments at the V3 stage (June 14) with repeated cultivations between the rows at the V4-V5 stage (June 19), the V5-V6 stage (June 29), the R1 stage (July 10), and the R3 stage (July 26).

Weather conditions were exceedingly dry from planting until July 16 with only 3.12 inches of precipitation recorded at the Aurora Research Farm. In fact, the 3.12 inches of precipitation in 2018 was the driest 5/17-7/16 period ever in 59 years of record keeping at the Aurora site (<http://climod.nrcc.cornell.edu/runClimod/1d121489c4dfec7b/3/>). The Aurora Research Farm, however, received 10 inches of rain over the next 2-month period (7/16-9/15), the date when organic soybeans attained physiological maturity (R7 stage). The 10 inches of rain was the 8th wettest 7/16-9/15 period ever at Aurora (<http://climod.nrcc.cornell.edu/runClimod/60f4a05670d22553/1/>), which contributed to high soybean yields throughout the area.

We discussed early plant establishment of our 2018 soybeans in a previous article (<http://blogs.cornell.edu/whatscroppingup/2018/06/05/more-rapid-emergence-but-lower-early-plant-densities-v1-stage-in-organic-compared-to-conventional-2018-soybean/>). Briefly, organic soybeans emerged earlier but only had 67-76% early plant establishment compared with 78-91% in conventional soybeans (Table 2). We noted that the organic soybeans with recommended inputs had early plant stands mostly below 105,000 plants/acre, and wondered if stands would be too low for maximum yields. We do not have our final plant stand data for soybeans completely counted yet so we are not sure if final stands in recommended input organic soybeans dipped below 100,000 plants/acre. Regardless, organic soybeans with recommended inputs yielded the same as organic soybeans with high inputs (~54 bushels/acre and ~55 bushels/acre, respectively), despite having 40,000-50,000 fewer plants/acre established at the V1 stage (Table 2).

As in 2017, organic soybeans in the soybean-wheat/red clover-corn rotation yielded around 55 bushels/acre, a significant 7 bushel/acre lower yield than high input conventional management. Organic soybeans in the corn-soybean rotation yielded 53 bushels/acre, statistically similar to organic soybeans in the soybean-wheat/red clover-corn rotation. We thought that the extended rotation of the soybean-wheat/red clover-corn rotation in conjunction with its somewhat lower weed densities in 2018 (Table 2) would boost yields more, perhaps resulting in similar yields between organic and conventional soybeans. But that was not



Fig 1a. Conventional soybean remained weed-free throughout the season.



Fig 1b. Organic soybean was generally clean but the weeds were quite robust in locations of the field where weeds were not controlled.

Table 2. Days to emergence and % plant establishment of soybean at the 1st node stage (V1) following either wheat/ red clover (RC) or corn under conventional management (P22T41R2, treated with insecticide and fungicide) and organic management (P21A20-non-treated) after the rotary hoe operation in organic soybean at recommended inputs (~150,000 seeds/acre) and high input (~200,000 seeds/acre plus the organic seed treatment, Sabrex, in the organic cropping system). Red highlighted values are significantly higher for comparisons within a column (i.e. previous crops), based on the interaction LSD.

TREATMENTS	PREVIOUS CROP (2014)		
	SMALL GRAIN	CORN	SOYBEANS
Plant densities-V4 stage (plants/acre)			
CONVENTIONAL			
Recommended-wheat/RC	127,457 (85%)	116,625 (78%)	126,735 (85%)
Recommended-corn	136,657 (91%)	121,599 (81%)	133,999 (89%)
High Input-wheat/RC	174,445 (91%)	159,866 (80%)	172,853 (86%)
High Input-corn	179,996 (85%)	178,399 (90%)	173,954 (87%)
ORGANIC			
Recommended-wheat/RC	112,662 (75%)	103,538 (69%)	101,749 (68%)
Recommended-corn	105,864 (71%)	104,533 (70%)	100,367 (67%)
High Input-wheat/RC	146,864 (73%)	152,533 (76%)	150,367 (75%)
High Input-corn	142,025 (71%)	147,733 (74%)	141,163 (71%)
LSD-% 0.05	3.8%	3.7%	4.1
Weed densities-R4 stage (weeds/m²)			
CONVENTIONAL			
Recommended-wheat/RC	0.03	0.05	0.03
Recommended-corn	0.11	0.07	0.07
High Input-wheat/RC	0.03	0.03	0.02
High Input-corn	0.09	0.08	0.02
ORGANIC			
Recommended-wheat/RC	0.31	0.40	0.50
Recommended-corn	0.70	0.85	1.10
High Input-wheat/RC	0.29	0.67	0.46
High Input-corn	1.15	0.72	0.95
LSD-% 0.05	0.42	0.38	0.45
Yield (bushels/acre)			
CONVENTIONAL			
Recommended-wheat/RC	59	55	59
Recommended-corn	59	56	58
High Input-wheat/RC	63	60	62
High Input-corn	63	60	63
ORGANIC			
Recommended-wheat/RC	55	51	58
Recommended-corn	48	56	55
High Input-wheat/RC	56	53	58
High Input-corn	50	56	55
LSD-% 0.05	7	6	6

the case in 2018. What was the case, however, was the lack of yield response to higher seeding rates for organic soybeans in 2018, for the 4th consecutive year in this study.

When averaged across the three previous 2014 crops (or three different fields) and the two different rotations (corn-soybean and wheat-red clover-corn-soybean), conventional soybean with high inputs yielded about 62 bushels/acre compared to about 58 bushels/acre in recommended conventional soybeans. The 4 bushel/acre yield response for high input conventional soybean was probably associated with the fungicide application rather than the higher seeding rates (conventional soybeans had average early stands of greater than 125,000 plants/acre-too high for a seeding rate response). We sampled two 1.52 square meter areas of each plot for yield component analysis so once those samples have been processed, we can determine if plant number, pod number, seed number, or seed weight contributed the most to the 4 bushel/acre yield advantage for high input conventional soybeans. If seed weight contributed the most, then the 4 bushel/acre response was probably associated with the fungicide application.

In conclusion, conventional soybean yielded higher than organic soybean for the second consecutive year of this study. Organic soybean, however, would receive the organic price premium (typically more than 2x the conventional soybean price). Consequently, organic soybean, despite the ~10% overall lower yield, would be more profitable, especially at the recommended 150,000 seeds/acre seeding rate and no organic seed treatment. We will conduct a final economic analyses of soybeans and the entire study over the winter and write up the final results next spring or early summer.

High Seeding Rates, Fall Herbicide Application, Split-Application of N, and a Timely Fungicide Application Did Not Increase Spike Number, Kernels/Spike, Kernel Weight, nor Yield in 2018 Conventional Wheat

Bill Cox¹, Eric Sandsted¹, Phil Atkins², and Wes Baum³

¹Soil and Crop Sciences, ²New York Seed Improvement Project, ³Cornell University Agricultural Experiment Station



Fig 1. High input conventional wheat did not increase spike number, kernels/spike, kernel weight, and yield in 2018.

High input wheat, which is characterized by high seeding rates, a herbicide application in the fall, split-application of N in the spring (resulting in higher total N rates), and a timely spring fungicide application(s) was introduced to New York in the early 1980s. Known as intensive management of wheat in the 1980s, it was modeled after European wheat management systems, where yields were often twice that of NY wheat yields. Consultants or farmers from other countries or regions came to NY to share with NY farmers and industry personnel on how they grew wheat. Wheat prices in NY, however, plummeted to \$2.80/bushel in 1985 and \$2.25/bushel in 1986, which abruptly ended the push for adoption of intensive management of wheat in NY in the 1980s.

Wheat prices in NY still hovered around ~\$2.80/bushel in the early 2000s and intensive or high input wheat management hadn't been mentioned in years. Prices, however, skyrocketed to more than \$6.50/bushel from 2007-2013, resulting in a resurrection of the promotion of high input wheat management. Indeed, some individuals in the NY wheat community referred to high input management as the "new way" of managing wheat. Once again, experts from Canada, England, or Michigan came to New York to instruct us on how to grow wheat. Our research from the 1980s, which included three varieties at two planting dates, reported that wheat yields were increased (10-15%) in 3 years but limited in response (2-5%) in 2 other years. More importantly, we found that intensive management of wheat did not pencil out unless prices exceeded ~\$3.75/

bushel, high prices back in the 1980s. Regardless, this research was totally ignored by industry and extension personnel in NY in their rush to embrace this "new way of managing wheat".

We compared high input and recommended input management in conventional (and organic) wheat at the Aurora Research Farm in 2016, a year characterized by very dry conditions from April through June (4.61 inches total precipitation). We reported that there was no response to high input wheat in that very dry growing season (<http://blogs.cornell.edu/whatscroppingup/2016/09/26/organic-wheat-looked-great-but-yielded-7-5-less-than-conventional-wheat-in-20152016/>). We also reported that weed densities were generally low negating a response to fall herbicide application, that the extra N applied to high input wheat did not increase spike number nor kernel number/spike, and that the fungicide application did not increase kernel weight (<http://blogs.cornell.edu/whatscroppingup/2016/09/29/wheat-does-not-respond-to-high-inputs-at-the-aurora-research-farm-in-the-dry-2016-growing-season/>). We attributed the lack of response to high input wheat in that year to the very dry growing conditions.

We repeated the study again this year and provided a detailed description of the inputs and their timing in high input and recommended input wheat management in a previous 2018 article (<http://blogs.cornell.edu/whatscroppingup/2018/07/23/another-shocker-organic-wheat-with-high-inputs-86-buacre-vs-79-buacre-for-conventional-wheat-both-yield-80-bushelsacre-with-recommended-inputs/>). Briefly, high input wheat was seeded at 1.7M seeds/acre in late September, received an herbicide application (Harmony extra) in late October, a split-application of N in the spring (~50 lbs. /acre of actual N in late March and another ~50 lbs. /acre of actual N in late April), and a timely fungicide application (Prosaro) at the end of May at anthesis. In contrast, recommended input wheat was seeded at 1.2M seeds/acre and received a single 70 lb. /acre N application in late March. That was it-essentially a plant, top-dress, and harvest management system.

Table 1. Grain yield, spikes/m², kernels/spikes, and kernel weight of high input conventional wheat (treated 25R46 planted at 1.7M seeds/acre, with a fall herbicide application, a split N application of 100 lb. /acre of actual N in the spring, and a fungicide application at anthesis); and recommended input conventional wheat (untreated P25R46 planted at 1.2M seeds/acre with a single application of 70 lb. /acre of actual N in the spring).

TREATMENTS	Yield	Spikes/m ²	Kernels/spike	Kernel wt.
	Bu/acre	No.	No.	mg
CONVENTIONAL				
Recommended	80 a ⁺	537 a	27.8 a	36.7 a
High Input	80 a	557 a	26.6 a	36.2 a

⁺Values within a column followed by the same letters are significantly similar at the 0.05 level.

We sub-sampled 1.52 m² areas (8 rows by 1 meter) in two locations of all wheat plots to determine yield components of all treatments on July 8, the day before harvest. The sub-samples were first weighed, and then the spikes were counted. The spikes were then threshed so all the kernels (~20,000 kernels/sample) could be counted with a seed counter before being weighed. From the sub-sample data, we determined the number of spikes/m² and kernels/spike, as well as individual kernel weight of all the treatments.

We reported in the above-cited 2018 article that once again there was no response to high input conventional wheat management in 2018 with recommended management yielding 80 bushels/acre and high input management yielding 79 bushels/acre. Let's examine the yield component response to determine why there was once again a lack of response to high input management in conventional wheat. Table 1 indicates that there was no statistical response in spikes/m², kernels/spike, or in kernel weight of individual kernels to the additional inputs in high input wheat. As in 2016, the relatively dry weather conditions in April and May (4.87 inches of precipitation total) probably resulted in no leaching or denitrification of the applied N (70 lbs. /acre) in late March in the recommended input management treatment. The lack of response to an additional 30 lbs. /acre of N is especially interesting in 2018 because the record cold temperature in April (coldest April ever at the Aurora Research Farm and most of upstate NY) resulted in limited if any mineralization of organic

N. Consequently, the 70 lb. /acre application of N in late March (as well as the recommended seeding rate of 1.2M seeds/acre) provided adequate N for optimum tillering and subsequent spike development. Thus, the recommended input management treatment, despite being planted at 500,000 fewer seeds/acre and receiving 30 lbs. /acre of less N, had similar spike numbers as the high input treatment.

The single 70 lb. /acre application of N also provided adequate N for optimum kernel/spike development as indicated by the statistically similar number of kernels/spike between treatments. The potential number of flowers or florets in wheat is determined at the double ridge stage (sometime around the end of tillering or the end of April), successful fertilization of the florets occurs during stem elongation or during May, and successful kernel set and retention, thus final kernel number, is determined during anthesis and in the 1-week period after anthesis. Nitrogen and soil water availability (as well as genetics, tiller number, and or light) are major drivers in determining kernel number. Again, the statistically similar number of kernels/spike between high input and recommended input management indicates adequate N in the recommended treatment.

Finally, the dry June conditions (1.63 inches of precipitation) evidently limited disease development, as indicated by the similar kernel weights between the high input and recommended input management treatments. Obviously, a fungicide application was not required on wheat during the dry spring of 2018. The yield component data is quite robust. If you do the math, you will find that the estimated yield from the recommended input subsamples came in at 81.6 bushels/acre and the estimated yield from the high input subsamples came in at 79.9 bushels/acre. You can't get much more precise than that.

So now we have compared high input vs. recommended

Field Crop Production

input wheat management 7 times (5 times in the 1980s, and again in 2016 and in 2018). We only observed a yield response in 3 of 7 years. We only observed an economic yield response in 1 of 7 years. I realize that all the data is specific to the Aurora Research Farm where yields are not as high as they are in western NY. But I would think that data from central NY would be more relevant than data from SW Ontario, Kentucky, or from Michigan? Especially replicated data with lots of supporting measurement to quantify responses.

Certainly, in some years (wet spring conditions), a split-application of additional N in tandem with a timely fungicide application around anthesis would certainly be warranted. But to accept carte blanche the “new way” of managing wheat is not a good management strategy unless you are totally risk-averse. I would recommend managing wheat like you manage corn. If it is a wet spring and you apply most or all your N to corn up-front, you need to come back with a side-dress application of additional N. Same thing with wheat. If you put all your N on in late March or early April and April is very wet, an additional 30 to 40 lb./acre N top-dress application in late April would certainly be warranted. Likewise, with a fungicide application. If May is wet and disease is prevalent and there is a high likelihood of head scab development, a fungicide application is a must. But as in corn, there is no need to apply a fungicide, if disease incidence is low and there is a low probability of disease development in the near future.

Spring weather conditions vary greatly from year to year. At the Aurora Research Farm over the last 5 years, April has been exceedingly wet (6.14 inches in 2017) and exceedingly dry (1.87 inches in 2018); May has been exceedingly wet (~5.50 inches in 2015 and 2017) and exceedingly dry (~2.0 inches in 2016 and 2018); and June has been exceedingly wet (8.0 inches in 2015) and exceedingly dry (0.74 inches in 2016 and 1.63 inches in 2018). I would recommend managing wheat in the spring according to weather conditions. First, apply the recommended N rate (60-70 lbs. /acre of actual N) in late March or early April. But if April turns wet, I would suggest applying an additional 30-40 lbs. N/acre as soon as you can get on the field. Likewise,

with disease management. If May turns wet, scout the fields frequently. If disease development is prevalent and especially if there is a high probability that head scab will develop once wheat heads out, I would suggest a timely fungicide application (anthesis stage). But if conditions have been dry and are predicted to stay dry, I suggest saving yourself some money.

Survey of Farmers in New York Reveals Challenges and Opportunities in Soil Health

Soil Health

Cedric Mason (cwm77@cornell.edu) and David Wolfe (dww5@cornell.edu), Cornell University

The condition of a farm’s soil has a vital impact on crop production and the environment. Healthy agricultural soil holds adequate nutrients, absorbs heavy rainfall, and stores water. But in many annual production systems these functions are compromised by tillage, which diminishes soil organic matter and creates compaction, ultimately restricting crop growth while increasing susceptibility to drought, erosion, and nutrient losses. Healthy soils, containing substantial levels of organic matter and beneficial pore space, can be developed over time by reducing tillage and using cover crops. But to put in place, both strategies require significant investments of time and resources, while the benefits may vary with context and can require some years to take effect.

To help clarify exactly what costs and benefits farmers in New York experience when using these soil health-

enhancing practices, we conducted a state-wide survey during the winter of 2017-18. Over 180 farmers from 46 NY counties provided information about the crops they grow, and how using reduced tillage and cover crops have impacted their farm business. From the survey results, we identified the most frequent expenses and benefits (Table 1).

The most common benefit of both reduced tillage and cover crops was less erosion or sedimentation repair. Greater yield was reported by 52% of farmers using reduced tillage, and by 50% of those using cover crops. Lower yield was reported by 10% and 3% of farmers using reduced tillage and cover crops respectively (Table 1). Note that costs and benefits reported in Table 1 go beyond revenue associated with yield, to include increases or decreases in annual input costs, as well as capital investment costs (e.g., new equipment) or avoided costs (e.g., drainage system installation).

When asked about profitability, less than 5% reported that either practice had a negative net impact (data not shown).

Our survey also found distinctions in the costs and benefits depending on the type of cash crop being produced, for example greater yield of cash crops attributed to the use of cover crops was more frequently reported for vegetable systems than for corn and soybean, while corn and soybean systems in particular were more likely to benefit from forage uses of cover crops (data not shown). Our study results

Table 1. Common costs and benefits of reduced tillage and cover crops ranked by prevalence among New York farmers of all crop types. The percent of farmers who reported each cost or benefit is given in parentheses; n = 125 for reduced tillage and n = 149 for cover crops.

		Benefits of reduced tillage	Costs of reduced tillage	Benefits of cover crops	Costs of cover crops
Rank	1	Less erosion or sedimentation repair (83.2%)	Specialized tillage equipment (48%)	Less erosion or sedimentation repair (83.9%)	Cover crop seed costs (89.9%)
	2	Less labor, fuel, or equipment use (74.4%)	Specialized planting equipment (48%)	Greater yields of cash crops (50.3%)	Cover crop termination costs (51.0%)
	3	Greater yields (52%)	Greater herbicide-related costs (34.4%)	Lower fertilizer inputs (47.0%)	Planting or rolling equipment (modification, purchase, or rental) (45.0%)
	4	Easier or faster harvest (38.4%)	Increased labor (12.8%)	Source of animal forage (use/sale) (32.2%)	Additional research, scouting, or labor (18.8%)
	5	Lower fertilizer inputs (28.8%)	Lower yields (10.4%)	Lower herbicide inputs (28.9%)	Greater nitrogen requirements (12.8%)
	6	Access to cost-share programs (16%)	Other costs (4%)	Less labor, fuel, or equipment use (19.5%)	An outside party is hired to plant and manage my cover crops (6.7%)
	7	Lower herbicide inputs (15.2%)	NA	Access to cost share programs or incentives (15.4%)	Lower yields of cash crops (3.4%)
	8	Avoided drainage investments (12%)	NA	Easier or faster harvest (15.4%)	Other costs (3.4%)
	9	Less irrigation (10.4%)	NA	Avoided drainage investments (13.4%)	Other effect on income (0.7%)
	10	Lower insecticide inputs (9.6%)	NA	Less irrigation (11.4%)	NA
	11	Other cost savings (0.8%)	NA	Lower insecticide inputs (9.4%)	NA
	12	Other effect on income (0.8%)	NA	Other effect on income (2.7%)	NA

Soil Health

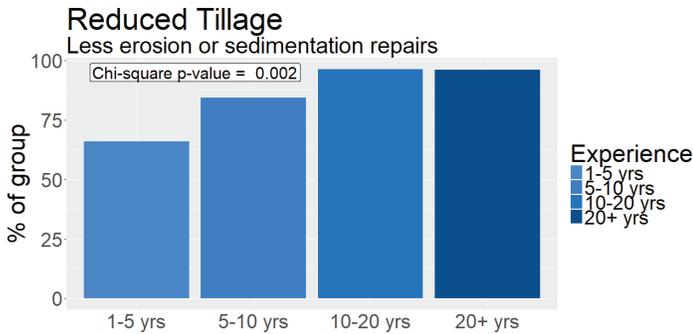


Fig 1. Reducing tillage helps protect against erosion, especially when practiced for more than 10 years.

highlight the differences that exist between cropping systems, and show that any decision to implement a specific soil health practice should be made on a case-by-case basis, carefully evaluating both the positive and the negative impacts that could occur following a shift in management practice.

Some benefits that result from these practices are realized over many years as the productivity and function of the soil is gradually improved. We asked farmers how long they had been using reduced tillage and cover crops, and found that there was an association between the length of time a farmer had been using those practices and what benefits they saw; farmers that had been using reduced tillage or cover crops the longest saw greater benefits. One such benefit is less erosion. While about 66% of farmers who had used reduced tillage for less than 5 years reported this benefit, after 10 years that number had risen to almost 100% (Fig 1). Similarly, among farmers

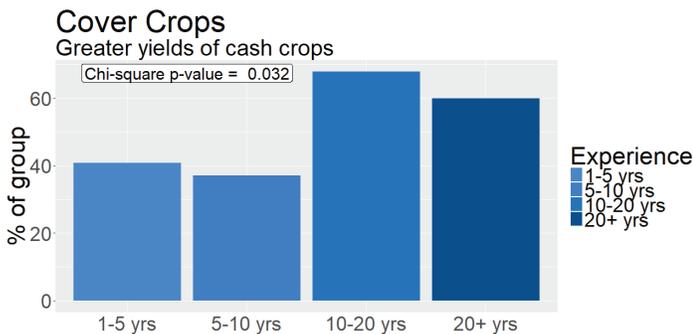


Fig 2. The use of cover crops can result in greater yields of cash crops, but this benefit is most common when the practice is in place for 10 years or more.

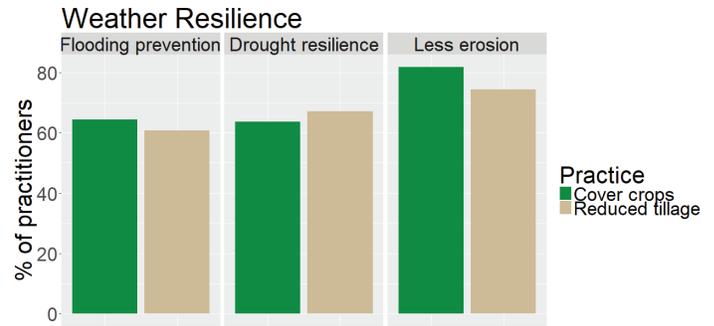


Fig 3. Over 60% of farmers surveyed confirmed that reduced tillage and cover crops help protect against extreme weather events.

who used cover crops, greater yield of cash crops was more frequently associated with long-term cover crop use (Fig 2).

We also wanted to know if farmers in New York state are improving their resilience to severe weather events by using soil health practices. Rainfall patterns in the region could change in the future, and we hypothesized that enhanced soil health provides protection against flooding and erosion from especially heavy downpours, due to the presence of stable aggregates and the soil's increased capacity to absorb water. That same healthy soil may also help a farmer during times of drought by storing water in the soil profile and making it available for crop growth. Both reduced tillage and cover crops were found to help farmers cope with extreme weather events, with over 60% reporting resilience benefits (Fig. 3).

This study was conducted by New York Soil Health, and funded by NYS Dept. of Ag & Markets and Cornell University College of Agriculture and Life Sciences (CALs). To learn more about soil health in New York, visit newyorksoilhealth.org.

Adapt-N tool leads to reduced nitrate leaching compared to Corn N Calculator

Joseph Amsili, Aaron Ristow, Márcio Nunes, Harold van Es, Robert Schidelbeck, Mike Davis
Soil and Crop Sciences, Cornell University and Cornell University Agricultural Experiment Station

Take-Aways:

- Corn N Calculator (CNC) N rates based on realistic yield expectations were on average 59 lbs N acre⁻¹ higher than Adapt-N rates, but did not result in yield increases.
- Adapt-N nitrogen (N) rates led to 58% (clay loam) and 68% (loamy sand) less nitrate leaching compared to CNC N rates.
- Adapt-N rates resulted in savings of \$29 acre⁻¹ compared to CNC N rates.

The over-application of nitrogen (N) fertilizer leads to large environmental problems and represents a considerable financial cost to the farmer. Despite these issues, farmers tend to over-apply nitrogen due to the difficulty of predicting the economic optimum N rate and the need to ensure high yields. Static N rate tools, like Cornell's Corn N Calculator (CNC; <http://nmsp.cals.cornell.edu/software/calculators.html>), are promoted widely but don't capture the dynamic interactions between site-specific weather, soil, and management variables. Adapt-N (<http://www.adapt-n.com>), a dynamic-adaptive N recommendation tool, was designed to integrate real-time weather and site-specific soil and management data to predict the optimum N rate.

In previous studies, it was demonstrated that Adapt-N can produce comparable yields to static N models and grower selected rates, while reducing overall N inputs ([What's Cropping Up? article on comparing](#)

[static and Adaptive N Tools; What's Cropping Up? article on comparing Adapt-N and CNC Tools](#)). Yet no field experiments had been conducted to compare the effects of Adapt-N and a static N calculator on measured nitrate leaching. This study utilized two long-term tillage experiments to measure the effects of modeled N rates (Adapt N vs. CNC), soil type (clay loam vs. sandy loam), and tillage practices (no-till vs. plow-till) on nitrate leaching.

Methods

Adapt-N and CNC nitrogen recommendations were superimposed onto two long-term tillage experiments (plow and no-till) at the Cornell Willsboro Research Farm for four years (2014-2017). The trials were done on contrasting soil types, one on a Muskellunge clay loam and the other on a Cosad loamy fine sand. Nitrogen rates included 15 lbs N/acre as starter fertilizer and the rest was side-dressed approximately six weeks after planting. CNC N rates were calculated using accurate yield potentials for each plot at the two sites (default yield potentials in the tool are unrealistically low). Adapt-N recommendations were developed considering plot-specific soil textures, organic matter contents, rooting depths, crop rotations, tillage practice, crop cultivar and population, previous N applications, drainage, and yield potentials, as well as daily weather information and grain and fertilizer prices.

Corn silage yield was collected each year by hand harvesting two 5 m corn rows at three locations per plot. Drainage water samples were collected on 14 dates between April 2015 and October 2017 (Figure 1) on dates when the drain lines discharged. Water samples were analyzed for nitrate, NO₃⁻, and nitrite, NO₂⁻, which we simply refer to as nitrate in this article because the nitrite fraction is generally less than 1%.

Table 1. N rates, corn silage yields and NO₃⁻ + NO₂⁻ concentrations in leached water for clay loam and loamy sand sites. Lowercase letters indicate significance (α=0.05) for Ntool treatment comparisons. Capital letters indicate significance (α=0.05) of soil type or grand mean treatment comparisons.

Soil Type – N Tool	N Rate	Yield	NO ₃ ⁻ +NO ₂ ⁻
Clay loam	lbs acre ⁻¹	tons acre ⁻¹	mg L ⁻¹
AdaptN Mean	133	15.29 a	6.55 b
CNC Mean	198	14.93 a	10.32 a
Clay loam mean	166	15.11 B	8.34 B
Loamy sand			
AdaptN Mean	122	17.32 a	12.29 b
CNC Mean	175	17.66 a	20.69 a
Loamy sand mean	149	17.48 A	16.47 A
Grand Means			
AdaptN	127	16.30 A	9.42 B
CNC	186	16.28 A	15.51 A

Results and Discussion

Nitrogen rates and Yield

The CNC tool calculated 59 lbs acre⁻¹ higher average N application rates than Adapt N (186 vs. 127 lbs N acre⁻¹; Table

Nutrient Management

1). There were only two instances (both wet seasons on the clay loam soil) where Adapt-N predicted higher N rates than the CNC tool.

Soil type had a very strong effect on corn silage yield, which were 2.37 tons acre⁻¹ higher in the loamy sand plots than the clay loam plots. Despite a lower yield potential for the clay loam site, the mean recommended N rate for that soil was 17 lbs acre⁻¹ higher than the loamy sand site. This indicates that both N tools

assume a lower nitrogen use efficiency (NUE) for finer textured soils.

While CNC N rates were much higher than Adapt N rates, they did not result in increases in yield (16.28 vs. 16.30 tons acre⁻¹; Table 1). We found no relationship between N rate and yield as equally high yields were achievable at 100 lbs N acre⁻¹ with Adapt-N as with CNC rates higher than 180 lbs N acre⁻¹ (Figure 1). The Adapt-N rates resulted in calculated savings of \$29 acre⁻¹ (based on a fertilizer price of \$0.50 lb N⁻¹) compared to the CNC N rates since yields between the N tools were indistinguishable.

Nitrate Leaching

Soil type and N Tool were important drivers of nitrate leaching in this study. Nitrate leaching averaged two times higher in sandy loam soils than clay loam soils (16.47 vs. 8.34 mg NO₃⁻+NO₂⁻ L⁻¹; Table 1) despite slightly higher N rates for the clay loam soils. This “missing” nitrogen in leached waters under the clay loam soils suggests that denitrification is an important N loss pathway in these finer textured soils, which is a well-documented phenomenon.

In addition to higher fertilizer costs per acre, CNC N rates led to 58% higher nitrate leaching in clay loam soils (10.32 vs. 6.55 mg NO₃⁻+NO₂⁻ L⁻¹) and 68% higher nitrate leaching in loamy sand soils (20.69 vs. 12.29 mg NO₃⁻+NO₂⁻ L⁻¹) compared to Adapt-N (Table 1). Increases in nitrate leaching were proportionally larger than the increases in N rates (46% higher for CNC than Adapt N for clay loam; 43% higher for loamy sand). This pattern indicates that N rates above the optimum have disproportionately large environmental impacts. Also, average nitrate concentrations in leached water under CNC plots exceeded the U.S. EPA drinking water standard of 10 mg NO₃⁻ L⁻¹ for both soil types. But nitrate concentrations under Adapt-N plots only exceeded the EPA standard at the loamy sand site.

Despite high variability in nitrate concentrations at different sampling dates, there was a positive relationship between N rate and nitrate

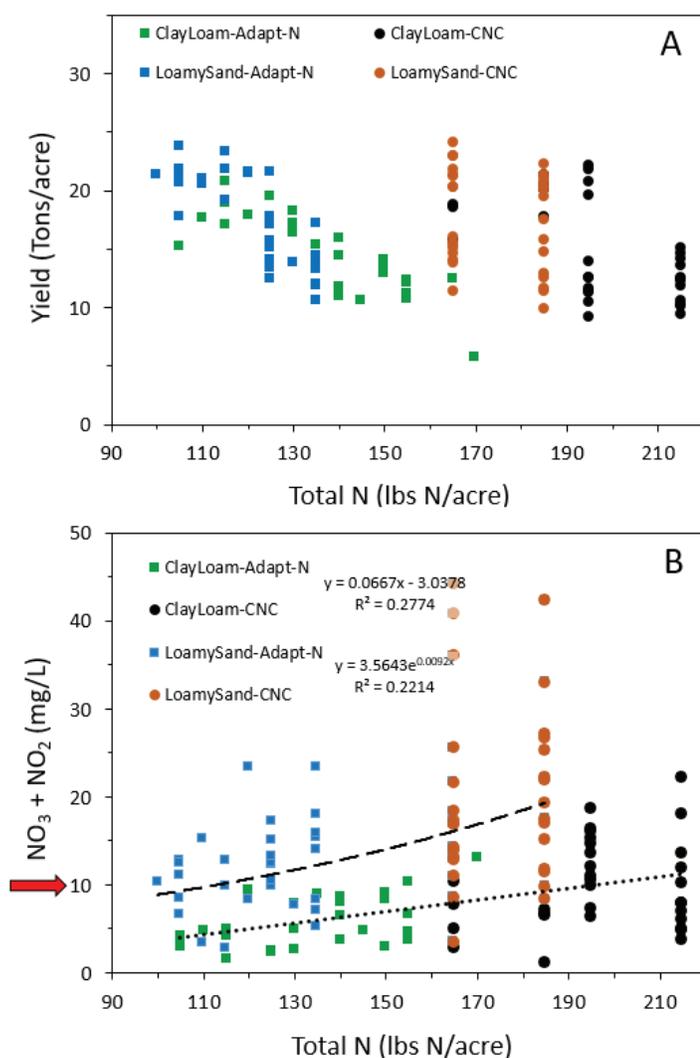


Fig 1. Silage corn yield (A) and amount of inorganic nitrogen (NO₃⁻+NO₂⁻) in the leached water (B) as a function of total N applied for each soil type and NTool. Regression coefficients were not significant. Red arrow indicates the EPA drinking water standard.

concentrations in leached water (Figure 1). The exponential relationship suggests that nitrate leaching is more sensitive to increasing N rates on loamy sand soils than clay loam soils (Figure 1). We noticed that extremely high nitrate concentrations ($> 50 \text{ mg NO}_3^- + \text{NO}_2^- \text{ L}^{-1}$) in leached water in loamy sands occurred after long dry periods (e.g., in the 2016 growing season) under CNC N rates, but not Adapt-N rates.

Tillage effects were modestly significant and on average the mean nitrate concentrations were 45% higher for the plow than no-till in the clay loam and 5% higher in the loamy sand.

Conclusions

This study compared the static Corn N Calculator and Adapt-N and showed that the CNC seriously over-predicts the optimum N rate when based on realistic corn yields because the higher N rates did not result in yield benefits. Use of Adapt-N led to savings of \$29 acre⁻¹, reduced nitrate leaching by between 58% (clay loam) and 68% (loamy sand), and helped keep nitrate concentrations in drain water below or near the U.S. EPA drinking water standard.

Acknowledgements:

Research was funded by the Northern New York Agricultural Development Program, USDA-NRCS, and New York Farm Viability Institute.

Akio Enders^a, John Gaunt^{a,b}, Joshua Stone^a, Leilah Krounbi^a, Johannes Lehmann^a, and Rajesh Chintala^c

^aSoil and Crop Sciences Section, Cornell University; ^bGreenTree Garden Supply; ^cInnovation Center for U.S. Dairy

Total milk production in New York was 14,765 million pounds in 2016 (NYS Department of Agriculture and Markets, 2017). In 2018, New York State had the 3rd highest number of milk cows behind California and Wisconsin, with 625,000 cows (USDA NASS, 2018). Dairy manure excretion averages 12,821,616 tons per year in NY state alone (NYS Department of Agriculture and Markets, 2017; NRCS, 2018). This translates into 64,108 tons N, 38,465 tons P₂O₅, and 44,876 tons K₂O (SARE, 2018) which can be recycled back for agricultural and horticultural use. In places where available manure nutrients exceed the needs of nearby field crops, the challenge becomes offsetting transportation costs. Unfortunately, these transportation costs can at times equal the manure's value as a fertilizer (Pennington et al.).

Manure management generates 44% of total methane emissions on dairy farms (Wright et al., 2017). A more potent greenhouse gas than CO₂ by 34-fold (Pronto et al., 2017), methane can be captured in anaerobic digesters for use as a fuel. Since 1998, 34 anaerobic digesters for dairy manure were installed and are operating across the state (EPA AGstar, 2018). These digesters facilitate a reduction in methane emissions by 1,502,327 MT CO₂ equivalent units per year (EPA AGstar, 2018; Pronto et al., 2017).

Methane biogas is just one of the products generated in anaerobic digesters. The remaining digestate of wet reactors is comprised of partially-degraded biomass and nutrients, and contains up to 16% solids (Ward et al., 2008). Plant nutrients are concentrated by the microbial activity. Notably, ammonium nitrogen increases by up to 33% (Möller et al., 2008; Möller and Müller, 2012). The digestate slurry can screw-pressed to separate solids from liquids and recycled into useful products such as bedding or organic fertilizers. The solids can be further stabilized against decomposition through pyrolysis.

Heating under oxygen-free conditions, known as pyrolysis, converts biomass into a charcoal-like substance called biochar. During this process, carbon chains fuse into rings (McBeath et al., 2014). These substances resist decomposition in the soil, and can

even slow the decomposition of non-biochar carbon (DeCiucies et al., 2018). As pyrolysis temperature increases, biochar surface area increases along with pH (Mukherjee et al., 2011). Generally speaking, pyrolysis concentrates plant nutrients when compared to the biomass feedstock (Enders et al., 2012).

This research project, sponsored by the U.S. Center for Dairy Innovation, enabled an assessment of upgrading anaerobically digested, screw-pressed dairy manure into a higher value biochar product. In summary, dairy manure biochar is an odor- and pathogen-free, nutrient-rich fertilizer with approximately twice the nutrient content of the original manure by mass, and more than three times that by volume. The nutrient value of the biochar as a substitute for other organic fertilizers was calculated as \$240-340/ton. In addition, the carbon value as a substitute for commercially available biochar was calculated as \$1580/ton. Analyses suggest that over half of the carbon in the resulting biochar is stabilized to benefit soil fertility and carbon sequestration for over a century after application.

Workflow

Anaerobically digested, screw pressed, dairy manure was sourced from a 3000+ head New York dairy farm. Initial moisture content was 59%. After air drying to 12%, the feedstock was pyrolyzed at a highest temperature of 550 °C for 30 minute total residence time. Biochar yield was 38% of oven dry feedstock weight.

Biochar Basic Utility Properties and Toxicant Assessment were analyzed according to the International Biochar Initiative (IBI) Standard Product Testing Guidelines v 2.1. Total nutrient contents of feedstock and biochars were assessed to describe the effect of pyrolysis on plant nutrients. Transformations in nutrient availability of the manure and biochar were investigated with three extractants. Leachable nutrients were determined with a 0.01 M calcium chloride, available with a modified Morgan's solution (ammonium acetate), and phosphorous with a fertilizer industry standard (2% citrate EDTA).

These data were used by our commercial partner, GreenTree Garden Supply, to substitute dairy manure

biochar for all of the commercial biochar as well as a portion of fertilizer they use in three of their commercial growing media.

Basic Properties

The dairy manure biochar is 178% more dense than the manure at 503 lbs/cu yd, with ash content increased to 38%.

The IBI classification tool calculates the Carbon Storage Class of this biochar as 1, on a scale of 1-5 with 5 providing the highest carbon storage potential. This rating integrates both carbon quality and quantity. The high ash content of this biochar downplays the quality of the carbon present, hence the low rating. However, the quality of the carbon is such (i.e., low H/C_{org} ratio) that roughly half is expected to persist over 100 years, compared to practically 0% in the manure.

The pH of this biochar is 10.45. More importantly, it has a calcium carbonate equivalence of 3.30%. In other words, 100 pounds of biochar can neutralize acid as well as 3.30 pounds of lime. This falls under IBI Liming Class 1, rated on a scale of 0-3, with 3 relating to the highest lime equivalent. Therefore, this biochar is best suited for mildly acid soils that would benefit from increasing pH. Unlike biochar from biomass, this material possesses a moderate level of soluble salts with electrical conductivity (1:20 w:v) at 1.65 dS/m. For comparison, soil salinity begins to affect plant growth at levels over 2 dS/m.

The Fertilizer Class of this biochar, according to the IBI classification system, is 3 on a scale of 0-4. This is defined as providing adequate nutrition for corn at < 4.5 tons/acre provides for 3 out of 4 nutrients. Specifically, the calculation states that phosphorous, potassium, and magnesium requirements are met by application of 4.0, 1.3, and 1.3 tons/acre.

Toxicant Assessment

The IBI toxicant assessment is understandably quite

stringent, screening for persistent organic pollutants: polyaromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), dioxins (PCDD) and furans (PCDF); toxic heavy metals including: arsenic, cadmium, chromium, lead, mercury; trace elements that become toxic at higher quantities including: copper, molybdenum, nickel, selenium, and zinc; and phytotoxic elements including: boron, chlorine, and sodium. The dairy manure biochar was non-toxic on all counts, and contained 30 times less than the threshold value for any single analyte. A germination trial also assessed biochar toxicity. Of the three species used (lettuce, ryegrass, and radish) germination in dairy manure biochar amended media was nearly identical to the control.

Total Nutrients

Biochar contained 4.1% P₂O₅, 2.2% K₂O, and 4.4% MgO. Approximating from biochar yield, nutrient concentration in biochar could be as much 2.6x more than in manure. Gaseous losses during pyrolysis reduced the total content of plant nutrients in the biochar to 1.7x more than in manure feedstock. Sulfur is the most notable example where biochar contained 50% less than feedstock.

Element	Total content		Change due to pyrolysis	
	Manure (mg/kg)	Biochar (mg/kg)	Concentration	Retention
Phosphorous	10481.6	17728.6	69%	64%
Potassium	15721.5	21897.7	39%	53%
Calcium	154454.9	270710.8	75%	67%
Magnesium	15134.9	26391.3	74%	66%
Sulfur	8346.0	4212.6	-50%	19%
Iron	1801.3	4057.9	125%	86%
Manganese	214.3	369.7	72%	66%
Zinc	266.6	526.5	97%	75%

Available Nutrients

In addition to increasing total nutrient content, pyrolysis improved nutrient availability, exception for nitrogen and iron. The dairy manure biochar has a nitrogen content of 1.7%, however thermal treatment has converted this to plant unavailable forms and is therefore considered insignificant.

Research

Biochar provided 13% more available phosphorous than the manure feedstock with 1.2% of biochar mass as P₂O₅, i.e. as would be printed on a fertilizer label. Interestingly, increased available phosphorous was coupled with a 10-fold decrease in leachable phosphorous.

The biochar also demonstrated 59% more available potassium than the manure with 1.6% of biochar mass as K₂O.

production from manure is its moisture content. Waste heat from biogas combustion could fulfill this requirement, given the proper infrastructure. Additionally, pyrolysis coproduct gases could be upgraded and then co-fired alongside biogas for electricity generation to power on-farm pyrolysis. Biochar application to fields would increase fertility and offset nutrient inputs.

Organic farming is a feasible commercial application for dairy manure biochar. The biochar is cost competitive

Element	Manure		Biochar		Change due to pyrolysis	
	Leachable	Available	Leachable	Available	Leachable	Available
	mg/kg	mg/kg	mg/kg	mg/kg		
Phosphorous	409.8	4505.9	35.8	5088.2	-91%	13%
Potassium	7372.8	8114.2	9399.9	12891.2	27%	59%
Calcium	31257.5	80671.0	33720.8	142276.8	8%	76%
Magnesium	2785.9	6578.6	291.1	7654.5	-90%	16%
Sulfur	179.5	681.0	125.4	750.5	-30%	10%
Iron	1.6	41.7	0.0	8.9	-100%	-79%
Manganese	7.1	109.3	6.2	176.6	-13%	62%
Zinc	1.9	69.2	0.5	85.0	-74%	23%

with other organic phosphorous sources and organic farmers are accustomed to spreading the larger bulk quantities as fertilizer. Additional fertilizer (especially N) would be blended with the biochar to achieve a desired nutrient balance and concentration and the final product would contain biochar to benefit soil fertility in the long term.

Commercial Value

When all nutrient and carbon content is accounted for, the dairy manure biochar has a value between \$0.91 – \$0.96/lb (or \$1,828-\$1,912). This is calculation is based on the weighted average wholesale price for individual components in commercially available organic fertilizers as below. The majority of value, \$0.79/lb, arises from the biochar carbon.

Ammonia gas lost from leachate ponds is another resource that can be utilized when biochar is introduced to the system. Biochar has proven effective in adsorbing both ammonium in solution and ammonia gas (Wang et al., 2016). This nitrogen loading can be enhanced with repeated exposure to CO₂ to precipitate ammonium bicarbonate (Van Humbeck et al., 2014). Ammonium bicarbonate-

The product evaluation performed by GreenTree Garden Supply substituted all of the commercial biochar (80% C) with dairy manure biochar (43% C) on a carbon basis. The additional nutrient content in the dairy manure biochar reduced wholesale material cost for two products by 2.26% and 0.19%.

	Rock phosphate *1		Bone char *2		Bone meal *3		Manure biochar				
	%	individual value	biochar \$/lb	%	100% \$/lb	biochar \$/lb	%	100% \$/lb	biochar \$/lb		
Wholesale price		\$ 0.39		\$0.32		\$1.43					
Total P ₂ O ₅	20%	\$ 0.15	\$ 0.03	32%	\$0.13	\$ 0.02	\$ -		4.1%	←	
Available P ₂ O ₅	4%	\$ 0.03	\$ 0.01	16%	\$0.06	\$ 0.00	29%	\$0.69	\$ 0.03	1.2%	←
Total K ₂ O	2%	\$ 0.01	\$ 0.02		\$ -			\$ -		2.2%	\$ 0.04
Total Ca	25%	\$ 0.19	\$ 0.01	34%	\$0.13	\$ 0.01	31%	\$0.74	\$ 0.04	1.6%	←
Total Mg	1%	\$ 0.01	\$ 0.02		\$ -			\$ -		2.6%	\$ 0.05
Total S		\$ -			\$ -			\$ -		0.4%	\$ 0.01
Organic C										43.3%	\$ 0.79

*1 https://norganics.com/index-12/index-11/fertilizers/old_phosphate-rock/

*2 <https://norganics.com/index-12/index-11/fertilizers/bone-char/>

*3 <https://norganics.com/index-12/index-11/fertilizers/porcine-bone-meal/>

*4 Potash (\$0.83/lb) <https://www.norganics.com/label/SulPotash.pdf>

*5 Magnesium sulfate (\$0.48/lb)

*6 GreenTree Biocore wood biochar (\$1.45/lb)

Future Outlook

A practical challenge to biochar

biochar fertilizer has demonstrated greater efficiency than synthetic nitrogen alone (Mandal et al., 2016), however commercial production has not yet been achieved.

References

- New York State Department of Agriculture and Markets. 2017. New York State Dairy Statistics 2017 annual summary. NYS Agricultural Statistics Service, NYS Department of Agriculture and Markets, Division of Milk Control and Dairy Services, Albany, New York, pp.2.
- United States Department of Agriculture, National Agricultural Statistics Service. https://www.nass.usda.gov/Publications/Todays_Reports/reports/mkpr0718.pdf (last accessed Nov 27, 2018)
- Natural Resource Conservation Service. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/null/?cid=nrcs143_014154 (last accessed Oct 26, 2018)
- Sustainable Agriculture Research and Education. <https://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition/Text-Version/Animal-Manures-for-Increasing-Organic-Matter-and-Supplying-Nutrients/Chemical-Characteristics-of-Manures> (last accessed Oct 26, 2018)
- Pennington, J.A., VanDevender, K., and Jennings, J.A., Nutrient and Fertilizer Value of Dairy Manure. University of Arkansas Division of Agriculture, Cooperative Extension Service, Agriculture and Natural Resources bulletin FSA4017.
- Wright, P., Gooch, C. and Oliver, J.P., 2017. Estimating the Economic Value of the Greenhouse Gas Emission Reductions Associated with on-farm Dairy Manure Anaerobic Digestion Systems in New York State. In *2017 ASABE Annual International Meeting* (pp. 1). American Society of Agricultural and Biological Engineers.
- Pronto, J., Gooch, C., and Wright, P. 2017. Meeting New York State's Energy, Environmental and Economic Goals While Strengthening Dairy Farms Through the Widespread Adoption of Manure-Based Anaerobic Digestion Technology- Working Paper. Pro-Dairy program, Cornell University, Ithaca, NY p. 4. https://pro dairy.cals.cornell.edu/sites/pro dairy.cals.cornell.edu/files/shared/documents/ADworking_paper_Oct17.pdf (last accessed Oct 28, 2018)
- Environmental Protection Agency. 2018. AgSTAR Livestock anaerobic digester database. <https://www.epa.gov/agstar/livestock-anaerobic-digester-database> (last accessed Oct 28, 2018)
- Ward, A.J., Hobbs, P.J., Holliman, P.J. and Jones, D.L., 2008. Optimisation of the anaerobic digestion of agricultural resources. *Bioresource technology*, 99(17), pp.7928-7940.
- Möller, K., Stinner, W., Deuker, A. and Leithold, G., 2008. Effects of different manuring systems with and without biogas digestion on nitrogen cycle and crop yield in mixed organic dairy farming systems. *Nutrient cycling in agroecosystems*, 82(3), pp.209-232.
- Möller, K. and Müller, T., 2012. Effects of anaerobic digestion on digestate nutrient availability and crop growth: a review. *Engineering in Life Sciences*, 12(3), pp.242-257.
- McBeath, A.V., Smernik, R.J., Krull, E.S. and Lehmann, J., 2014. The influence of feedstock and production temperature on biochar carbon chemistry: a solid-state ¹³C NMR study. *Biomass and Bioenergy*, 60, pp.121-129.
- DeCiucies, S., Whitman, T., Woolf, D., Enders, A. and Lehmann, J., 2018. Priming mechanisms with additions of pyrogenic organic matter to soil. *Geochimica et Cosmochimica Acta*, 238, pp.329-342.
- Mukherjee, A., Zimmerman, A.R. and Harris, W., 2011. Surface chemistry variations among a series of laboratory-produced biochars. *Geoderma*, 163(3-4), pp.247-255.
- Enders, A., Hanley, K., Whitman, T., Joseph, S.,

Research

Lehmann, J., 2012. Characterization of biochars to evaluate recalcitrance and agronomic performance. *Bioresource Technology*, 114, pp.644-653.

Wang, B., Lehmann, J., Hanley, K., Hestrin, R. and Enders, A. (2016) Ammonium retention by oxidized biochars produced at different pyrolysis temperatures and residence times. *Royal Society of Chemistry Advances*, 6, pp.41907-41913.

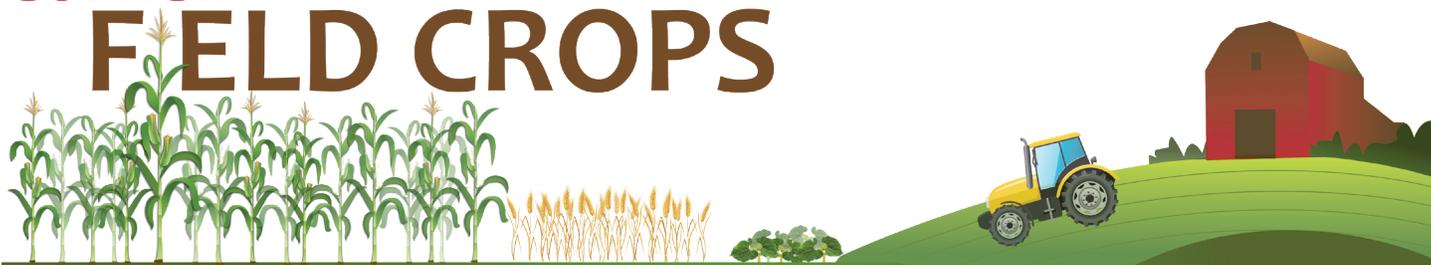
Van Humbeck, J.F., McDonald, T.M., Jing, X., Wiers, B.M., Zhu, G. and Long, J.R., 2014. Ammonia capture in porous organic polymers densely functionalized with brønsted acid groups. *Journal of the American Chemical Society*, 136, pp.2432-2440.

Mandal, S., Thangarajan, R., Bolan, N.S., Sarkar, B., Khan, N., Ok, Y.S. and Naidu, R. (2016) Biochar-induced concomitant decrease in ammonia volatilization and increase in nitrogen use efficiency by wheat. *Chemosphere*, 142, pp.120-127.



T h i s p a g e i n t e n t i o n a l l y l e f t b l a n k .

Cornell FIELD CROPS



 <http://fieldcrops.org>

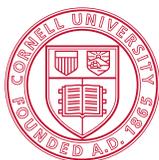
 [@fieldcrops_org](https://twitter.com/fieldcrops_org)



Calendar of Events

DEC 11	80th Annual Cornell Seed Conference - Geneva, NY
DEC 12 & 13	Empire State Barley and Malt Summit - Syracuse, NY
JAN 4	Oneida County Crop Congress - Clinton, NY
JAN 8	New York Certified Organic 2019 Winter Meetings - Geneva, NY
JAN 18 - 20	NOFA-NY 2019 Winter Conference - Saratoga Springs, NY

Have an event to share? Submit it to jnt3@cornell.edu!



Cornell University
Cooperative Extension
Soil and Crop Sciences Section
237 Emerson Hall
Cornell University
Ithaca, NY 14853



What's Cropping Up? is a bimonthly electronic newsletter distributed by the Soil and Crop Sciences Section at Cornell University. The purpose of the newsletter is to provide timely information on field crop production and environmental issues as it relates to New York agriculture. Articles are regularly contributed by the following Departments/Sections at Cornell University: Soil and Crop Sciences, Plant Breeding, Plant Pathology, Animal Science and Entomology. **To get on the email list, send your name and address to Jenn Thomas-Murphy, 237 Emerson Hall, Cornell University, Ithaca, NY 14853**

Stay Connected!

 Follow [@fieldcrops_org](https://twitter.com/fieldcrops_org)

 JOIN US ON
Facebook