Soil Fertility Consideration Surrounding Cover Crop Use

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General relationships of cover crops and soil fertility-

Cover crops of all types take up N and reduce over-winter loss of nitrate through leaching and denitrification of loose nitrate.

Legume cover crops add N to the soil system if left undisturbed or tilled in, decreasing supplement N requirement.

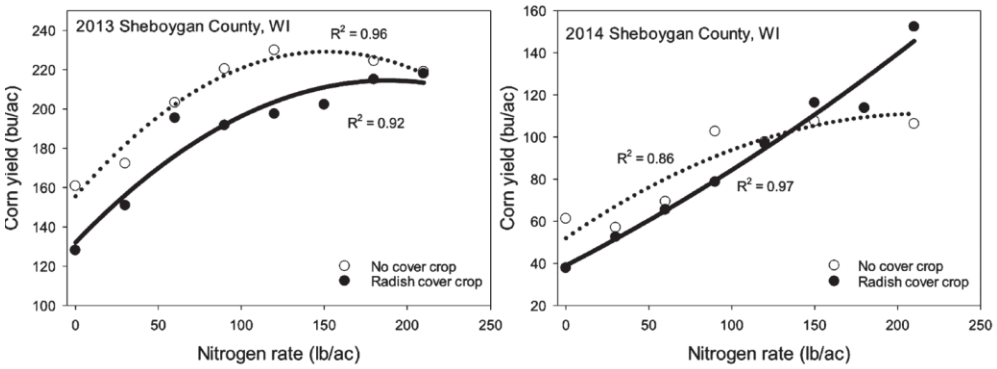
There is general thought that a substantial portion of any cover crop N taken up is available to the next crop.

Research Results, Northeast US, published in USDA-SARE Cover Crop Handbook

Estimate yield of cover crop at termination
Estimate % N in cover crop
(Younger legumes ~ 4%, older ~3.5%)
Most other covers have 2-3% before flowering
1.5-2% after flowering.

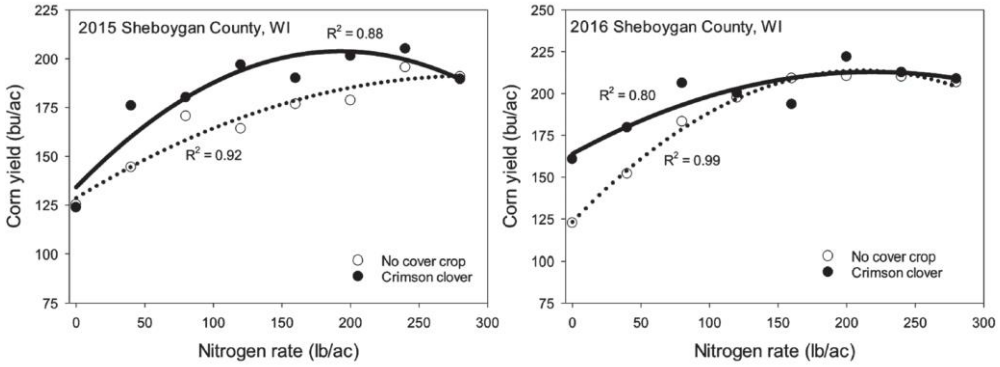
Yield X %N/100 = lb N in cover crop
divide by 2 if incorporated
divide by 4 if left on surface

Research Results, Wisconsin (Matt Ruark, Agronomy Journal 2019)



Forage radish did not contribute N to following corn crop despite having C/N ratio that indicated it would.

Research Results, Wisconsin (Matt Ruark, Agronomy Journal 2019)



Crimson clover resulted in N contribution to corn the following year.

Discounting the cover crop fail from interseeding sunflower with hairy vetch, conducted late 1980's, the real cover crop work at NDSU began in 2016.

Abbey Wick and I established two sites with a Corn, Soybean and Spring Wheat rotation in fall 2016.

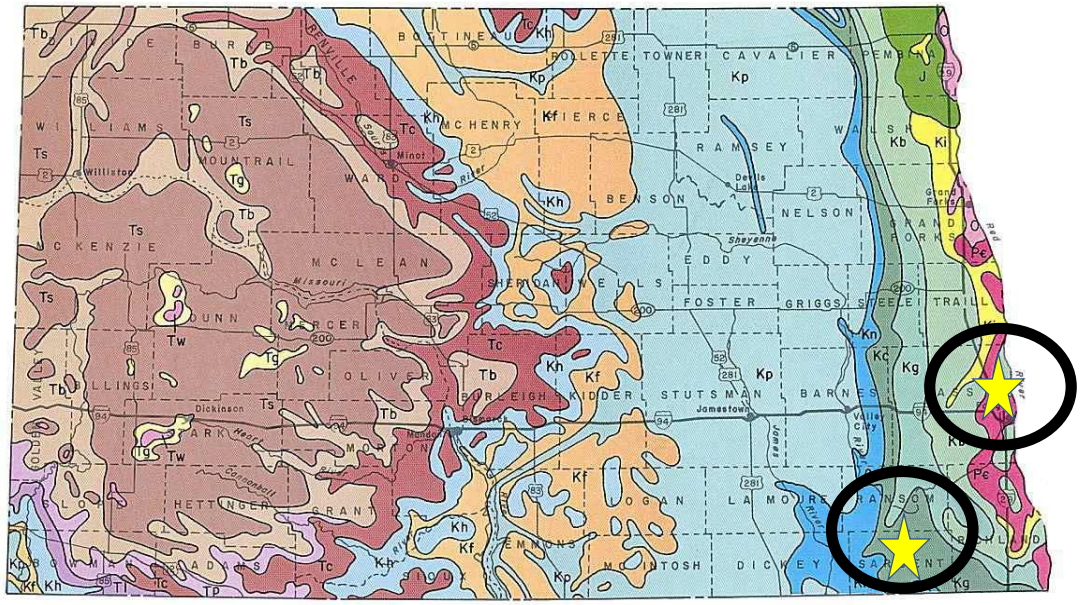
Gardner site, N of Fargo ~ 30 miles, between I-29 and the RRiver (Fargo silty clays- long term conventional till)
Rutland site, SSW of Fargo ~ 80 miles, north of SD border 2-5 miles depending on field.
(Overly silty clay, Forman loams, 30+ years no-till)

Objective-

To determine how much N is cycled through cover crop into the next season.

Cover crops of particular interest were mixes of cereal rye, forage radish and camelina.

Depending on next crop, oat was also used (before corn)



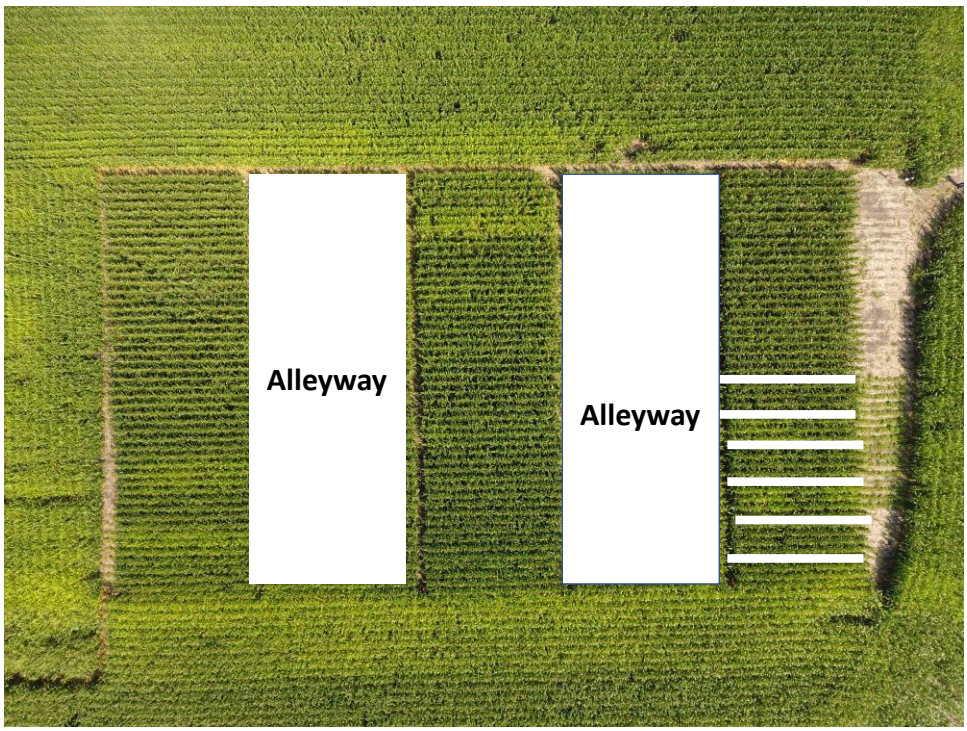
Initial year Rutland
2016, West field, following winter wheat-
Winter wheat volunteer, forage radish, flax, field pea in 'bio-striptill' configuration (pea between future rows, radish/flax in future corn rows -30 inch spacing)

Cover crop biomass late October 2016, Rutland west site

Cover crop	Dry Matter, lb/a	N, lb/a
Field Pea	1440	34 (C/N ratio ~ 18/1)
Radish tops	1770	38 (C/N ratio ~ 15/1)
Radish roots	1300	8 (C/N ratio ~ 30/1)
Flax	130	2 (C/N ratio ~ 20/1)
Winter wheat volunteer	450	3 (C/N ratio ~ 17/1)
Total	5090	85

Volumetric water content 10/21/2016
with cover crop 6.2 inches in top 2 feet soil
No cover crop 9.1 inches in top 2 feet soil

Residual nitrate-N to 2 feet
with cover crop 15 lb N/acre
without cover crop 114 lb N/acre



6/22/2017, Rutland west experiment cover crop inter-seeded
40 lb/a cereal rye, 2 lb/a forage radish and 2 lb/a camelina
Corn was at V8

Below is a piece of the 'Fargo-Aire' equipment made available through Amity in Fargo

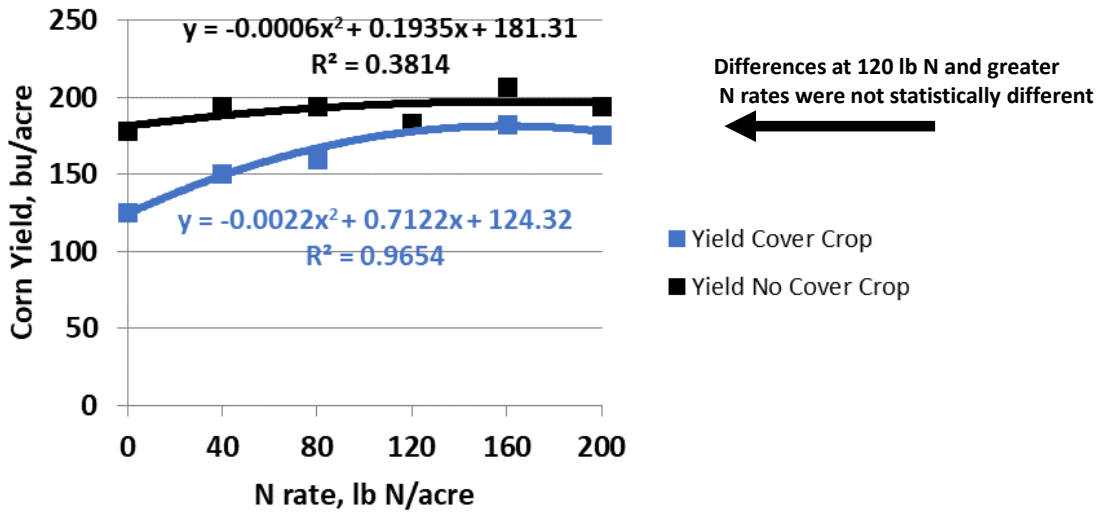
Rutland west inter-seeding August 16, 2017

Biomass of all
~ 84 lb/acre

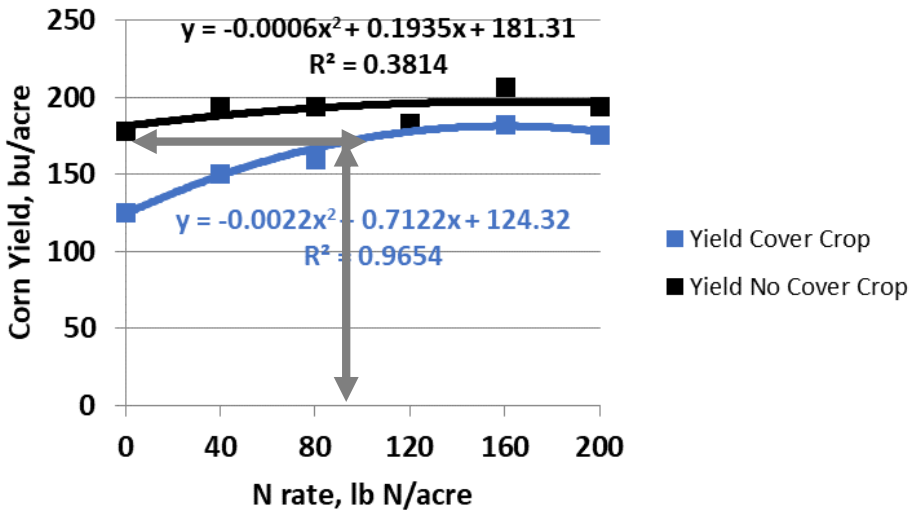
~ 3 lb N/acre in cover crop.

By May 11, 2017, gap in residual N narrowed to about 42 lb N/acre in cover crop vs 76 lb N/acre in no cover crop

At corn harvest, there was no difference in residual N between cover crop and no cover crop.



October 29, inches of water in top 2 feet of soil after cover crop 10.4
after no cover crop 8.4

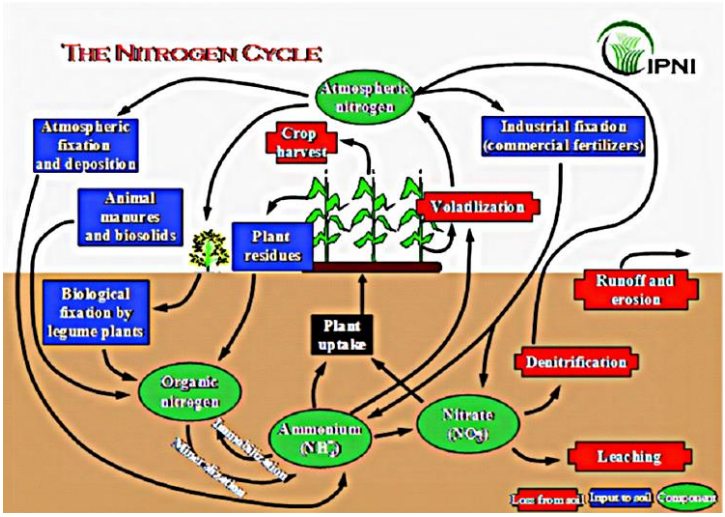


Rate of N necessary after cover crop to achieve yield of no cover crop at 0 N rate is about 90 lb/a - About the N that was in the cover crop!

The question is where did the 90 lb N go?

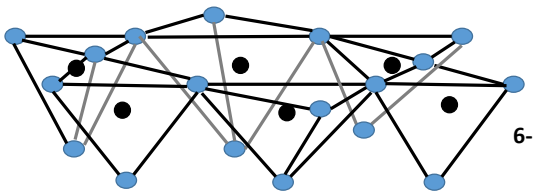
Not in soil nitrate-N, not in yield, cover crop largely disintegrated by November sampling.

What's missing??

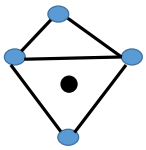


Clay chemistry short version:

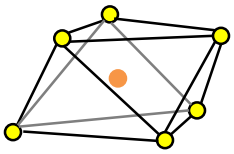
The silicon oxide sheet layer-



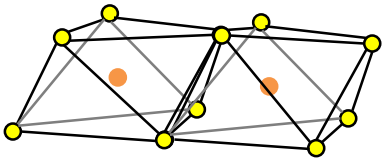
6- SiO_4 in a sheet



The SiO_4 building block

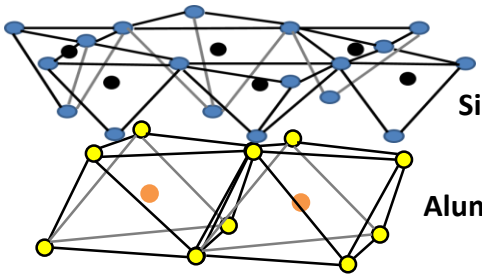


Aluminum hydroxide building block



Aluminum hydroxide sheet

A 1:1 silicon oxide sheet bound to an aluminum hydroxide sheet.

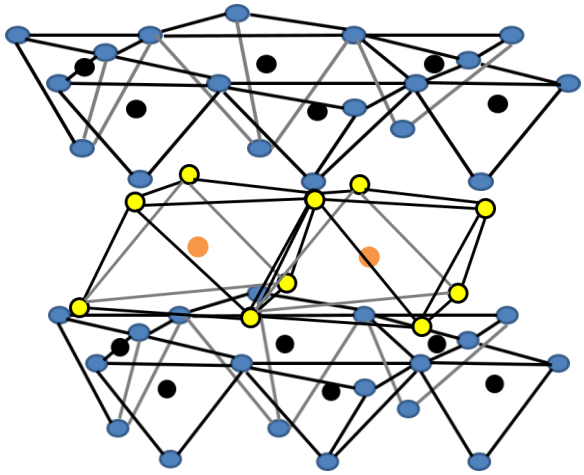


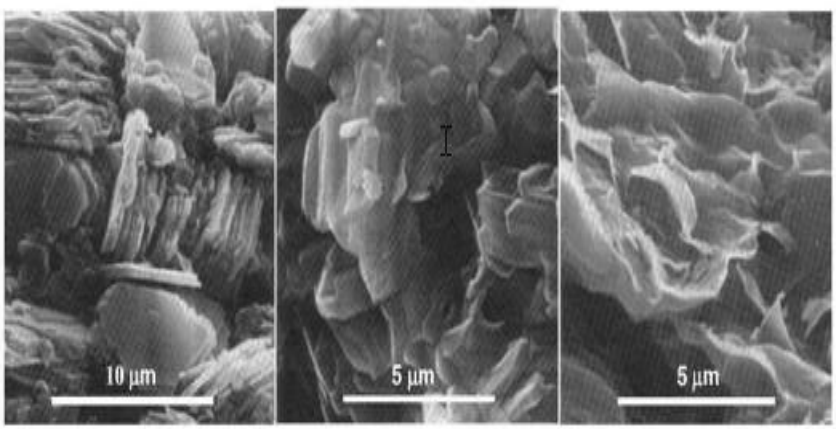
Silicon oxide sheet

Aluminum hydroxide sheet

Bound by partial charge from $O^{-\rho}$ and $OH^{+\rho}$

A 2:1 clay-
Sheet of Aluminum hydroxide with 2 sheets of Silicon oxide- one above, one beneath.





Micrographs of kaolinite (1:1 clay) left
Illite (limited shrinking 2:1 clay) center
and Smectite (high shrink/swell 2:1 clay) right

Smectites 'fix', or temporarily retain K when soil is dry

Illites do not 'fix' K when dry

What about ammonium?

Ionic radius of K^+ (133) is similar to that of NH_4^+ (143) and hydrated radius of NH_4^+ (250) is smaller than that of K^+ (450)

Smectite clays, particularly those with high interlayer charge (beidellite) 'fix' K during dry soil periods and prevent K release upon shrinking/collapse. This is a reversible process when the soil re-wets.

Minerals & Clays measured in survey-

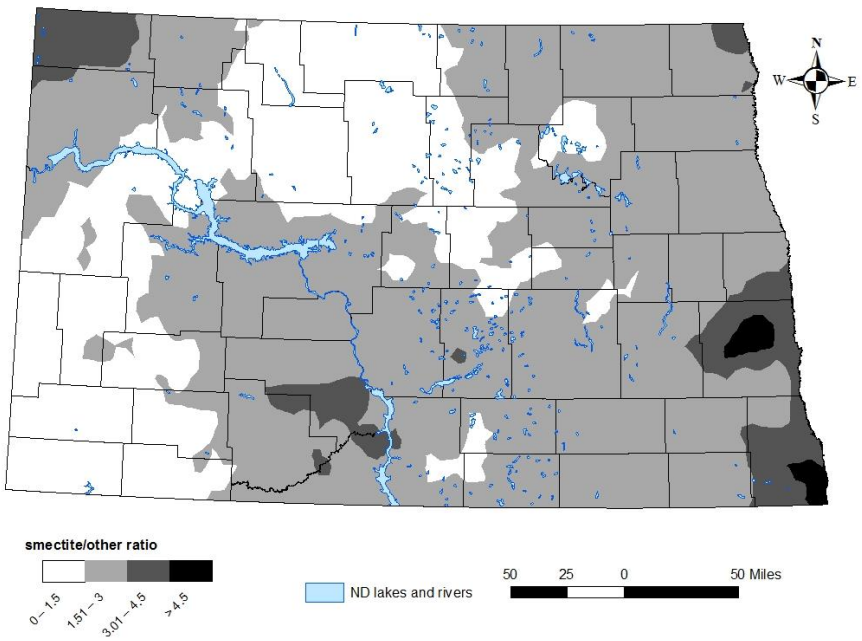
Smectite- (includes montmorillonite/beidelite)

Illite- 2-1 limited expanding clay

Kaolinite (1-1 non-expanding clays)

Chlorite (3-1 non-expanding clays)

Potassium feldspar



Smectites 'fix', or temporarily retain K when soil is dry

Illites do not 'fix' K when dry

What about ammonium?

Ionic radius of K^+ (133) is similar to that of NH_4^+ (143) and hydrated radius of NH_4^+ (250) is smaller than that of K^+ (450)

Therefore, since K is 'fixed', it is reasonable to NH_4^+ is also fixed.

Ammonium fixation has been recognized for a long time, but it is seldom considered as as source of N for crops.

North Dakota subregions for N fertilization. Each has different N response curves for spring wheat/durum, corn and sunflower

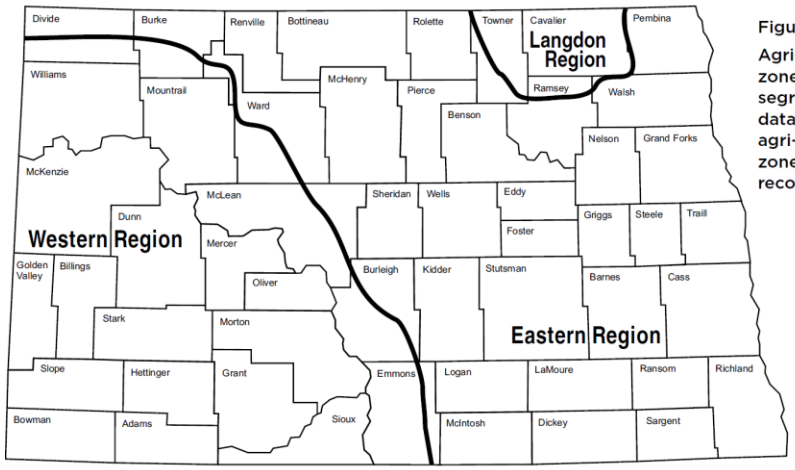


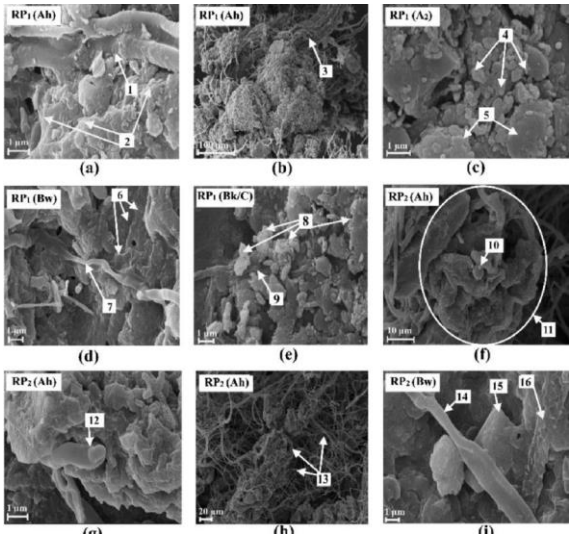
Figure 3.
Agri-climatology zones used to segregate N-rate data and develop agri-climatology zone N recommendations.

The Langdon area in North Dakota requires less N supplements than neighboring eastern ND areas.

The Langdon area has a high amount of mixed- in shales (>65 million years old)
The shale contains high amounts of mineralizable ammonium (ancient fixed ammonium).

So the soil acts as a slow release N fertilizer.

Likely the fixation occurs at the root-clay interface.



RP 1 images (SEM) of fine root (1), root exudates/biofilms (2), fine roots (3), clay mineral grains (4), clay mineral aggregates (5), root exudates/biofilms (6), organic filament (7), fine clay aggregates (8), fine root (9), and RP 2 images (SEM) of aggregates with abundant root remnants (10), pollen (11), root tap protruding through clay aggregate coated by exudates (12), dominant network of fine roots (13), and organic filament, primary mineral, clay minerals coating organic filament (14, 15, 16). From Razzaghi et al., 2017.

New site, Rutland East Experiment Initiated after spring wheat 2017

Seeded in bio-strip-till directly after seeding.

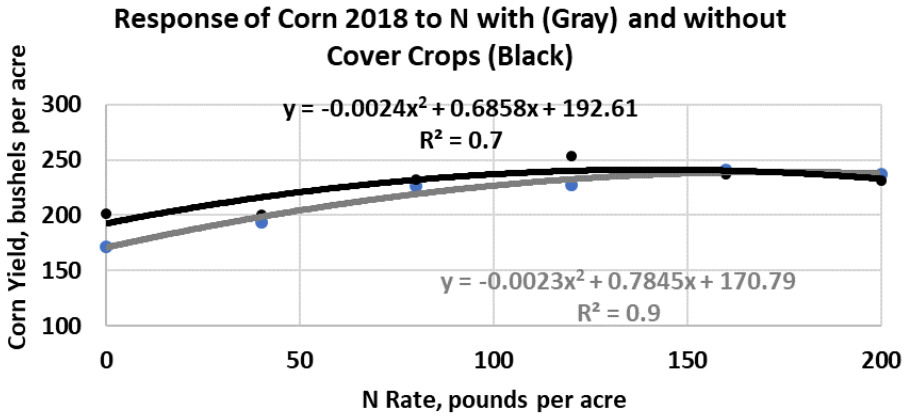
Faba bean, radish and flax directly into next year's corn row. Volunteer spring wheat in the rest.

Total dry matter at freeze-up was ~2,000 lb/a. Spring wheat almost headed out.
N content 70 lb/acre

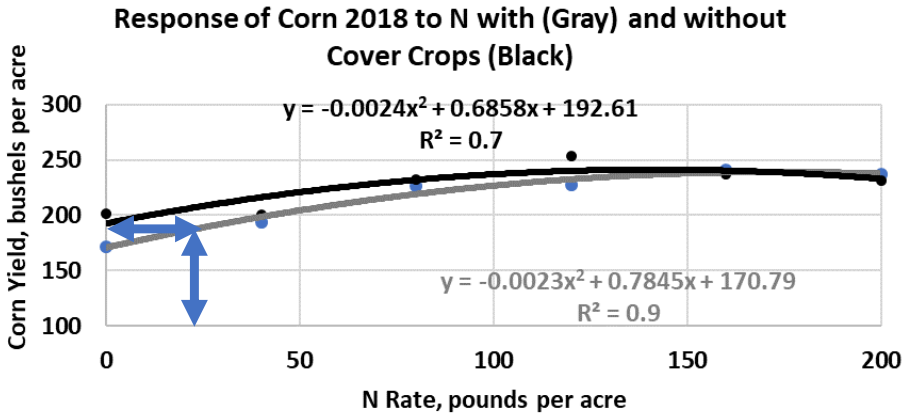
Residual nitrate-N Rutland East 8/28/2017
Cover crop 71 lb N/a
no cover crop 63 lb N/a

Non-Exchangeable ammonium after corn harvest 2018
After cover crop 480 lb N/acre
Without cover crop 328 lb N/acre

Rutland East Experiment Corn 2018

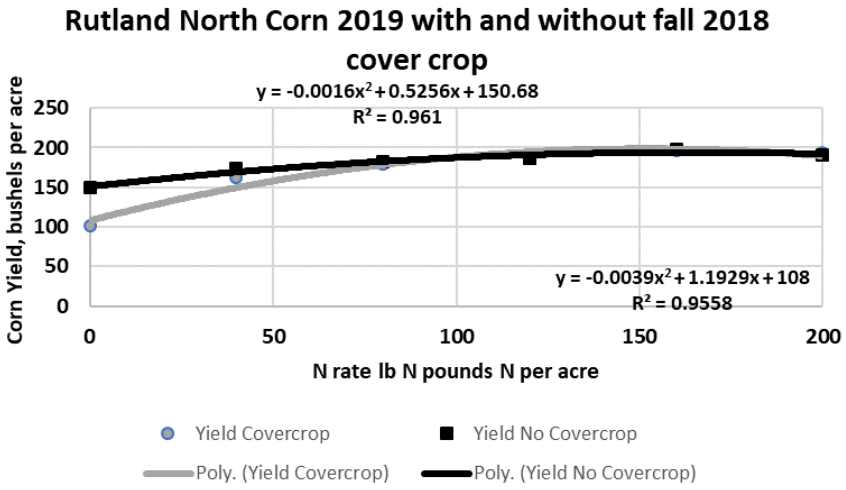


Rutland East Experiment Corn 2018



It took an additional 30 lb N/acre for the cover crop treatment yield to reach the 0 rate of N from the non-cover crop treatment.

Rutland North Experiment was also established in 2017 and had cover crop after soybean and wheat, then corn.



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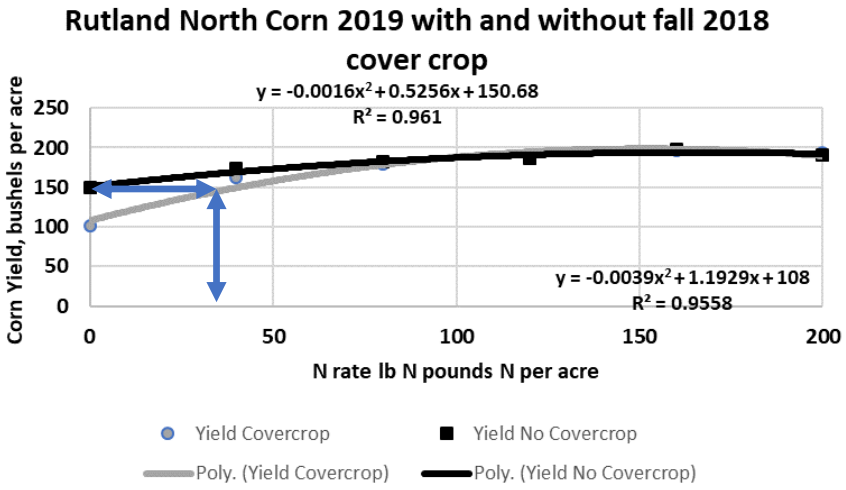


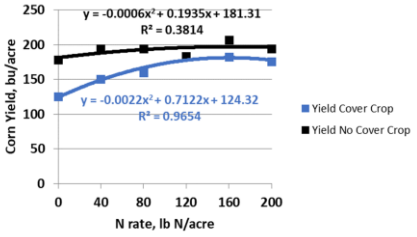
Non exchangeable ammonium

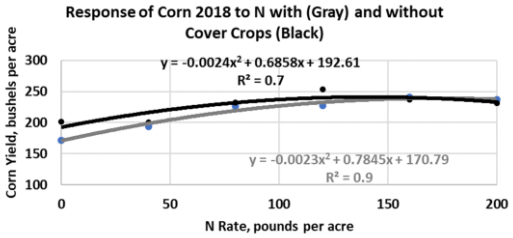
Difference was 144 lb/acre greater non-exchangeable ammonium with cover crop history than without.

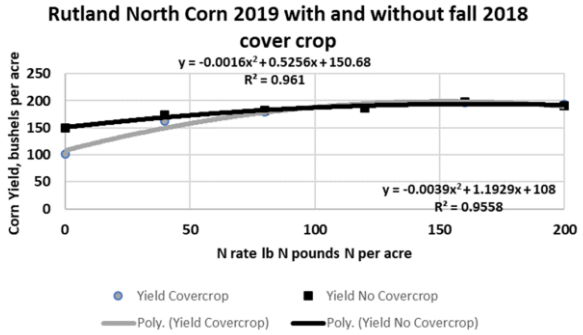
It appears that the first year after rye/radish cover crop, there is no N release.

However, the 2nd and 3rd year after their introduction, the extra N imbedded in the nonexchangeable ammonium is released so that maximum yield is achieved with less N.

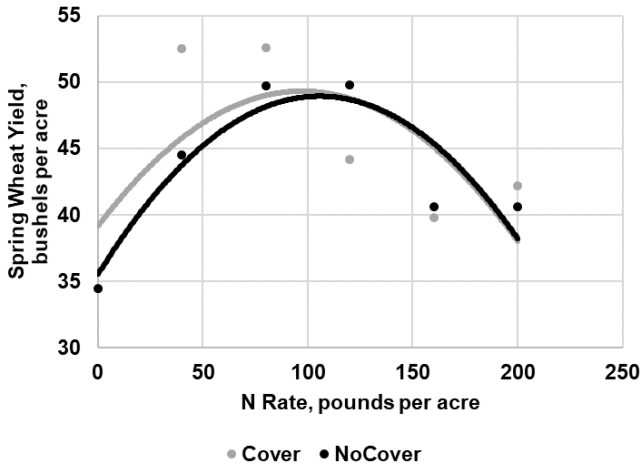
Note how the curves meet at lower N rates at Yr 2 vs Yr 1 and Yr 3 vs Yr 2 and 1.







Year 4 of cover crop experiments Rutland West Field
Cover Crop provides about 20 lb N/a more N at 0 N rate compared to no cover crop history



Yield reduction at > 80 lb N rate due to to pre-anthesis lodging (N rate too high)

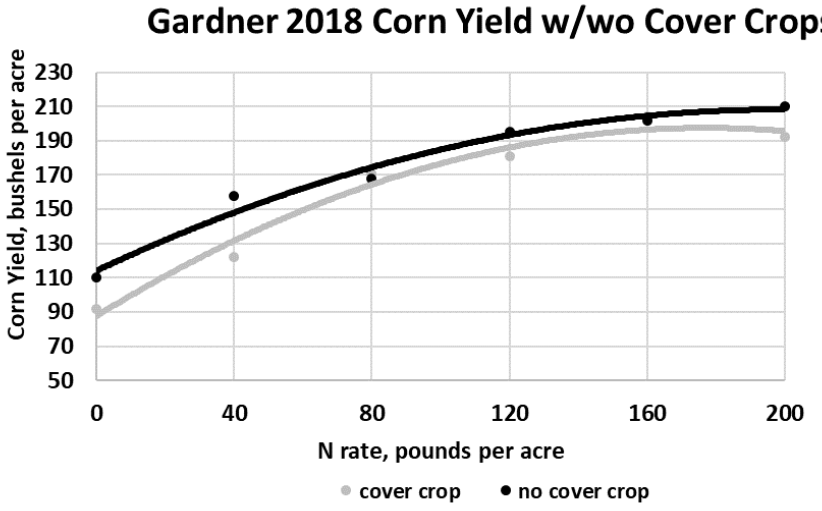
Gardner experiments-
in 2017, corn was interseeded with FargoAire tool

Stand was good (right) total growth until freeze up about 400 lb/acre summer was dry and expected yield reduction, but no yield difference was present cover crop vs none.

Gardner experiments

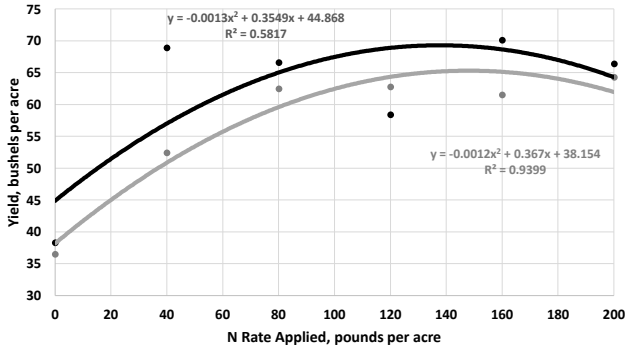
2018 cover crop to corn
Camelina had spring growth.

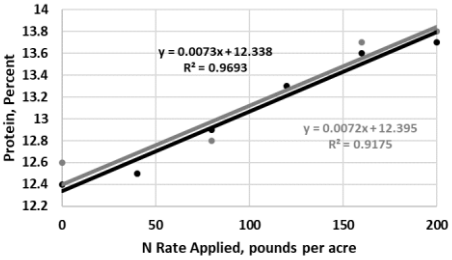
Radish and oats had died.



No cover crop N credit from terminated spring camelina with about 3% N.

Yield spring wheat Gardner 2018 after soybean with and without cover crop.
No N contribution of cover crop to wheat yield





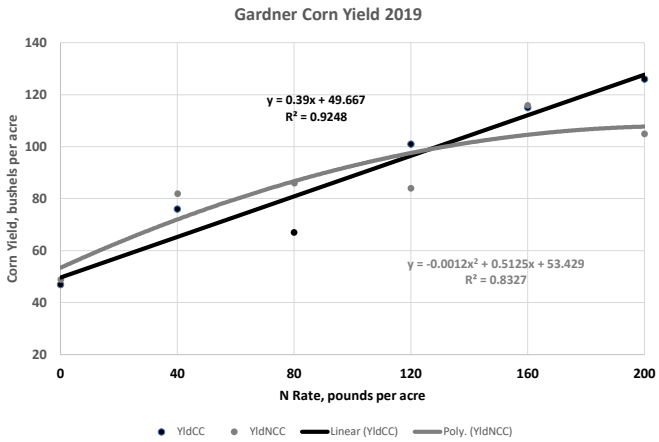
Non-exchangeable ammonium
Cover crop- 2730 lb/a
No Cover- 2584

Protein similar with or without cover crop

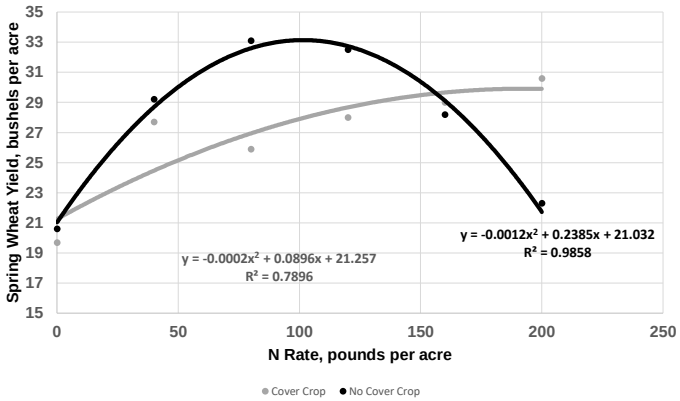
Soybean yield 2018

With cover crop 59.0
Without cover crop 61.7 bu/a
No differences P>0.49

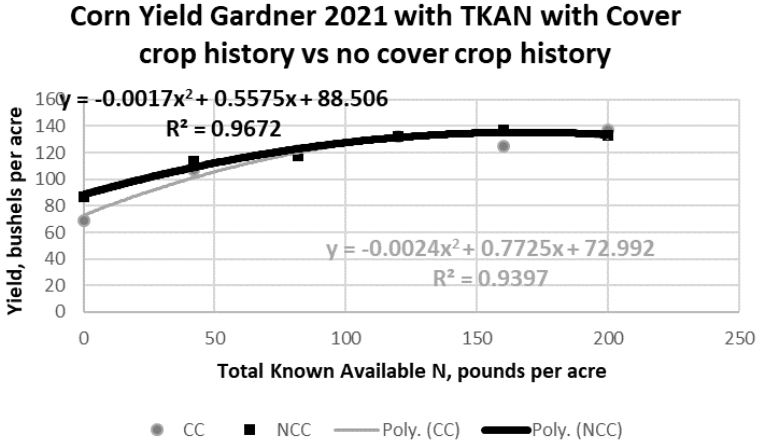
Soil moisture similar with or without cover crop



Gardner spring wheat, 2019, really wet season. Cover crops drowned out going into 2020.

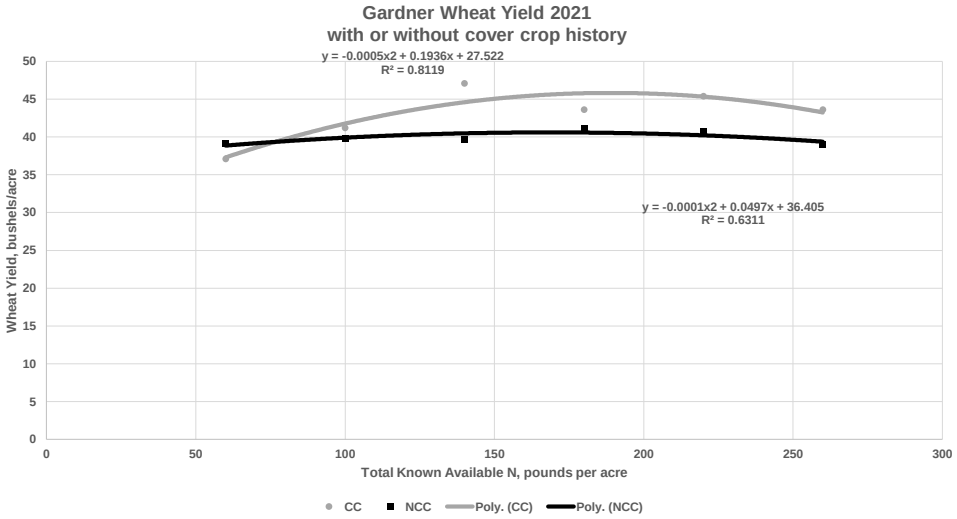


Gardner



Camelina before corn April 2021 ~ 200 lb DM per acre, about 3% N for about 6-8 lb N/acre in cover crop

No cover crop established fall 2020- too dry (really dry!) Yield increase with cover crop history may be improved mulching and moisture savings during 2021 growing season.



Take-home points

Pure stands of legumes before the next crop will likely contribute N as guidelines indicate.

Mixed stands with other crops do not, at least in our environment with winter mortality.

Cereal rye with forage radish and other cover crops produce the greatest biomass after a short-season crop
- **spring wheat**
- **winter wheat**
- **barley**
- **oats**

If there is no rain after seeding and the soil was dry at seeding, even early harvested crops will not support robust cover crop growth.

The N in cover crops not seen by the next crop in smectitic soils is likely 'fixed' into non-exchangeable ammonium.

Intermittent cover crop into rotations, particularly those with corn and soybean only, are unlikely to benefit greatly from released non-exchangeable ammonium.

Continuous cover crop seeding into all crops in the rotation appears to begin releasing N from non-exchangeable ammonium in the 2nd year, and at the 4th year, continuous release may have been achieved.

Corn yield did not suffer from interseeding rye and radish at V6-V9, even in a dry year.

In 2019, there were 35 days of leaf wetness not due to rainfall for a period of at least 8 hours.
In 2020, there were 56 days of leaf wetness not due to rainfall for at least 8 hours.

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