

Proceedings from the 12th Annual Nutrient Management Conference



12th Annual



**NUTRIENT
MANAGEMENT
CONFERENCE**

**Tuesday,
February 4,
2020**

**VERIZON
WIRELESS
CENTER
MANKATO**

**12th Annual
NUTRIENT MANAGEMENT CONFERENCE**

Sessions 9:00 a.m.-3:25 p.m.

■ **GENERAL SESSION**

8:30 a.m.	<i>Registration</i>	
9:00 a.m.	<i>Welcome</i> Tom Rothman	University of Minnesota
9:05 a.m.	<i>Lessons Learned in 2019, Opportunities for 2020</i> Liz Stahl Brad Carlson	
		University of Minnesota
9:55 a.m.	<i>Importance of Urban and Non-Urban Nutrient Reductions</i> Katrina Kessler	
		Minnesota Pollution Control Agency
10:30 a.m.	<i>Break</i>	
10:45 a.m.	<i>Farmers Working To Reduce Nutrient Losses</i> Brian Ryberg, Brian Biegler, Dan Coffman	
11:45	<i>Lunch</i>	

■ **BREAKOUT SESSION #1 - NUTRIENT REDUCTION STRATEGY TRACK**

12:45 p.m.	<i>Minnesota's Nutrient Reduction Strategy- Progress Toward Milestone Goals</i> Glenn Skuta	
		Minnesota Pollution Control Agency
1:25 p.m.	<i>Urban Efforts to Reduce Nutrient Pollution</i> Katrina Kessler	
		Minnesota Pollution Control Agency
2:05 p.m.	<i>Potential for Cover Crops to Improve Nutrient Use Efficiency</i> Axel Garcia y Garcia	
		University of Minnesota
2:45 p.m.	<i>Tile Drainage, Cover Crops and Nitrogen Interactions</i> Jeffrey Vetsch	
		University of Minnesota

■ **BREAKOUT SESSION #2 RESEARCH TRACK**

12:45 p.m.	<i>Looking at Soil Health Tests</i> Anna Cates, Liz Stahl	
		University of Minnesota
1:25 p.m.	<i>Evaluating Biologicals</i> Dan Kaiser	
		University of Minnesota
2:05 p.m.	<i>Updating MN's P Index</i> Lindsay Pease	
		University of Minnesota
2:45 p.m.	<i>Liquid Swine Manure - A Viable Nutrient Source for Sidedressing Corn?</i> Melissa Wilson	
		University of Minnesota
3:25 p.m.	<i>Adjourn</i>	

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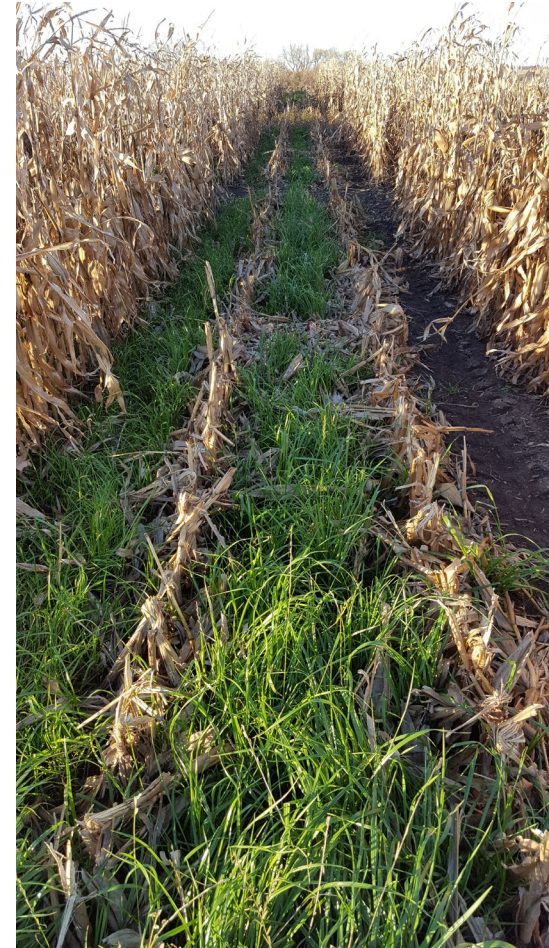
Potential for Cover Crops to Improve Nutrients Use Efficiency

Axel Garcia y Garcia

*Department of Agronomy and Plant Genetics
Southwest Research and Outreach Center | Lamberton, MN*

OUTLINE

- I. What is Nutrient Use Efficiency (NUE)
- II. Factors that Affect NUE
- III. Cover Crops & NUE
- IV. Cover Crops in MN
- V. How Cover Crops Could improve NUE
- VI. Research: Cover Crops and NUE
- VII. Nutrient Use Efficiency (NUE) in Corn Following Cover Crops
- VIII. Final Remarks



Nutrient Use Efficiency (NUE)

Nutrient use efficiency (NUE) is a measure of **how well plants use the available mineral nutrients**. It can be defined as **yield (biomass) per unit input (nutrient content)** (Hawkesford et al., 2014)

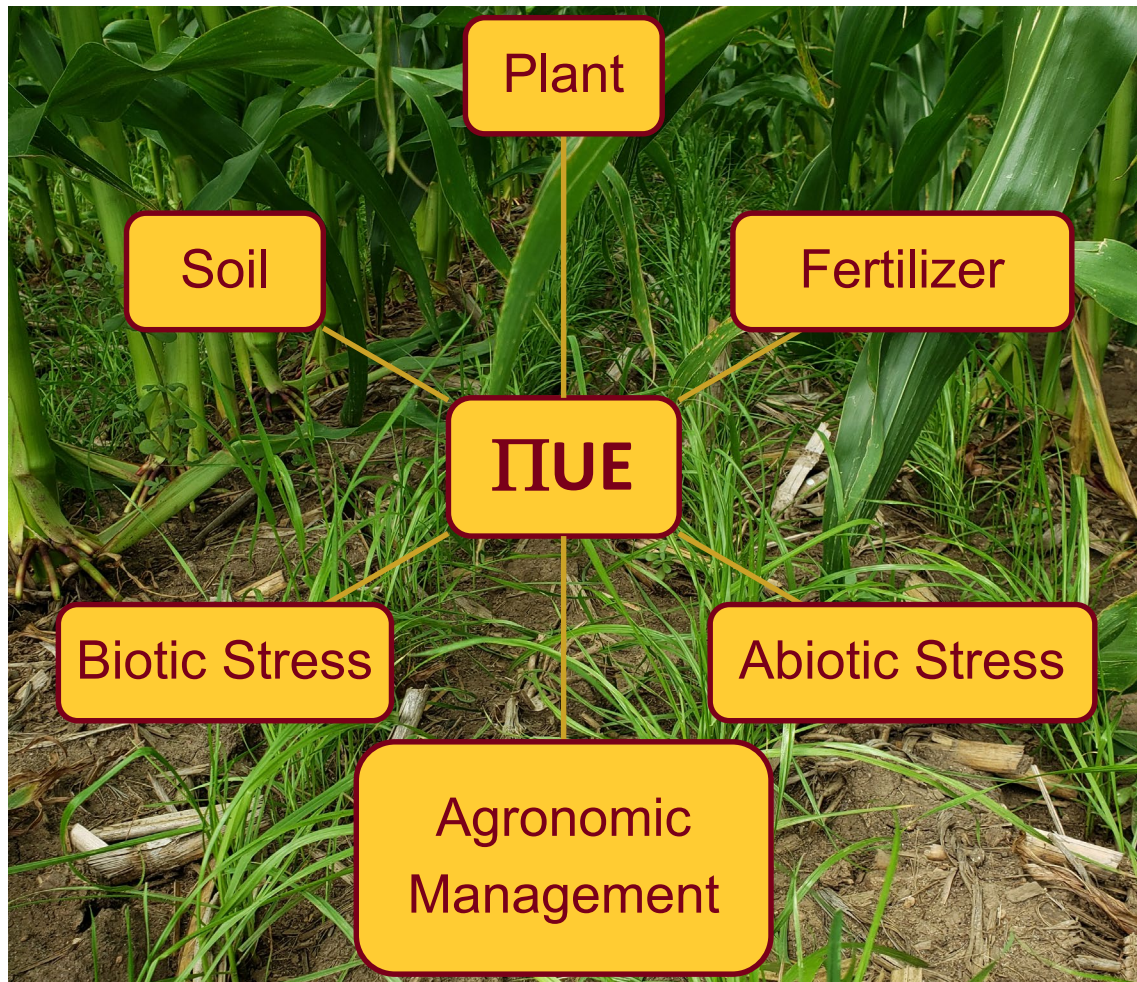
Four yellow sticky notes are shown, each containing a formula for a different type of Nutrient Use Efficiency (NUE):

- AE (lb/lb)** = $\frac{(Y_{\text{fertilized}} - Y_{\text{unfertilized}})}{\Pi_{\text{quantity}}}$
- APE (lb/lb)** = $\frac{\text{Yield}}{\Pi_{\text{tissue}}}$
- PER (lb/lb)** = $\frac{(GY_{\text{fertilized}} - GY_{\text{unfertilized}})}{(\Pi_{\text{up_fertilized}} - \Pi_{\text{up_unfertilized}})}$
- ARE (%)** = $\frac{(\Pi_{\text{up_fertilized}} - \Pi_{\text{up_unfertilized}})}{(\Pi_{\text{up_fertilized}} - \Pi_{\text{up_unfertilized}})}$

Baligar et al., 2001; Baligar and Fageria, 2015



Factors that Affect NUE



Adapted from: Baligar and Fageria, 2015

COVER CROPS AT WORK

Keeping the soil in place & increasing infiltration

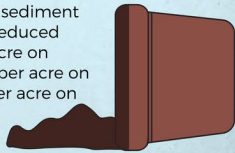


THE TOOLKIT

Cover crops are tools to keep the soil in place, improve soil health, and reduce nutrient pollution from farm fields. The cover crop toolkit includes grasses, brassicas, legumes, and other broadleaf species.

SOIL LOSS

Cover crops decrease, and in some cases, completely eliminate soil and sediment loss. On average, cover crops reduced sediment loss by 21 tons per acre on conventional-till fields, 6 tons per acre on reduced-till fields, and 1 ton per acre on no-till fields.



INFILTRATION

Studies have shown that cover crops can increase water infiltration to the soil profile by two to sixfold. This improves soil water conditions and prevents excess runoff and erosion.

HOW DO THEY DO IT?

Cover crops are able to provide these benefits to the soil because they:

- Cover and protect the soil surface from wind and water erosion
- Root into the soil profile, making channels for water flow
- Improve the soil structure
- Prevent the soil surface from sealing

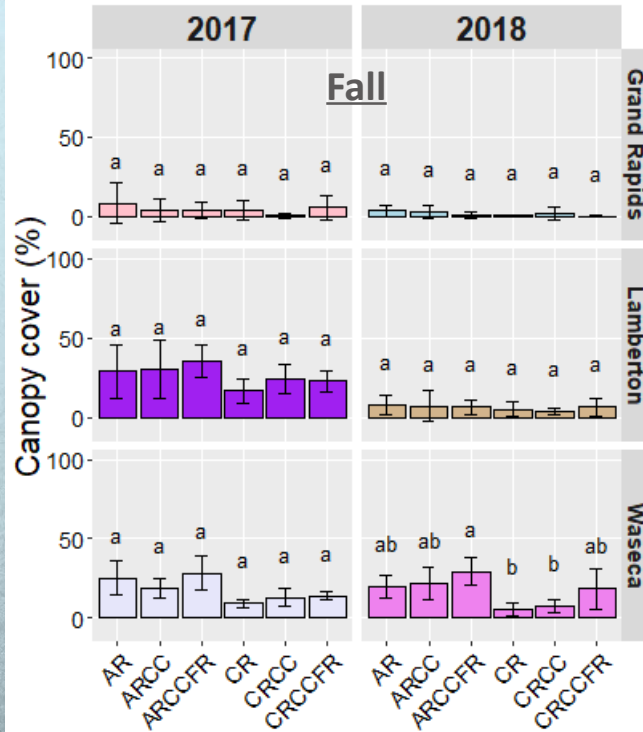


By keeping the soil in place and improving soil conditions, cover crops are mitigating pollution risk while also boosting the productive capacity of the soil.

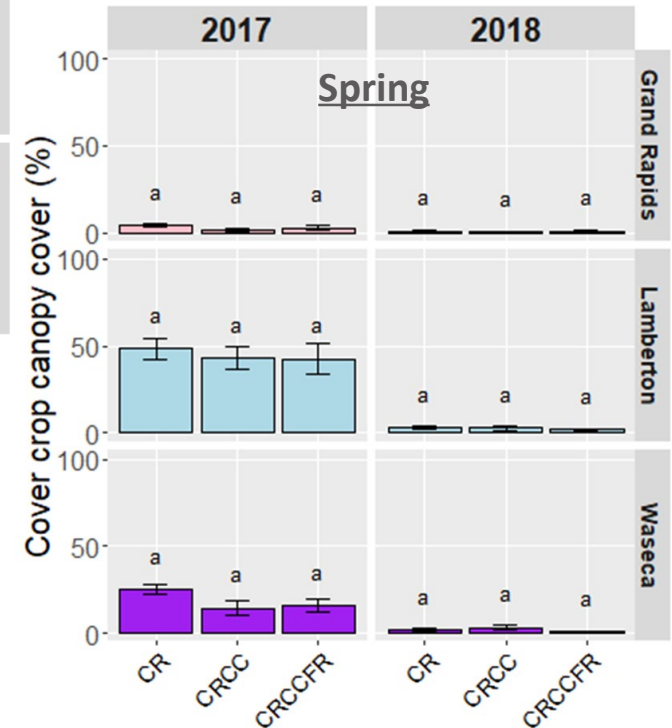
www.sare.org

All data comes from a bibliography compiled by the Sustainable Agriculture Research and Education Program (SARE) and the University of Minnesota. This graphic was developed under Cooperative Agreement No. 0399501 awarded by the U.S. Environmental Protection Agency. EPA made comments and suggestions on the document intended to improve the scientific analysis and technical accuracy of the document. The views expressed in this document are those of the authors and EPA does not endorse any products or commercial services mentioned in this publication.

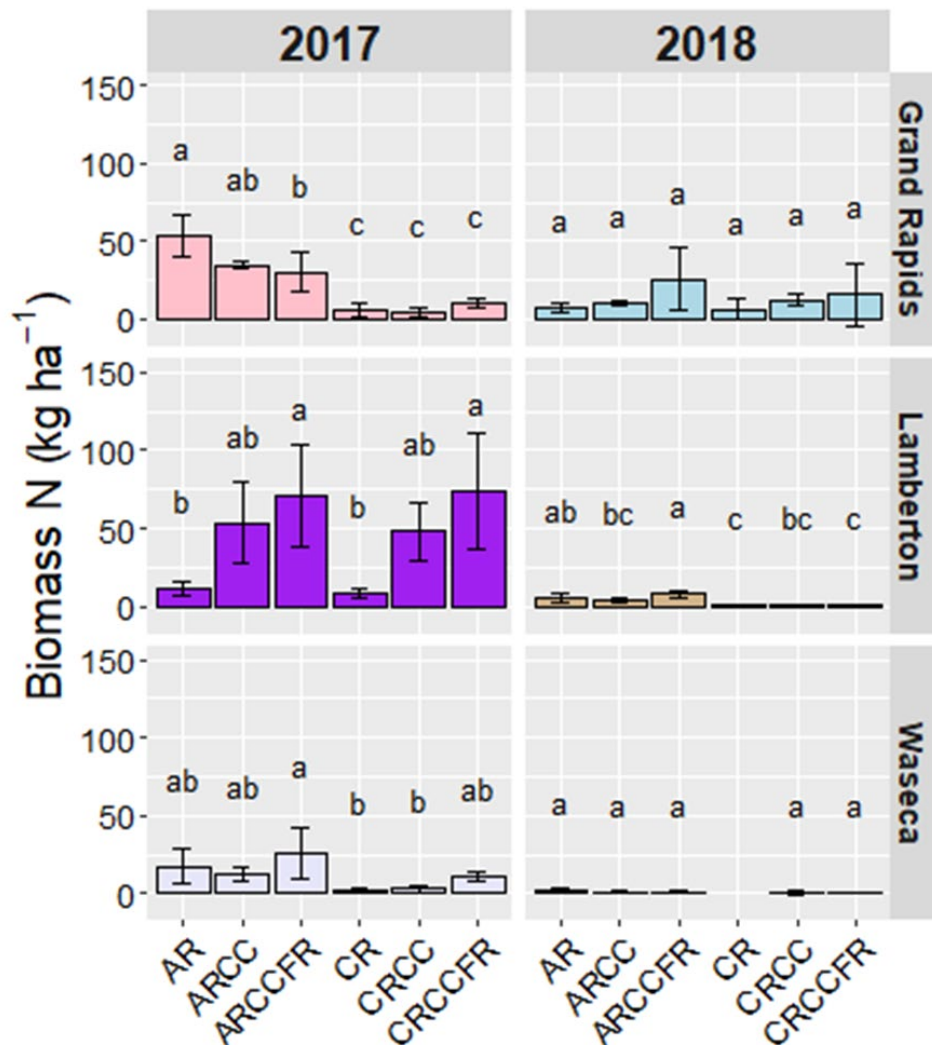
Cover Crops and NUE... erosion & infiltration



AR = annual ryegrass
CC = crimson clover
FR = forage radish
CR = cereal rye



Cover Crops and NUE... nutrients



COVER CROPS AT WORK

Improving water quality through nutrient loss reductions

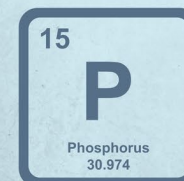
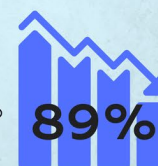


THE TOOLKIT

Cover crops are tools to keep the soil in place, improve soil health, and reduce nutrient pollution from farm fields. The cover crop toolkit includes grasses, brassicas, legumes, and other broadleaf species.

NITROGEN

Nitrogen is an important nutrient for plant growth but can become a pollutant when displaced to waterways. Cover crops reduced nitrogen losses from farm fields by up to 89%, with a median figure of 48% across 10 studies.



PHOSPHORUS

Though more research on cover crop impacts on phosphorus is needed, some studies demonstrated that cover crops reduced phosphorus losses by 15 to 92%.

HOW DO THEY DO IT?

Cover crops are able to reduce nutrient losses to the environment because they:

- Cover and protect the soil surface from runoff and erosion
- Scavenge nitrogen, keeping it within the soil profile and making it less susceptible to leaching
- Reduce the need for fertilizers by supplying nutrients naturally



When faced by problems such as eutrophication and hypoxia in our waterways, we can turn to cover crops as tools to mitigate pollution.

www.sare.org

All data comes from a bibliography compiled by the Sustainable Agriculture Research and Education Program (SARE) and the University of Missouri. This graphic was developed under Cooperative Agreement No. 83695601 awarded by the U.S. Environmental Protection Agency. EPA made comments and suggestions on the document intended to improve the scientific analysis and technical accuracy of the document. The views expressed in this document are those of the authors and EPA does not endorse any products or commercial services mentioned in this publication.

COVER CROPS AT WORK

Increasing soil organic matter



THE TOOLKIT

Cover crops are tools to keep the soil in place, improve soil health, and reduce nutrient pollution from farm fields. The cover crop toolkit includes grasses, brassicas, legumes, and other broadleaf species.

SOIL ORGANIC MATTER

Soil organic matter is decomposed organic material (leaves, roots, microorganisms) that exists in the soil and acts as a reservoir of water and nutrients.



Across several studies, legume cover crops were found to increase levels of soil organic matter by 8 to 114%, and non-legume cover crops were found to increase soil organic matter levels by 4 to 62%.



WATER QUALITY BENEFITS

- Soil organic matter enhances soil processes and properties, and alleviates soil compaction.
- Organic matter also increases water retention capacity and can absorb and filter pollutants in runoff and groundwater.



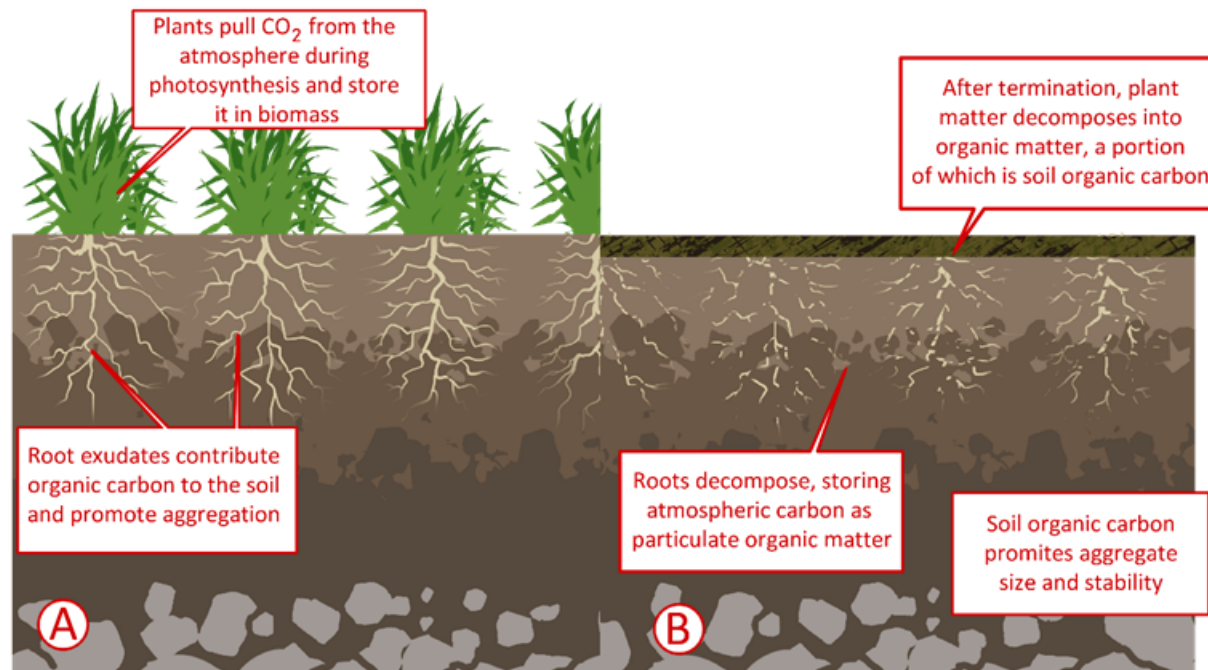
By increasing soil organic matter, cover crops contribute to enhanced water quality and improved soil water and nutrient conditions.

www.sare.org

All data comes from a bibliography compiled by the Sustainable Agriculture Research and Education Program (SARE) and the University of Missouri. This graphic was developed under Cooperative Agreement No.83695601 awarded by the U.S. Environmental Protection Agency. EPA made comments and suggestions on the document intended to improve the scientific analysis and technical accuracy of the document. The views expressed in this document are those of the authors and EPA does not endorse any products or commercial services mentioned in this publication.

Cover Crops and NUE... *organic matter*

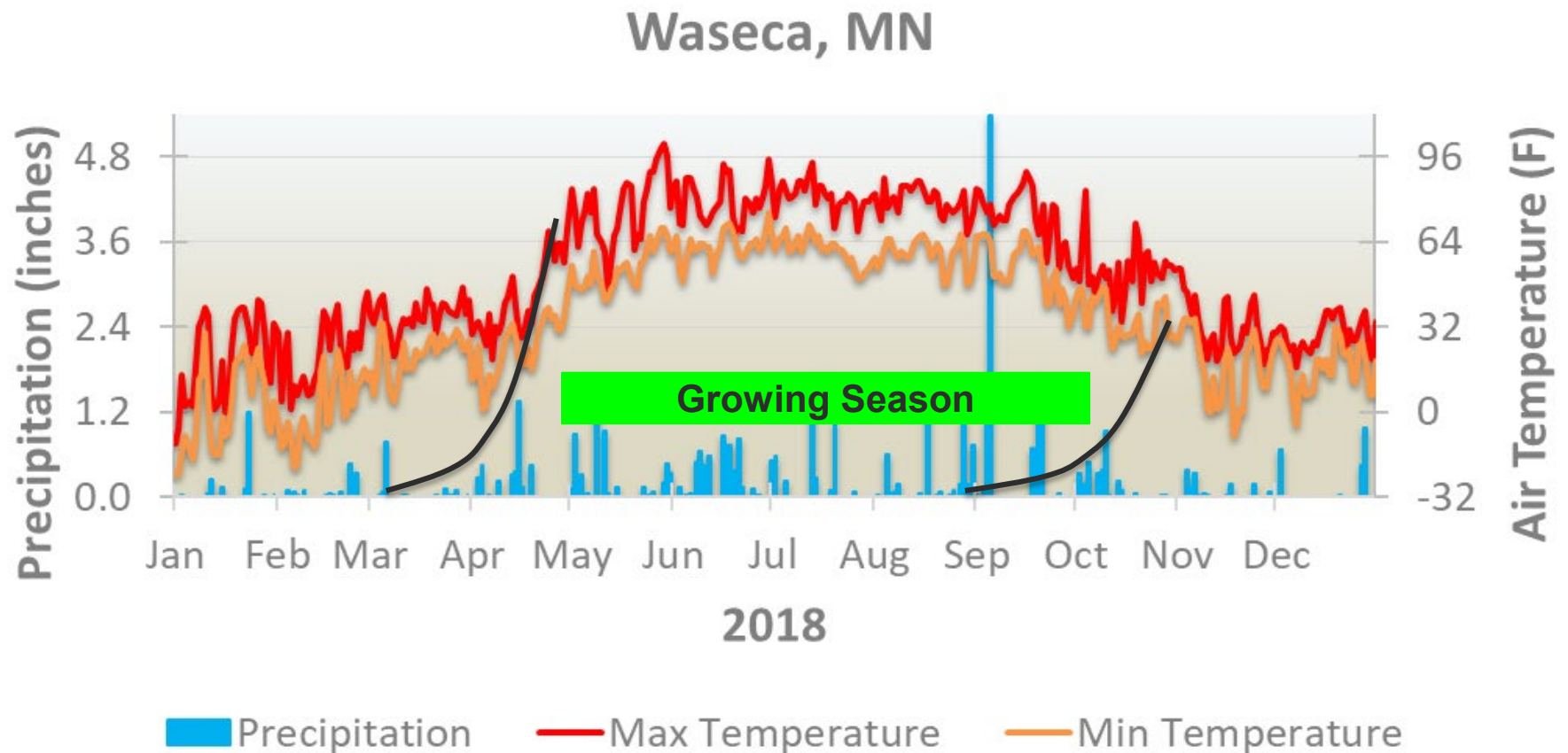
How plants sequester carbon A) before and B) after termination



Source: University of Nebraska - Lincoln

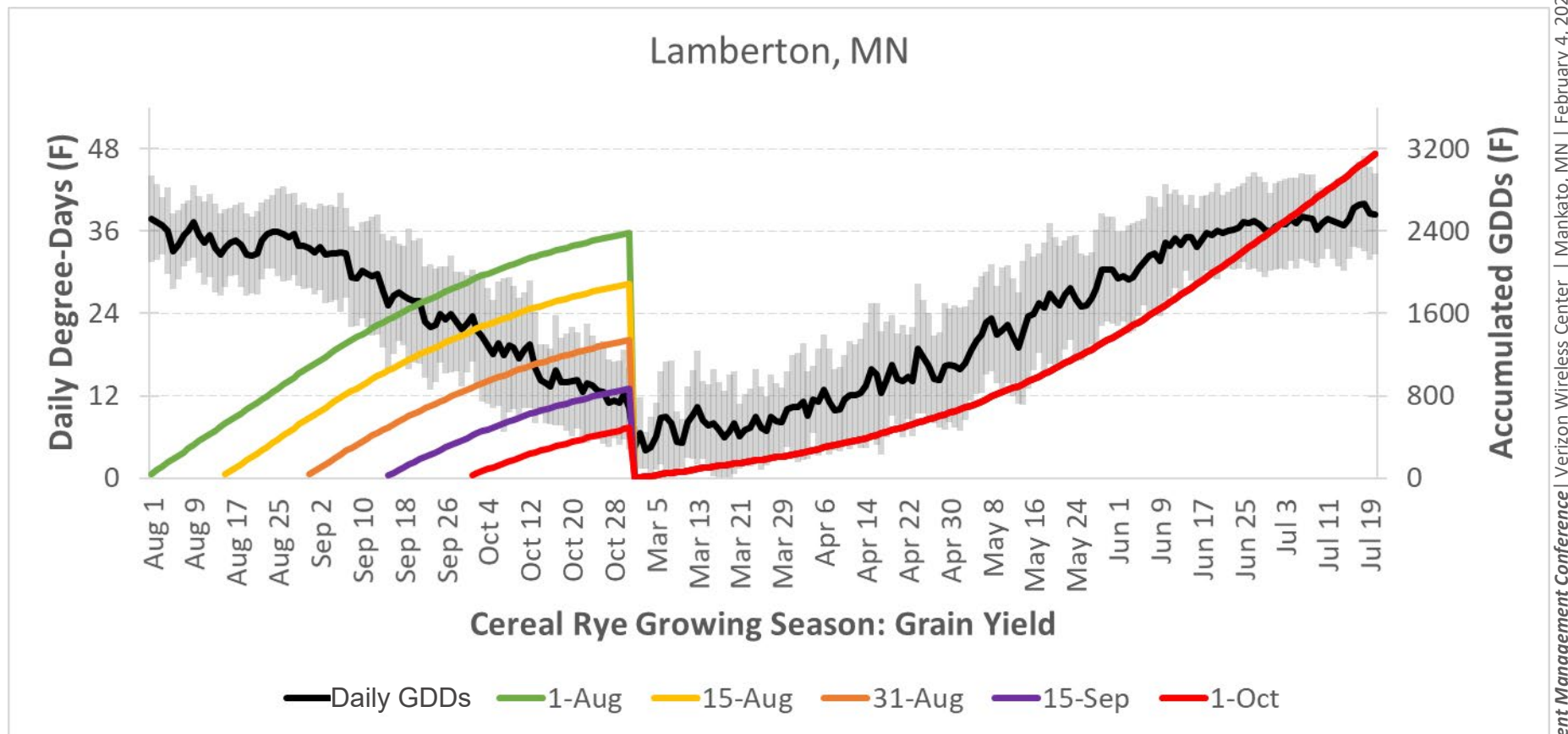
Cover Crops in Minnesota...

growing season

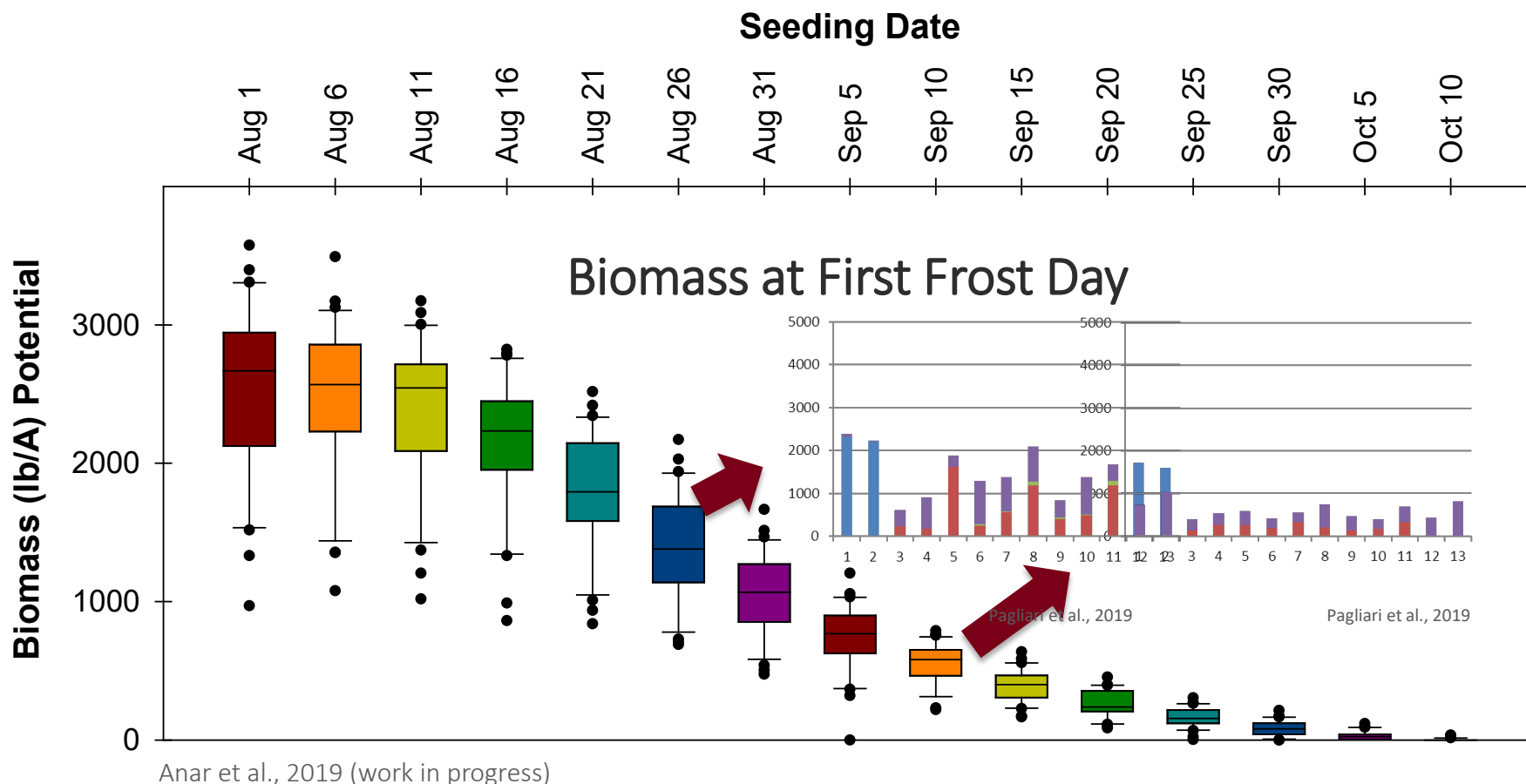


Cover Crops Use in MN...

heat units for winter rye



Cover Crops Use in MN... *winter rye* *seeding date x fall biomass*



In the spring, at termination (end April beginning May), biomass as high as 2,500 lb/A

How Cover Crops Could Improve NUE

Background on Nutrient Use

- Given to crops from fertilizers (synthetic sources) and organic amendments, and by ***building soil health*** to maintain nutrients in the soil for plants to use
- Most of ***nutrients applied aren't immediately taken up by crops***
- Excess nutrients stay in the soil, are emitted as gases, leach into groundwater, or run-off into surface waters
- Our objective: to improve NUE (***amount of crop yield you get out of the amount of fertilizer you put in***) while minimizing nutrient loss

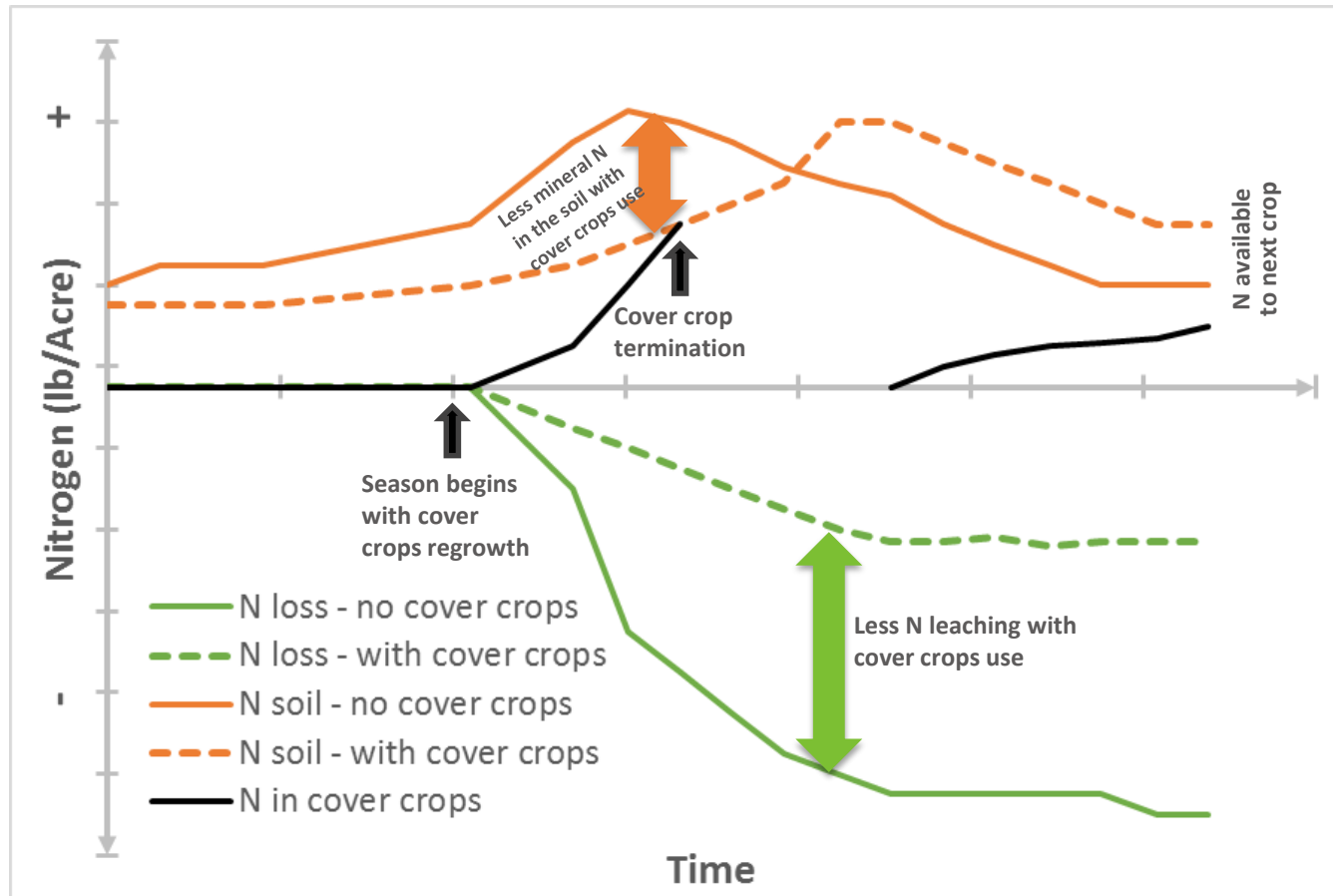
Adapted from asi.ucdavis.edu



Management Strategies to Improve NUE

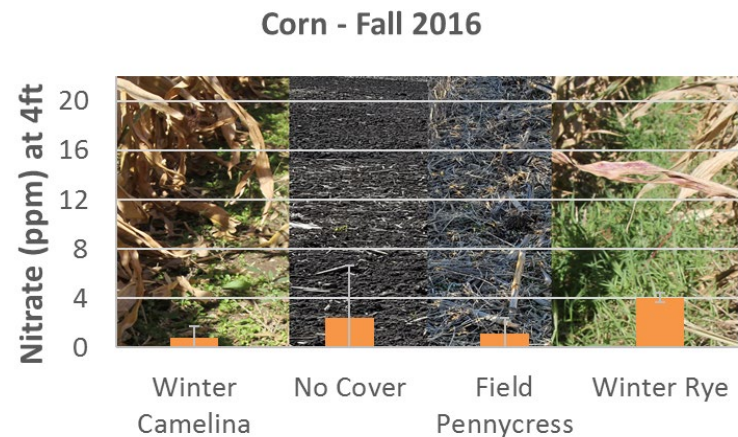
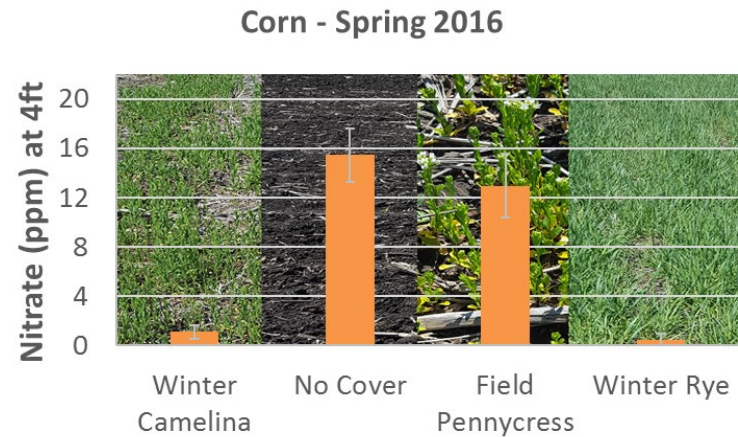
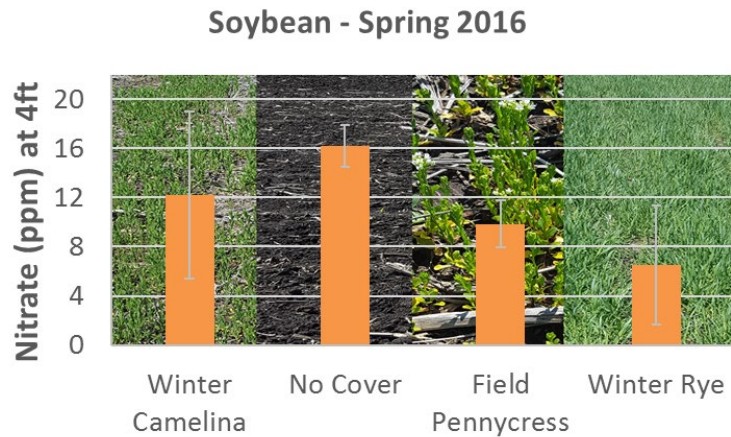
- Smart use of fertilizers (e.g.: 4Rs)
- Sufficient water
- Control of pests, diseases, weeds...
- ***Nutrients cycling*** through the use of ***cover crops***

How Cover Crops Could Improve NUE



How Cover Crops Could Improve NUE

Nitrate levels in leachate from ceramic cups placed at 4 ft. soil depth. SWROC – Lamberton, MN



Research on Cover Crops and NUE...

what and where?

Lamberton (MDA-MSR&PC)

Winter Rye

Camelina

Pennycress

Summer Cover Crops (summer-seeded)

Grand Rapids, Lamberton, and Waseca (MCR&PC and MDA-CWF)

AR CR

AR+CC CR+CC

AR+CC+FR CR+CC+FR

Lamberton and Waseca (MCR&PC)

- Conventional-till
 - Strip-till (spring)
 - No-till
- } AR, [AR+CC], [AR+CC+FR]

Lamberton and Morris (NSF-INFEWS)

Camelina in corn-soybean rotations

All locations

- ✓ Corn and soybean RR, optimum planting date (except sequence cropping)
- ✓ Cover crops interseeded into standing major crops:
 - ✓ Corn at either V4-V6 or R5-R6 (early- or late-seeded)
 - ✓ Soybean at R7-R8 (fall)
- ✓ Tillage:
 - ✓ Conventional till: spring, disc chisel plow at 10 in depth
 - ✓ Strip till: spring, 10" strips, disc at 6 in depth
- ✓ Fertilization: according to UMN guidelines
- ✓ Weed control

Data collected to understand

- Agronomics
- N Use & Transfer
- N and Water Balance
- Efficiency of Resources Use
- Effect on Yield of Primary Crops
- Environmental Benefits
- Long-term Effects (on soils, etc.)



www.cfans.umn.edu/research/roc-centers



Research: Cover Crops and NUE... *early-interseeded cover crops*

■ Annual rye (*Lolium multiflorum* L.)



Origin: Europe

- Cool season annual grass, grows 3-4' tall
- Roots: extensive, 3 – 4' by end-season
- Temperature: poor growth if drought
- Soils: well-drained preferred
- Seedbed: smooth and firm, soil at 55F for germination

- Biomass: 2 – 4 tones/A
- Potential Total N: 40 – 80 lb/A

Research: Cover Crops and NUE... *early-interseeded cover crops*

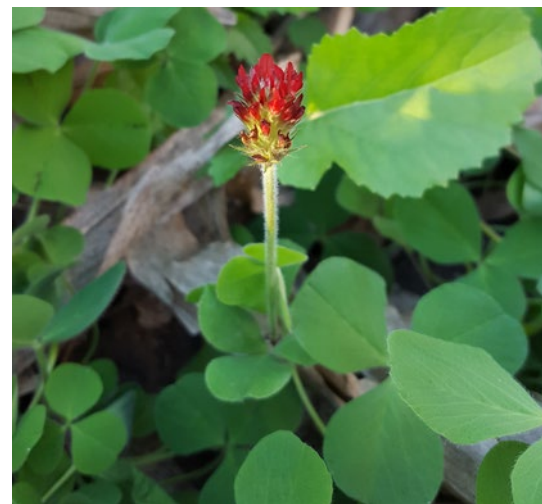
■ Crimson clover (*Trifolium incarnatum* L.)



Origin: Europe

- Biomass: 1.5 – 2.5 tones/A
- Potential Total N: 70 – 150 lb/A

- Annual legume, grows 1-3' tall
- Roots: taproot + fibrous roots, 1 – 2' by end-season
- Temperature: poor growth if drought, low or high,
- Soils: well-drained loamy, preferred
- Seedbed: smooth and firm, soil at 40F for germination



Research: Cover Crops and NUE... *late-interseeded cover crops*

■ Cereal rye (*Secale cereale* L.)



Origin: Southwest Asia

- Biomass: 1.5 – 2.5 tones/A
- Grain, bread, whiskey/vodka, animal fodder: 2000 – 3000 lb/A
- Total N: 30 – 70 lb/A in spring

- Cool season annual cereal grain, grows 3 to 7' tall
- Roots: extensive
- Temperature: over-winters, drought tolerant
- Soils: well-drained loamy/sandy; tolerates water-logging
- Seedbed: firm, soil at 34+F for germination



Research: Cover Crops and NUE... *late-interseeded cover crops*

- Camelina (*Camelina sativa* L.) & Pennycress (*Thlaspi arvense* L.)



Origin: Mediterranean Europe

- Biomass: 1.5 – 2.0 tones/A
- Grain yield: 500 – 1500 lb/A
- Total N: 45 – 60 lb/A

- Winter oilseed crops, grow 3 to 4' tall
- Roots: limited
- Temperature: over-winter
- Soils: well-drained loamy; no water-logged
- Seedbed: firm, soil at 40°F for germination



Origin: Eurasia

- Biomass: 0.5 – 1.5 tones/A
- Grain yield: 500 – 1200 lb/A
- Total N: 20 – 60 lb/A

Research: Cover Crops and NUE...

summer-seeded cover crops

■ Teff [*Eragrostis tef* (Zuccagni) Trotter]



Origin: Ethiopia

- Fine-stemmed, annual bunchgrass, grows 2-4' tall
 - Roots: massive, fibrous, shallow
 - Temperature: highly susceptible to frost at all stages
 - Soils: well-drained preferred; poorly drained OK
 - Seedbed: smooth and firm, soil at 65F for germination
-
- Biomass: 3 – 5 tones/A
 - Grain, human consumption: grain Yield: 400 – 1500 lb/A
 - Total N: 50 – 100 lb/A

Research: Cover Crops and NUE...

summer-seeded cover crops

■ Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]



Origin: Central Africa

- Biomass: 5 – 8 tones/A
- Grain, mostly for poultry feed: 2000 – 3000 lb/A
- Total N: 70 – 150 lb/A

- Robust, multi-stemmed annual grass, grows 5 to 8' tall
- Roots: deep rooted (12'; 80% in the top four inches)
- Temperature: frost will kill tops, drought resistant
- Soils: fertile and well-drained; alkaline reduce growth
- Seedbed: firm, soil at 70F for germination

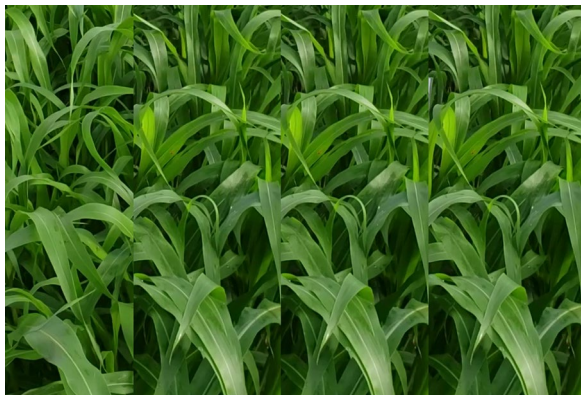


www2.ca.uky.edu

Research: Cover Crops and NUE...

summer-seeded cover crops

■ Sorghum Sudangrass [*Sorghum bicolor* (L.) Moench]



Origin: Northeast Africa

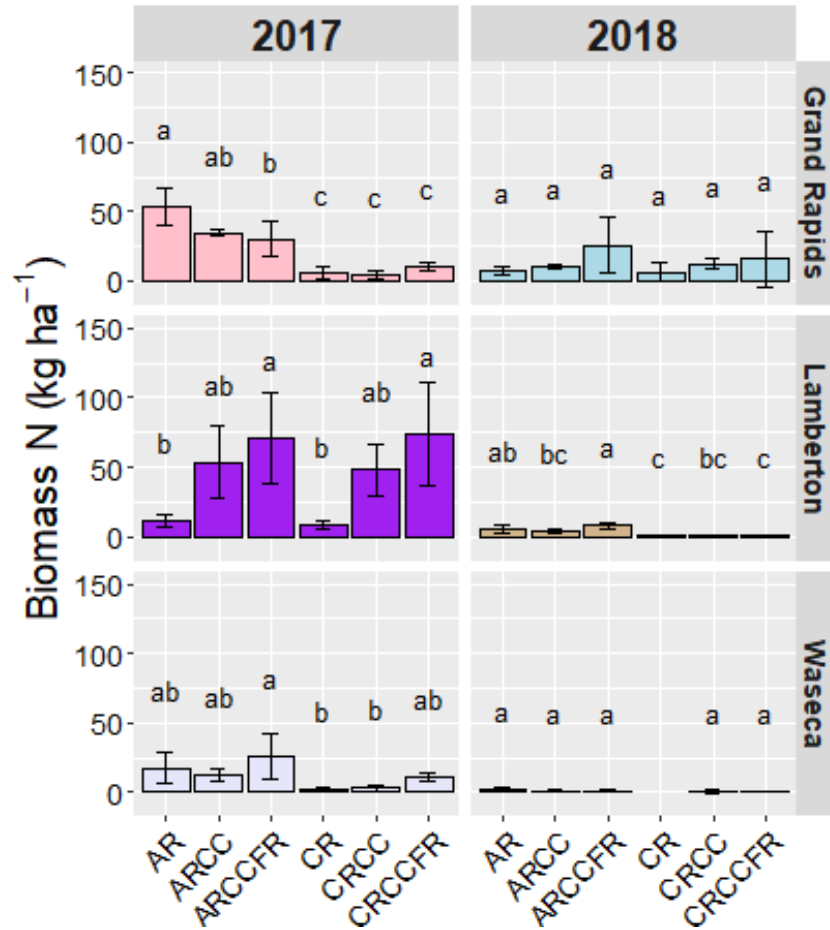
- Biomass: 5 – 8 tones/A
- Grain, mostly for poultry feed: 2000 – 3000 lb/A
- Total N: 70 – 130 lb/A

- Warm season annual grass, grows 3 to 7' tall
- Roots: extensive
- Temperature: very sensitive to frost, drought resistant
- Soils: well-drained loamy; no water-logged
- Seedbed: firm, soil at 65F for germination



<http://ieassa.org>

In Context: N Use of Early-Interseeded Cover Crop Mixes... *fall*



Towards sustainable maize production in the U.S. upper Midwest with interseeded cover crops

Hannah L. Rusch¹, Jeffrey A. Coulter¹, Julie M. Grossman², Gregg A. Johnson^{1,3}, Paul M. Porter¹, Axel Garcia y Garcia^{1,4}
(in review)

In Context: N Use of Late-Interseeded Winter Oilseed Cover Crops... *spring*

Journal Archives of Agronomy and Soil Science > Volume 65, 2019 - Issue 13

103 Views

0 Crossref citations to date

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Articles

Cover crop potential of winter oilseed crops in the Northern U.S. Corn Belt

Ronghao Liu, M. Scott Wells & Axel Garcia y Garcia

Pages 1845-1859 | Received 19 Sep 2018, Accepted 29 Jan 2019, Published online: 11 Feb 2019

Download citation | <https://doi.org/10.1080/03650340.2019.1578960>

Check for updates

Prior crop	Treatment	Aboveground biomass (kg DM ha ⁻¹)	N concentration (%)	N content (kg ha ⁻¹)	C:N
Corn	2016				
	WC	494.0b (20.4)	2.9a (0.5)	14.4b (3.1)	15b (2.2)
	FP	132.3c (24.9)	2.7a (0.3)	3.6c (0.9)	16ab (1.5)
	WR	1363.1a (184.1)	2.3a (0.3)	30.8a (4.3)	19a (1.7)
	2017				
	WC	237.3b (44.3)	4.1a (0.6)	9.8b (2.7)	10b (1.4)
	FP	427.3c (146.7)	2.4b (0.4)	10.0b (2.7)	17a (2.4)
	WR	1246.5a (76.4)	2.8b (0.8)	35.6a (11.5)	14a (4.1)
	Treatment	***	**	**	**
	Year	ns	ns	ns	*
	Treatment × Year	ns	ns	ns	ns
Soybean	2016				
	WC	546.7b (63.7)	4.0a (0.5)	21.7b (4.2)	11b (1.5)
	FP	171.1c (21.8)	3.4a (0.4)	5.8c (1.3)	13b (1.7)
	WR	2181.4a (111.8)	2.6b (0.4)	57.2a (10.6)	17a (2.3)
	2017				
	WC	604.3b (251.6)	3.5a (0.6)	20.7b (8.5)	11b (2.4)
	FP	482.3b (74.1)	2.5b (0.6)	11.8b (2.7)	17a (2.7)
	WR	1570.8a (98.8)	2.7ab (0.6)	42.6a (10.4)	16a (3.2)
	Treatment	**	**	**	**
	Year	ns	ns	ns	ns
	Treatment × Year	ns	ns	ns	ns

ns, *, **, *** indicates not significant and significant at $P = 0.05, 0.01, 0.001$, respectively. WC = winter camelina, FP = field pennycress, WR = winter rye. Values within parentheses indicate standard errors. In a column and within a year, values followed by different letters differ significantly at $P < 0.05$.



In Context: N Use of Late-Interseeded Cover Crop Mixes... *fall & spring*

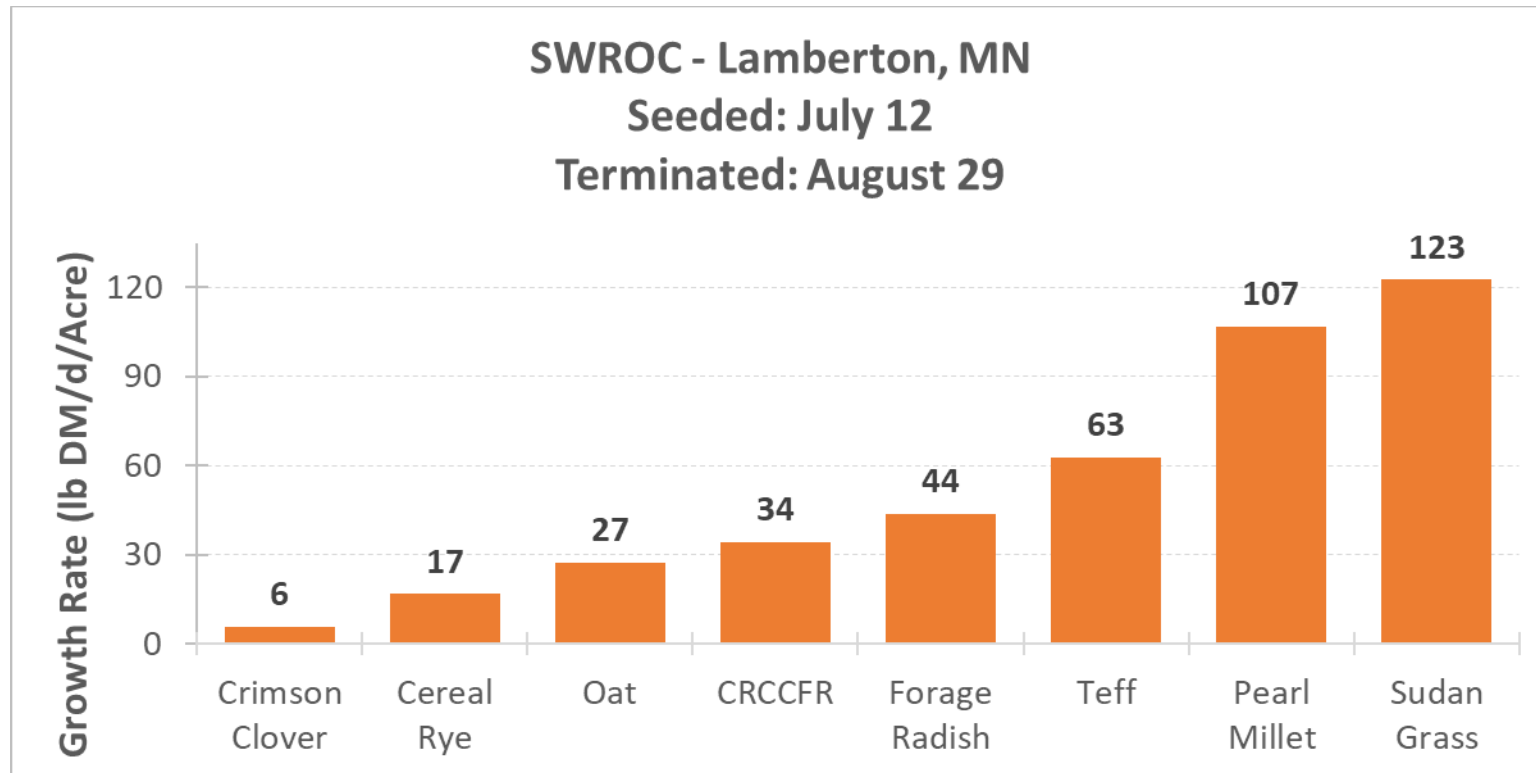
Location	Cover crop	Fall		Spring	
		2017	2018	2017	2018
		lb N acre ⁻¹			
Grand Rapids	All	2.0	0.5	13.0	-
Lamberton	AR	4.0 b			
	ARCC	10.0ab			
	ARCCFR	14.0a	3.0	18.0	0.50
	CR	4.0b			
	CRCC	8.0ab			
	CRCCFR	16.0a			
Waseca	AR		4.0b		
	ARCC	-	5.0b		
	ARCCFR		10.0a	16.0	2.50
	CR		2.5bc		
	CRCC		2.3c		
	CRCCFR		5.0bc		



Towards sustainable maize production in the U.S. upper Midwest with interseeded cover crops

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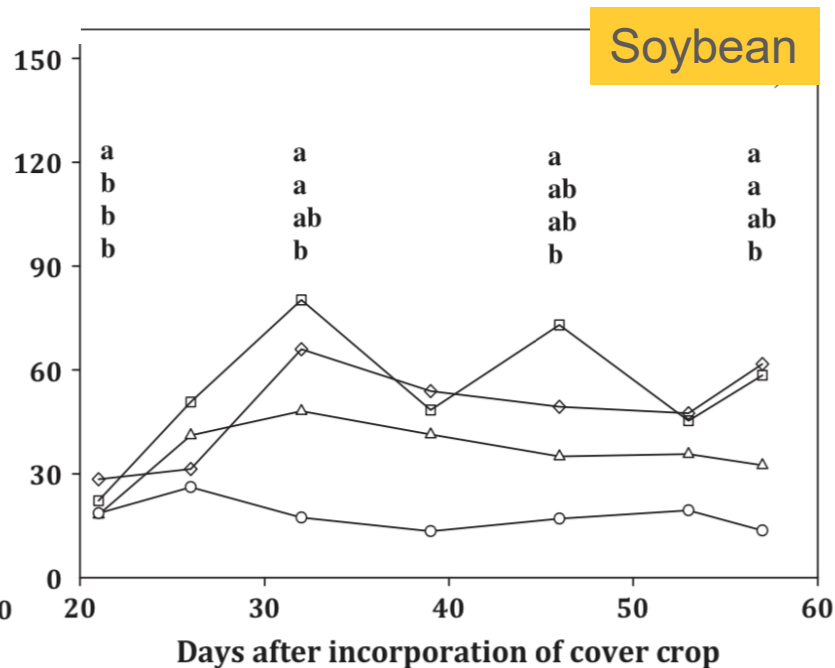
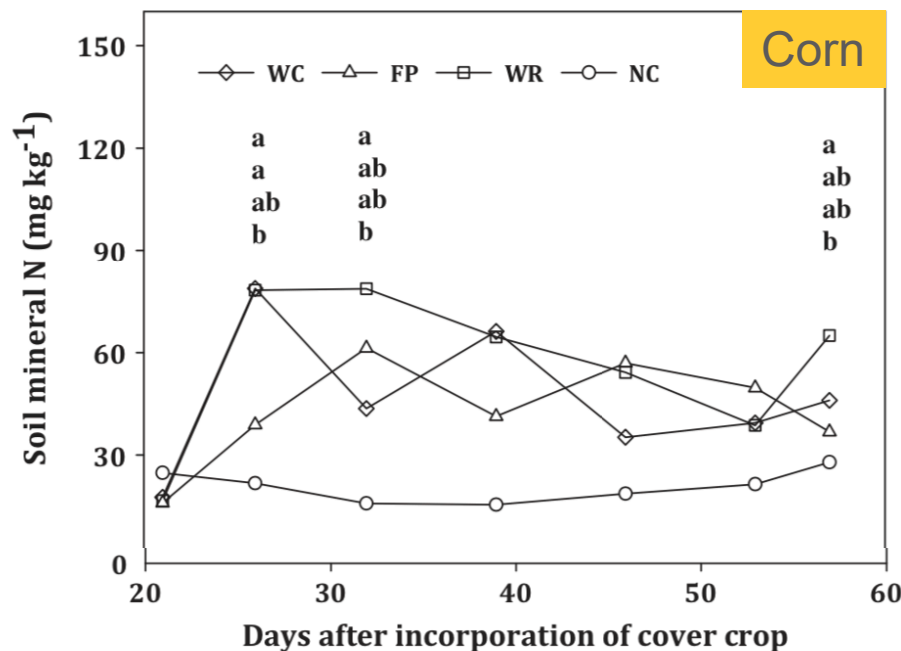
In Context: N Use of Summer-Seeded Cover Crops



Garcia y Garcia, A & Stahl, L. 2019.

Research: Cover Crops and NUE... *when is N from residue released?*

WC = winter camelina, FP = field pennycress, WR = winter rye, NC = no cover crop



Journal
Archives of Agronomy and Soil Science >
Volume 65, 2019 - Issue 13

103
Views

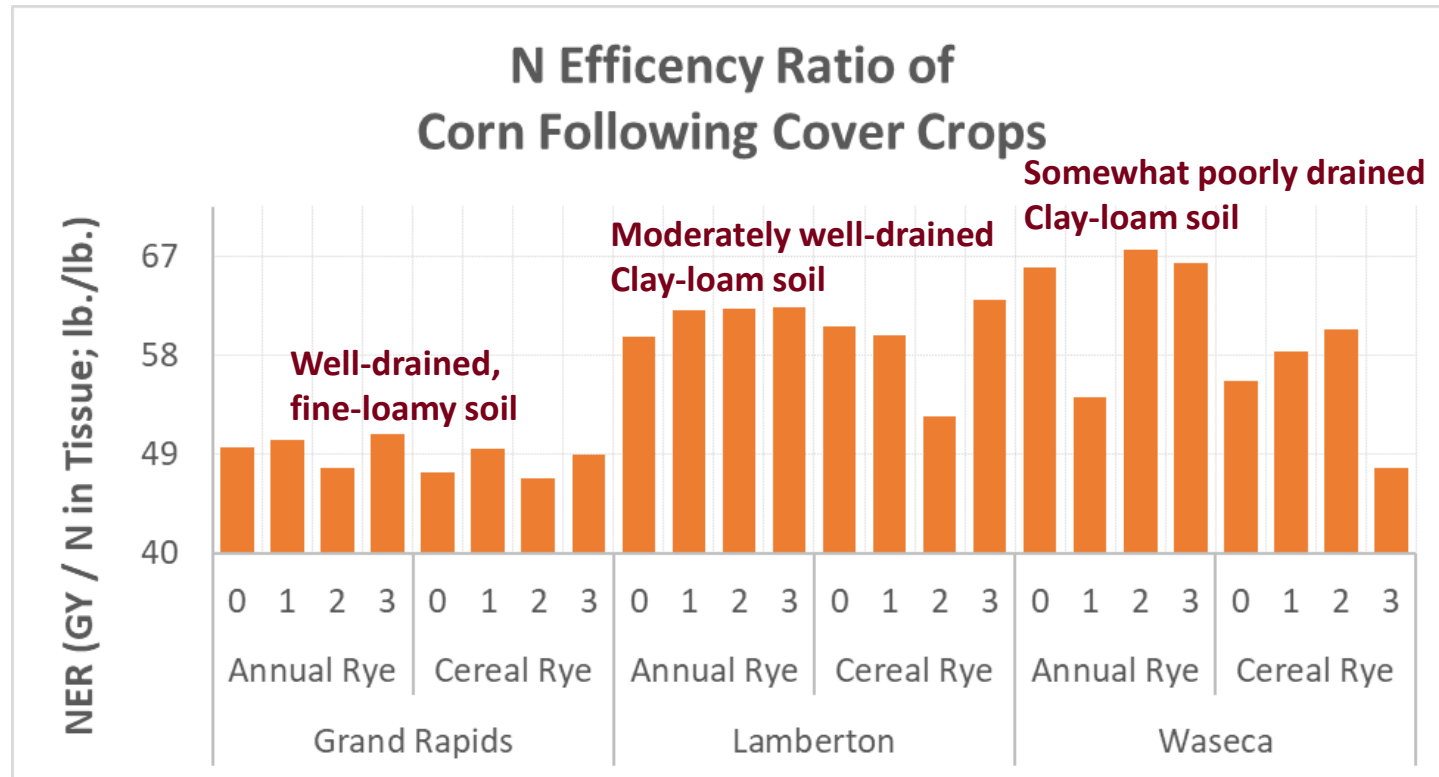
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Articles
Cover crop potential of winter oilseed crops in the Northern U.S. Corn Belt
Ronghao Liu, M. Scott Wells & Axel García y García
Pages 1845-1859 | Received 19 Sep 2018, Accepted 29 Jan 2019, Accepted author version posted online: 06 Feb 2019, Published online: 11 Feb 2019
Download citation | <https://doi.org/10.1080/03650340.2019.1578960> | Check for updates

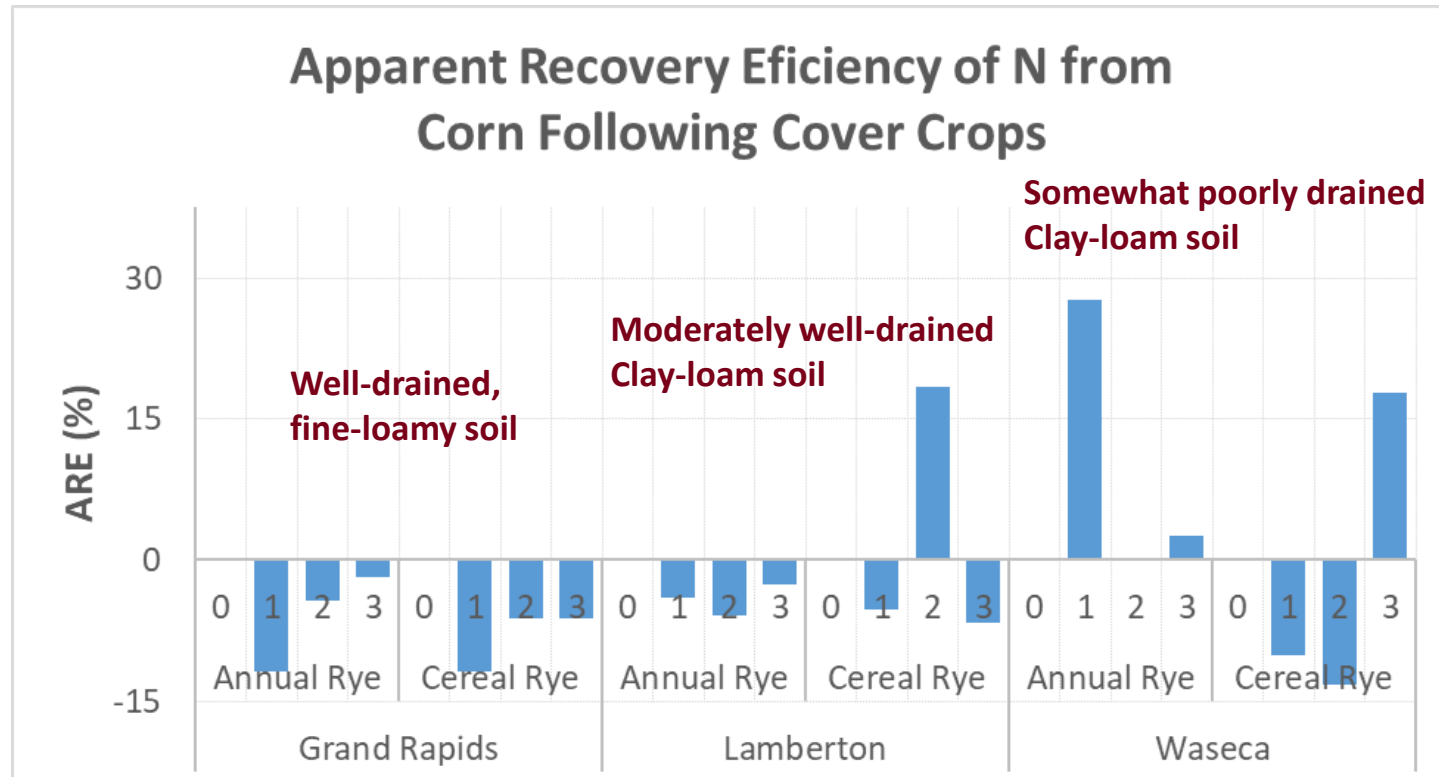
ΠUE of Corn Following Cover Crops

ΠER is na index to differentiate from efficient and inefficient nutrient utilizers



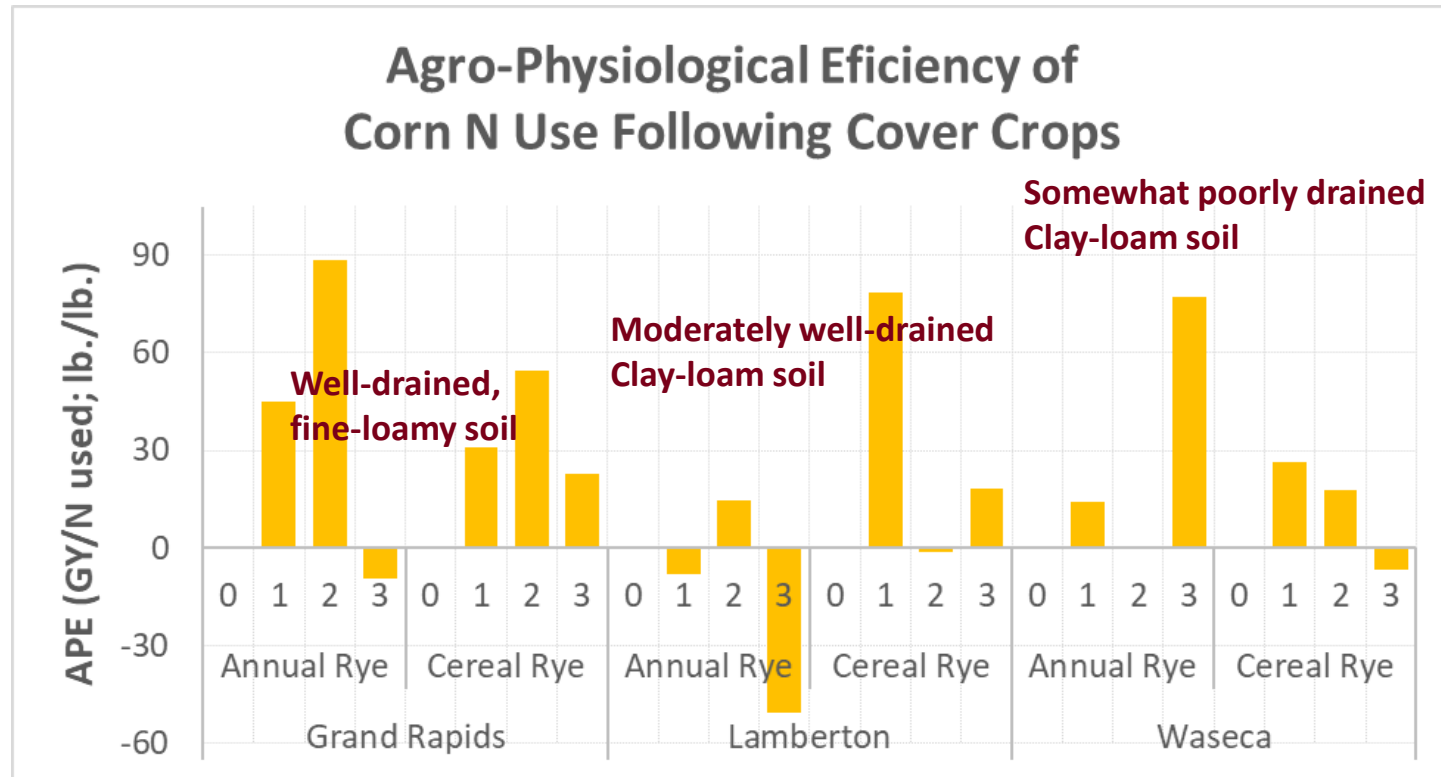
ΠUE of Corn Following Cover Crops

ARE is the plant ability to uptake the applied nutrient from soil



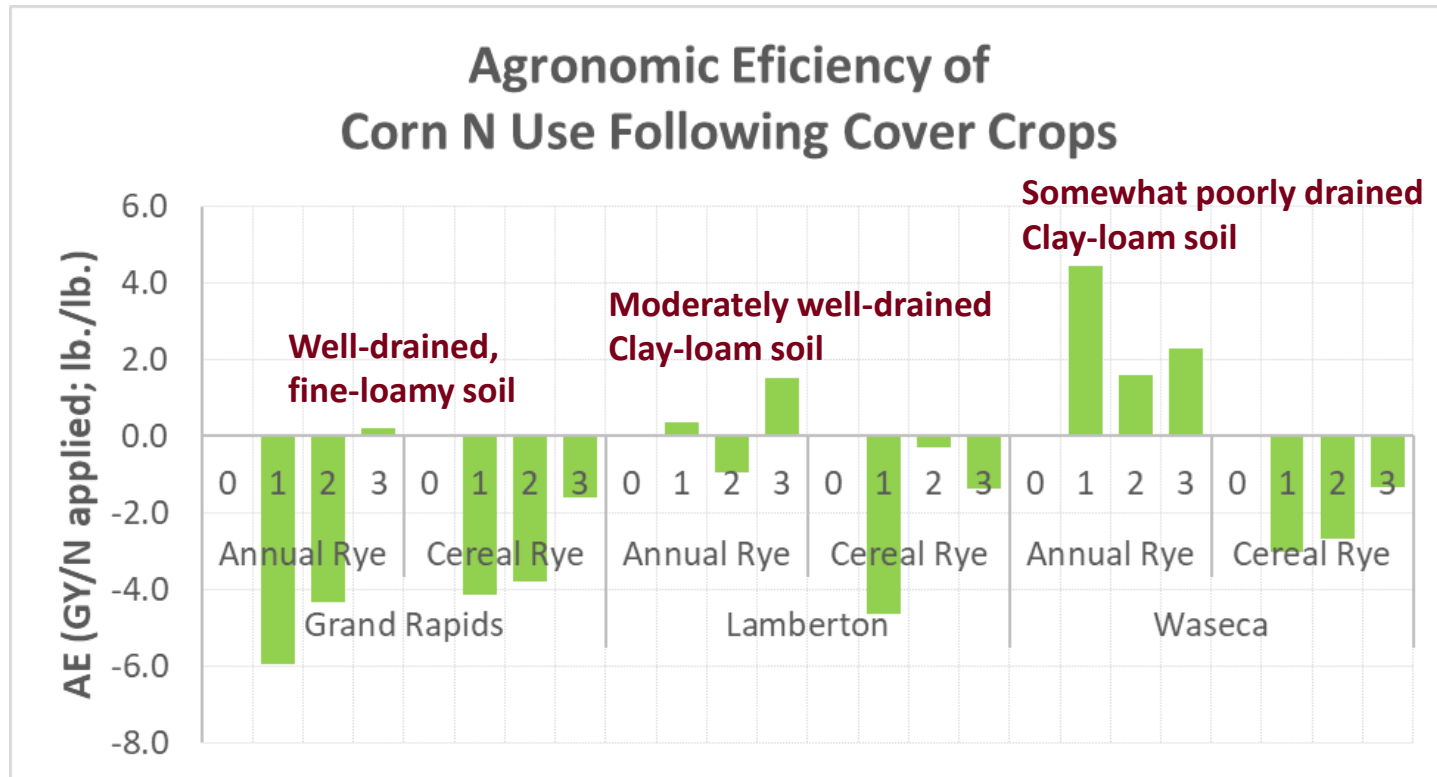
ΠUE of Corn Following Cover Crops

APE is the yield (e.g.: grain) achieved per unit of nutrient absorbed



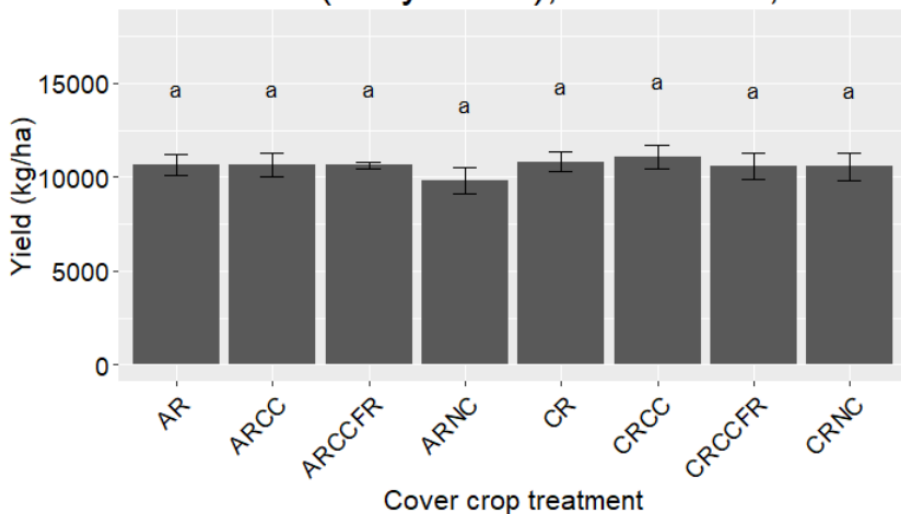
ΠUE of Corn Following Cover Crops

AE is the additional yield produced per unit of nutrient applied

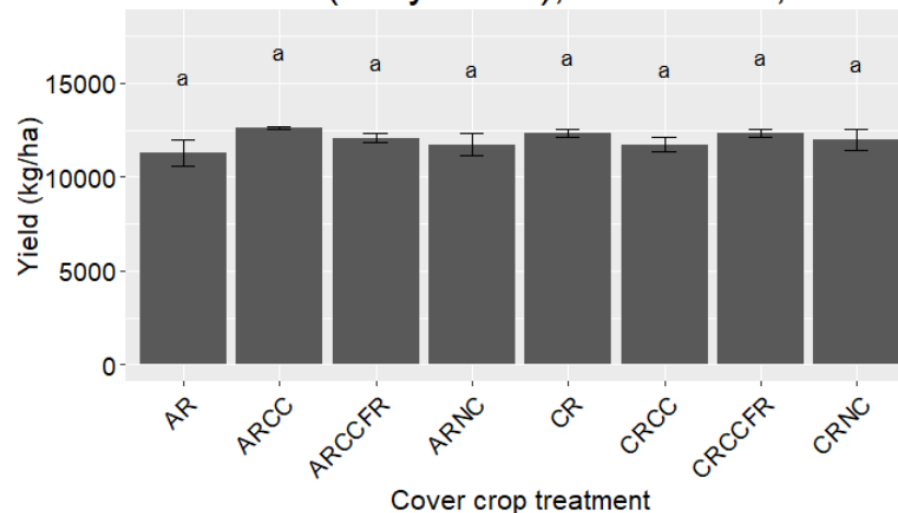


Do Cover Crops Affect Yield of Corn?

2017 corn (early cover), Lamberton, MN

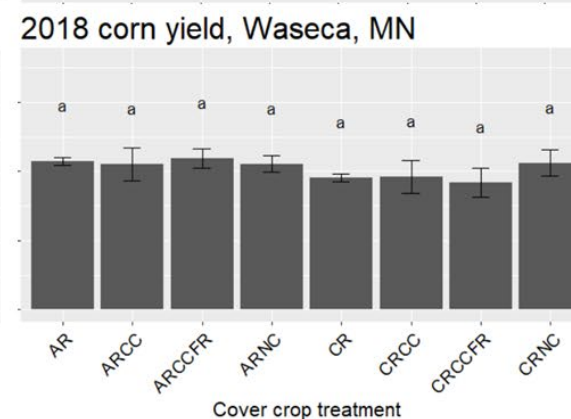
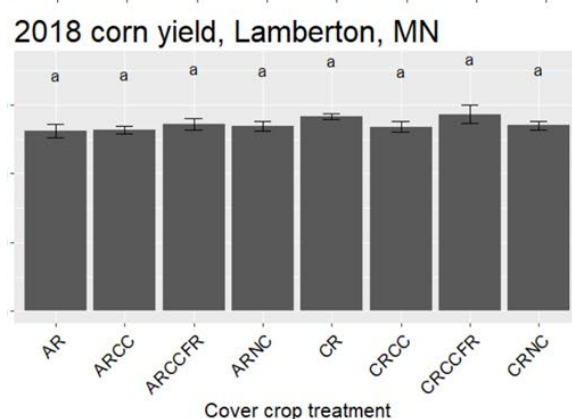
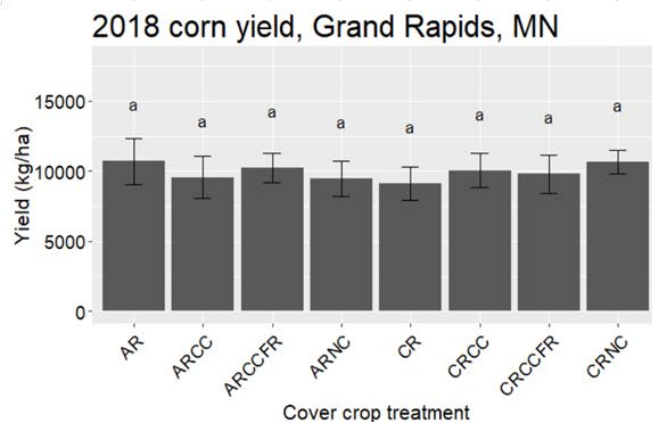
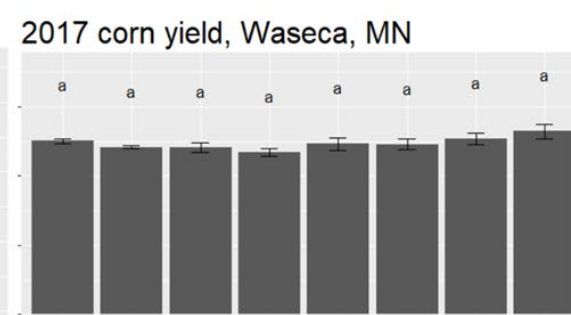
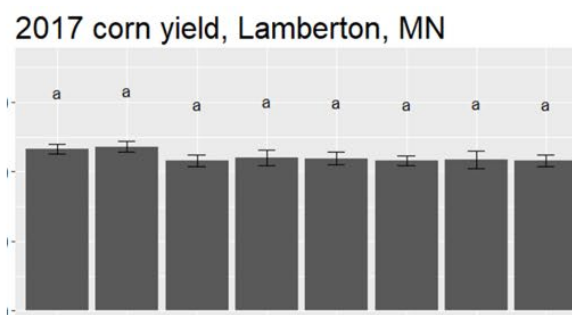
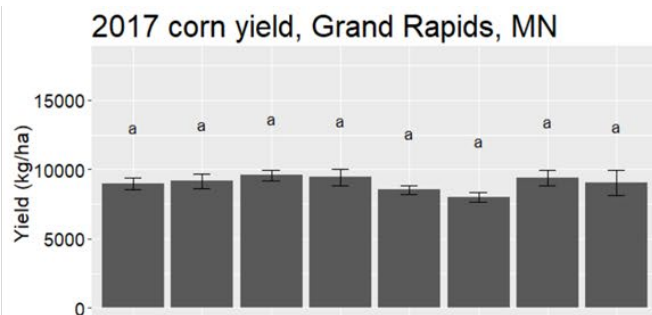


2018 corn (early cover), Lamberton, MN



Rusch, HL. 2019. MS student

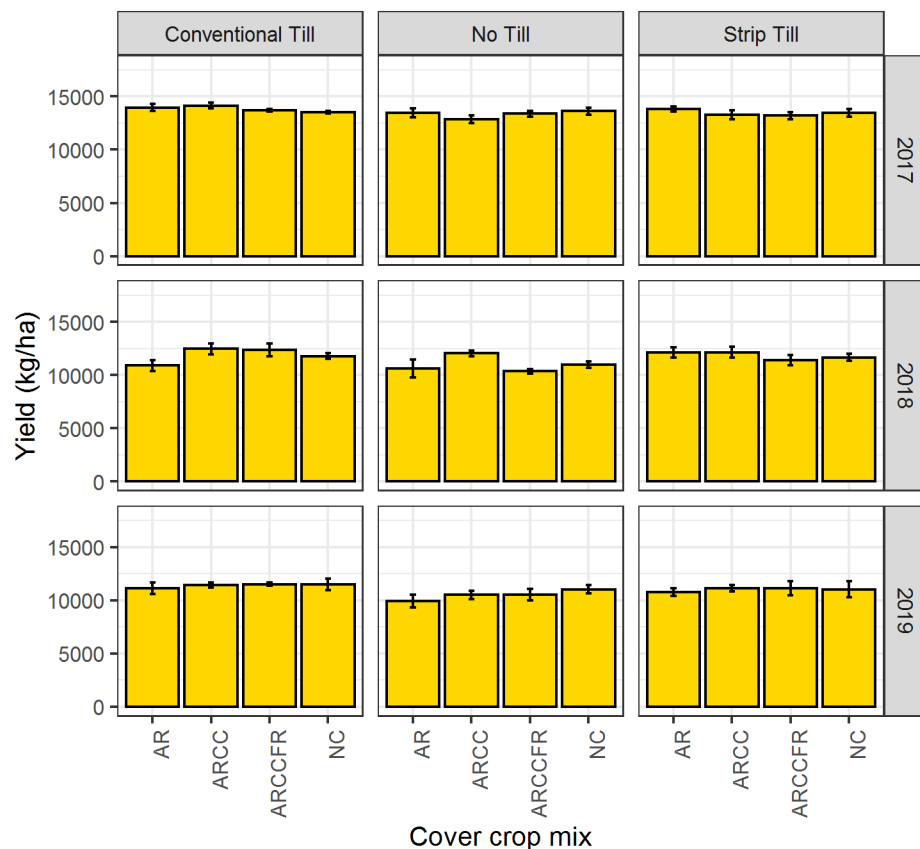
Do Cover Crops Affect Yield of Corn?



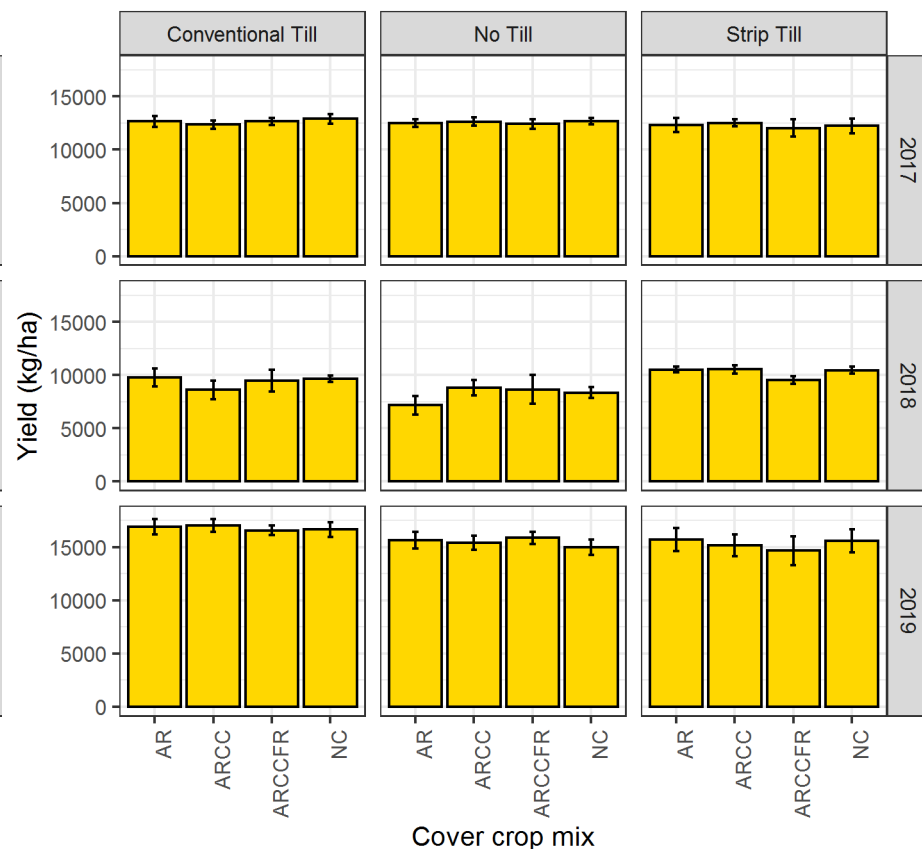
Rusch, HL. 2019. MS student

Do Cover Crops Affect Yield of Corn?

Corn Grain Yield, Lamberton



Corn Grain Yield, Waseca



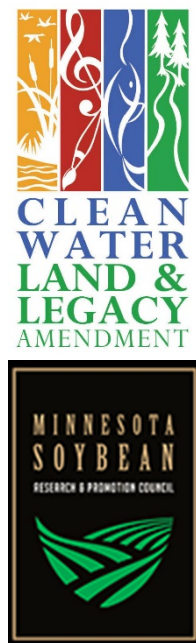
KC, R. 2019. MS student

FINAL

REMARKS

- Improved NUE increases crop yields and reduces production costs and environmental pollution
- In humid and cool climates, the potential of nutrients uptake by cover crops is limited by the small amount of growth
- Even if a short growing window, cover crops reduce $\text{NO}_3\text{-N}$ leaching, immobilize N, and increase N uptake and efficiency
- There is a knowledge-gap on N mineralization rates from cover crop residues that research should address to improve NUE in cropping systems





AXEL'S RESEARCH SUPPORT



Thank you!
axel@umn.edu

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