Potential for Cover Crops to Improve Nutrients Use Efficiency

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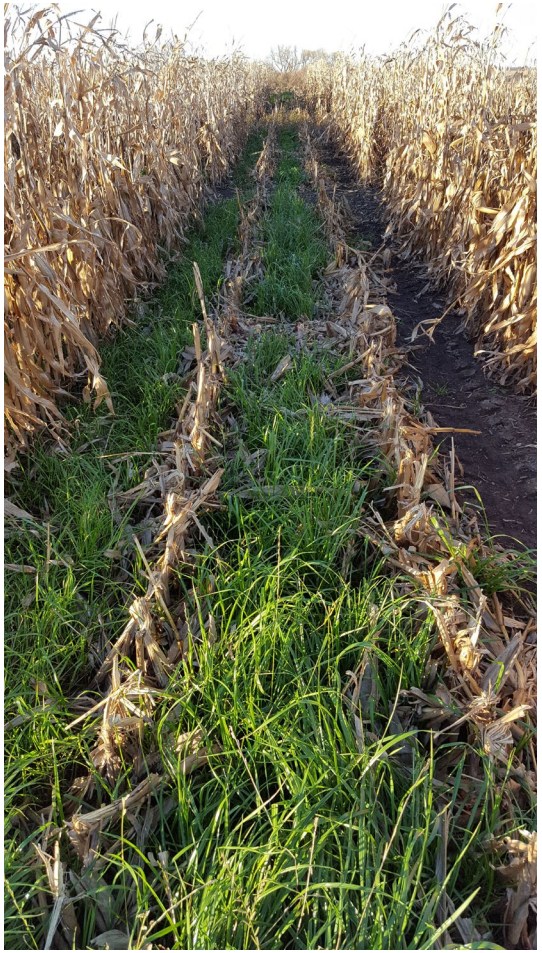
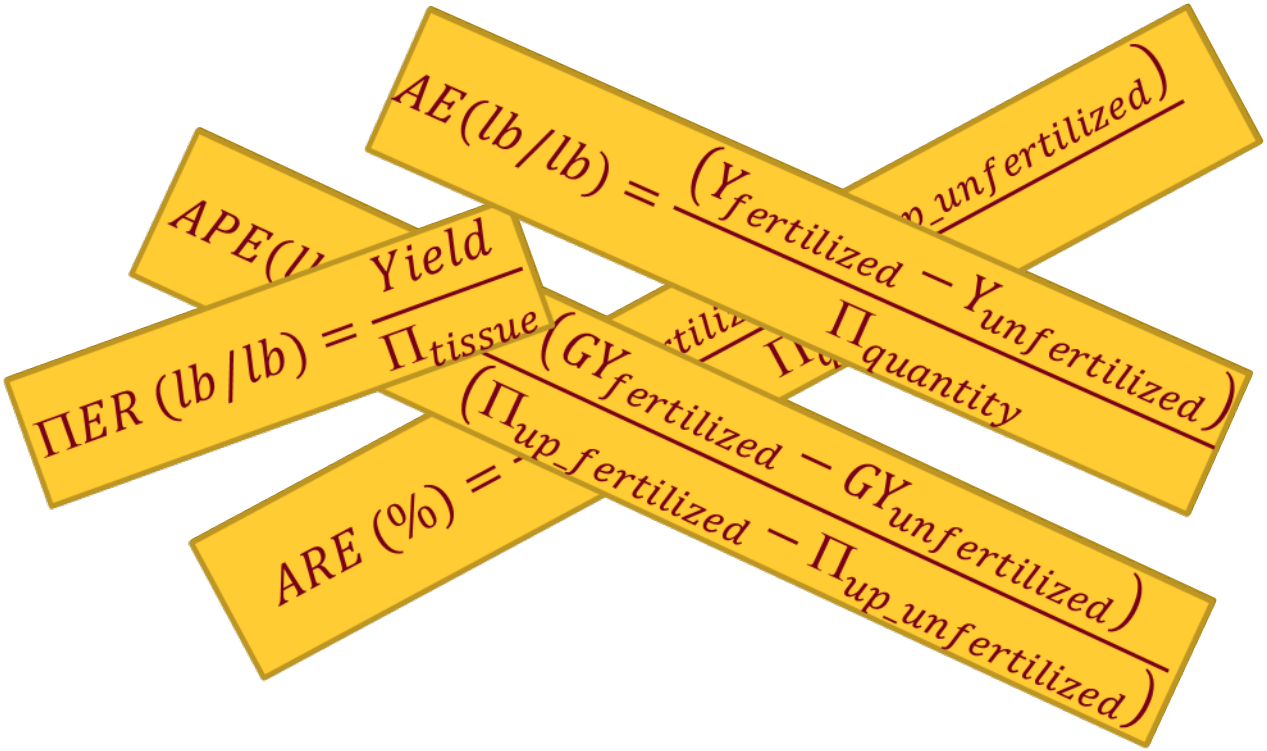
OUTLINE

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



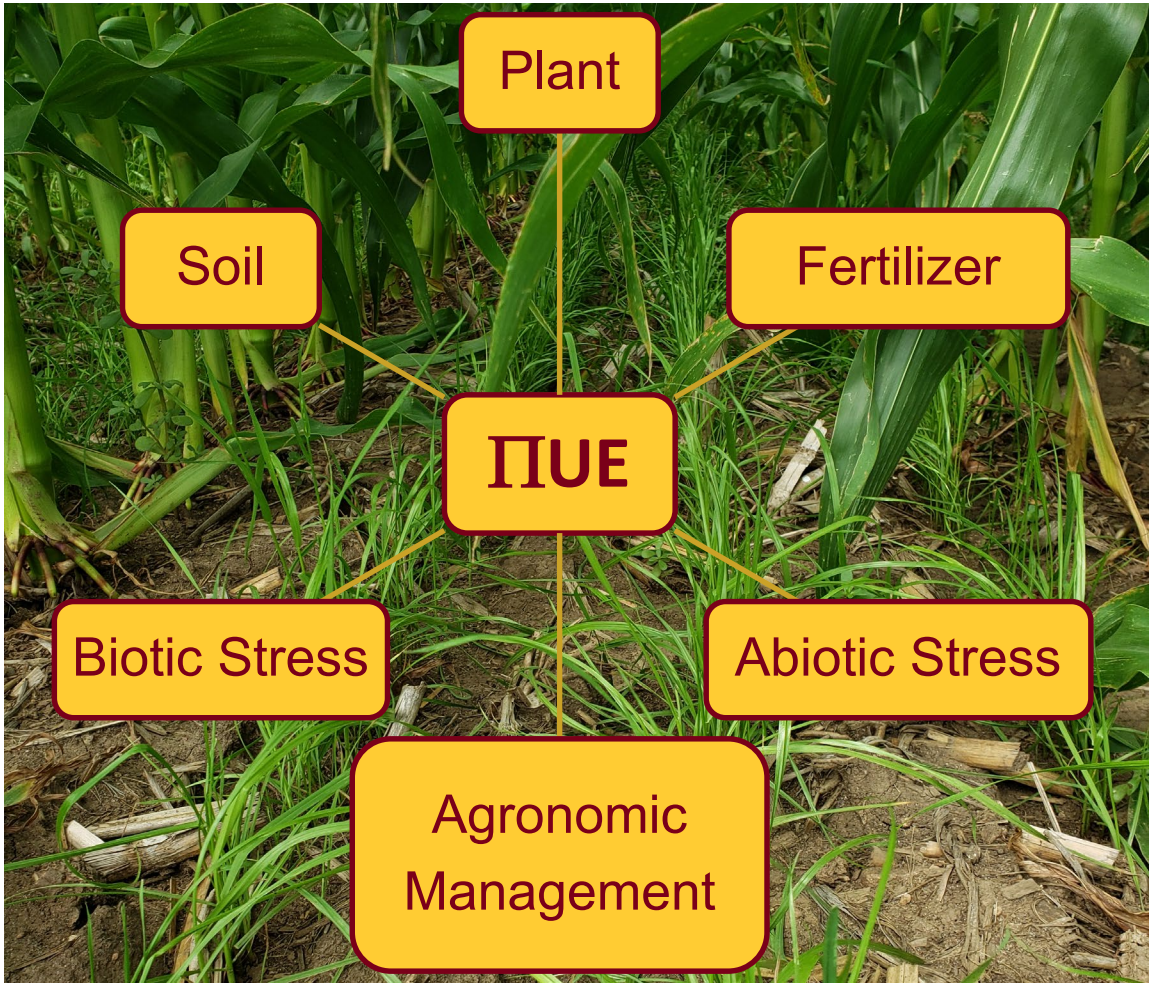
Nutrient Use Efficiency (ΠUE)

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



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

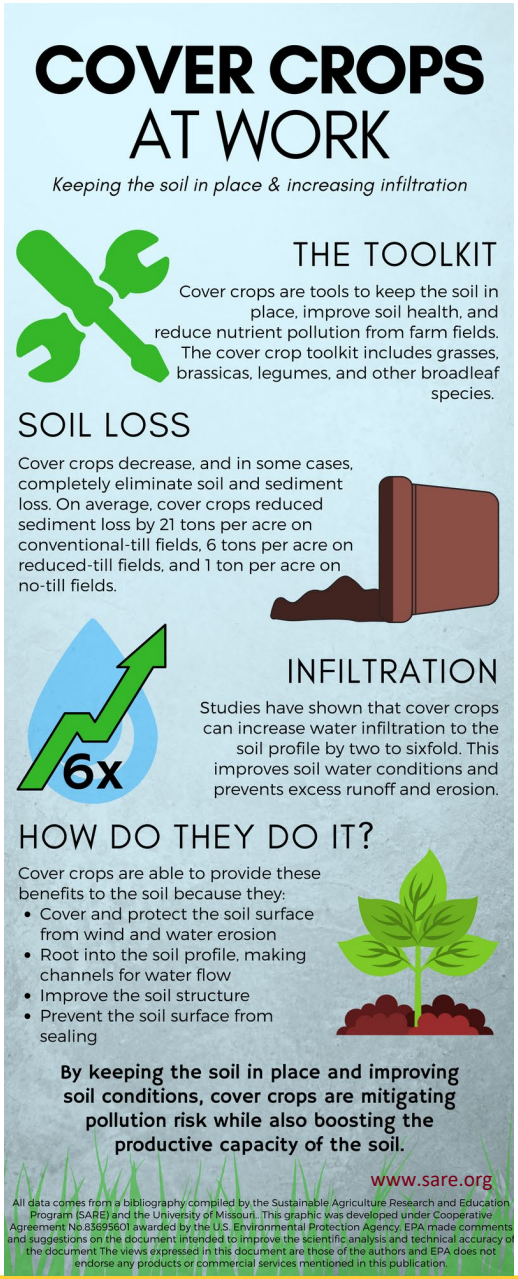
Factors that Affect ΠUE

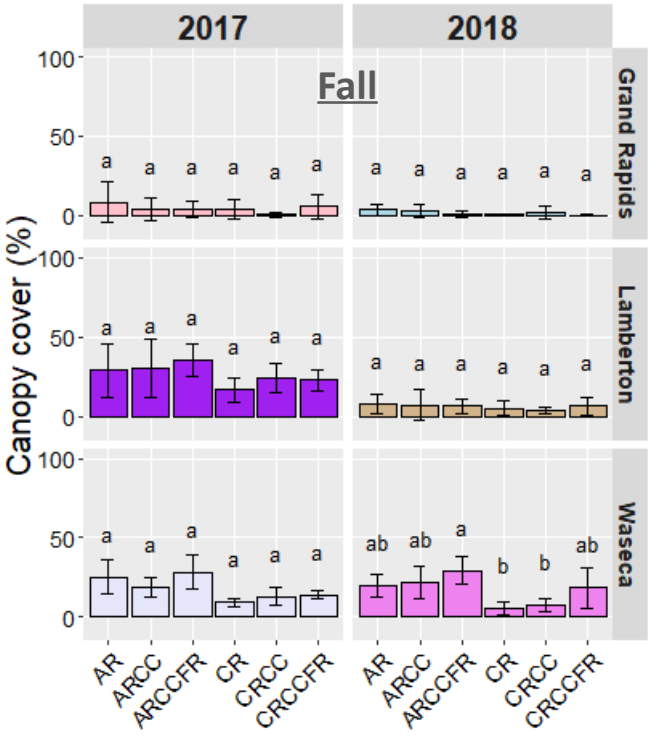


Adapted from: Baligar and Fageria, 2015

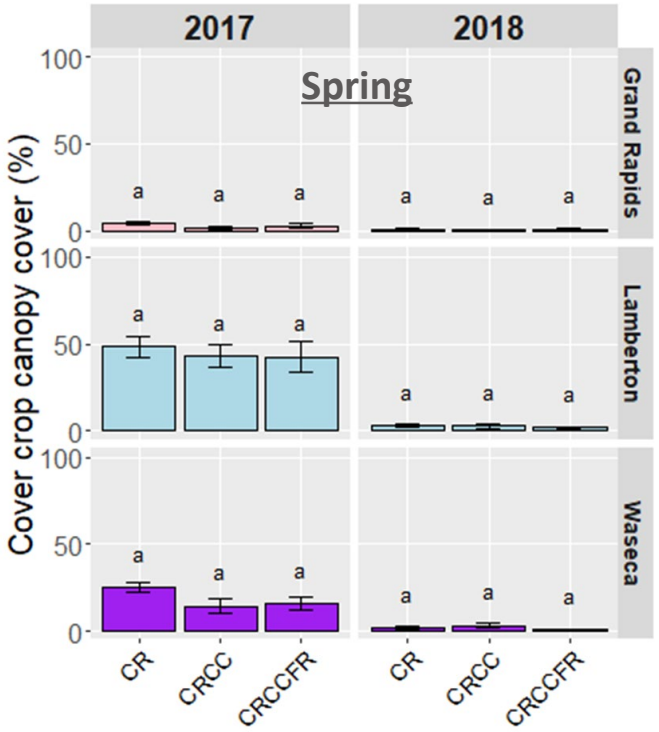
Cover Crops and ΠUE...

erosion & infiltration



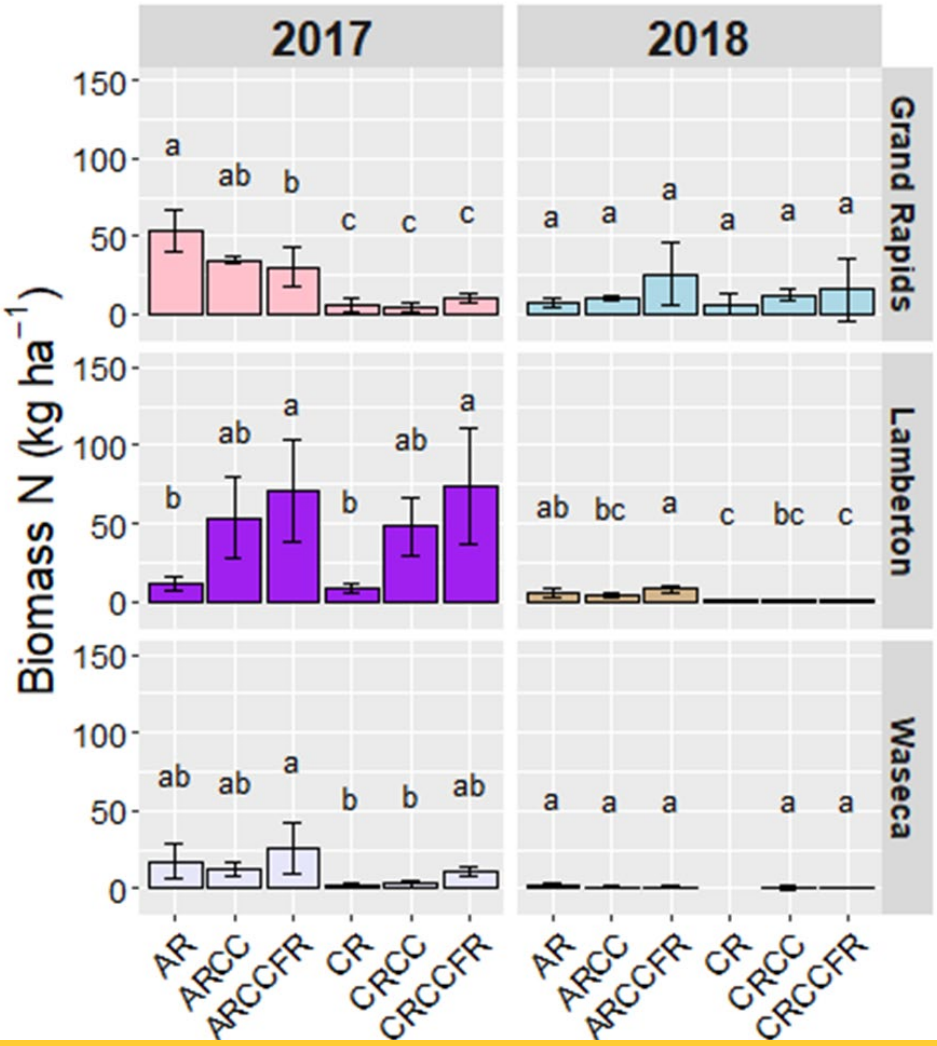


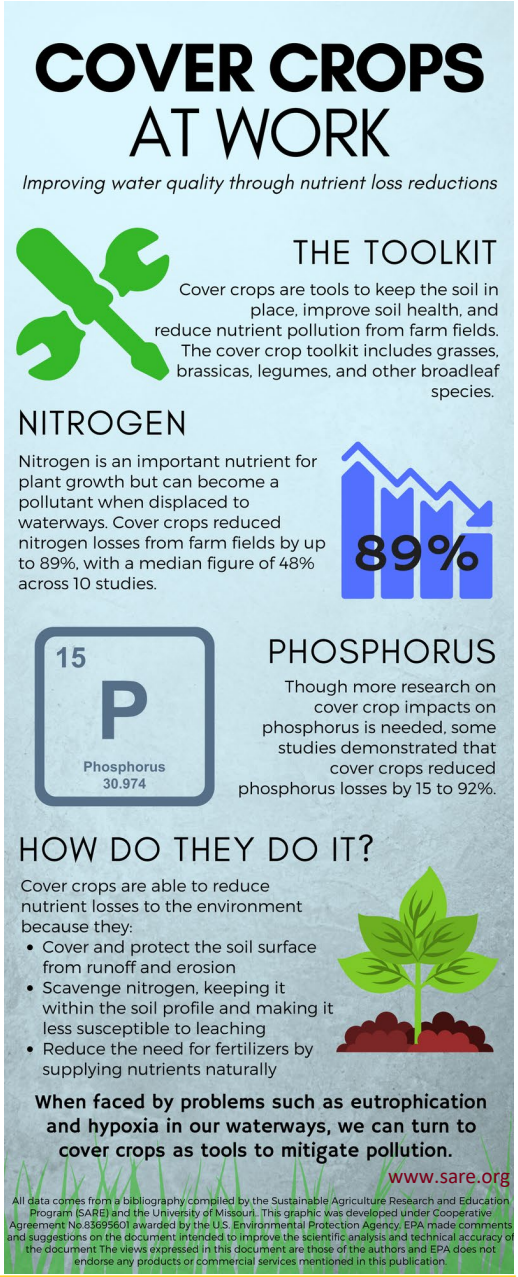
AR = annual ryegrass
CC = crimson clover
FR = forage radish
CR = cereal rye



Cover Crops and ΠUE…

nutrients

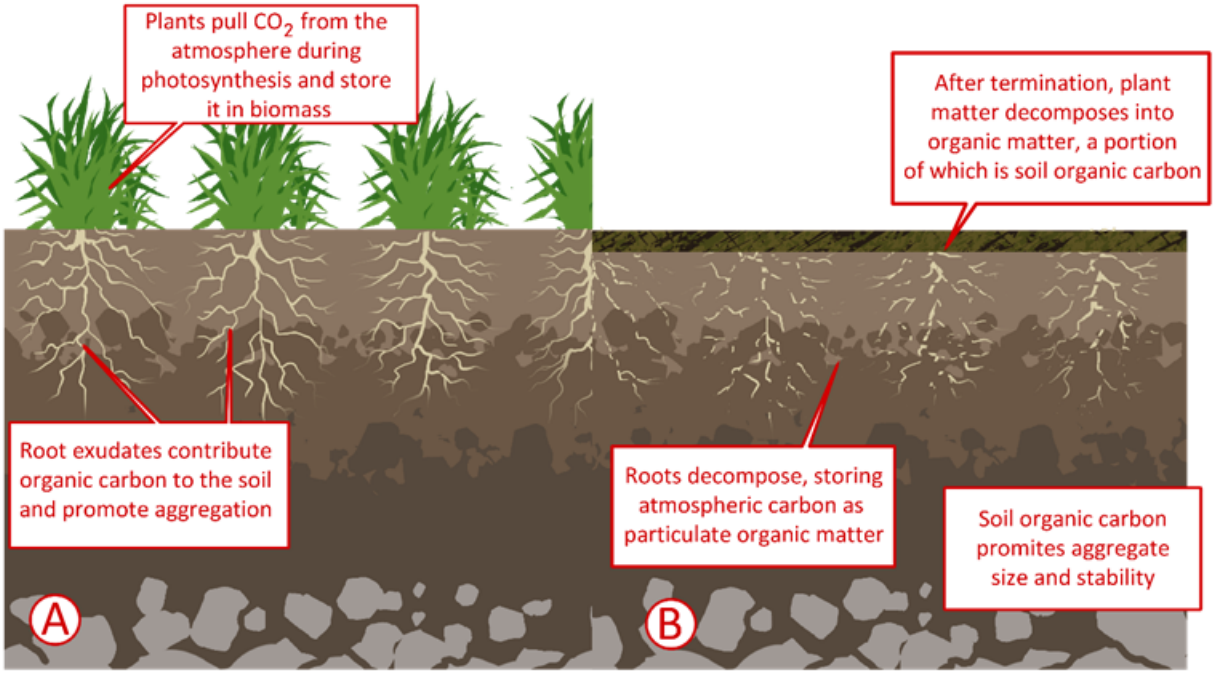




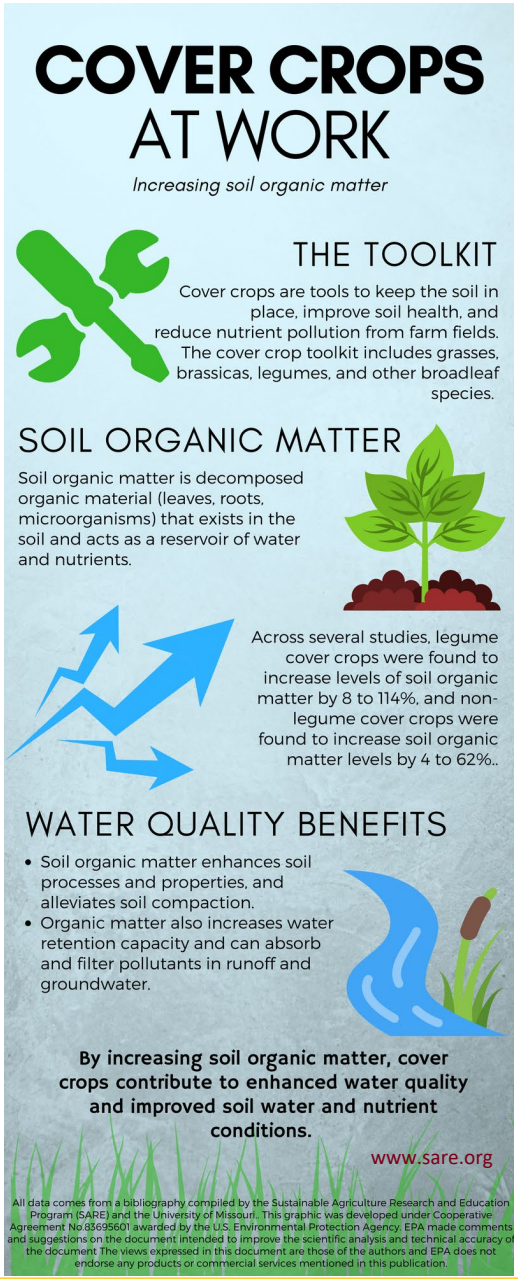
Cover Crops and ΠUE...

organic matter

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

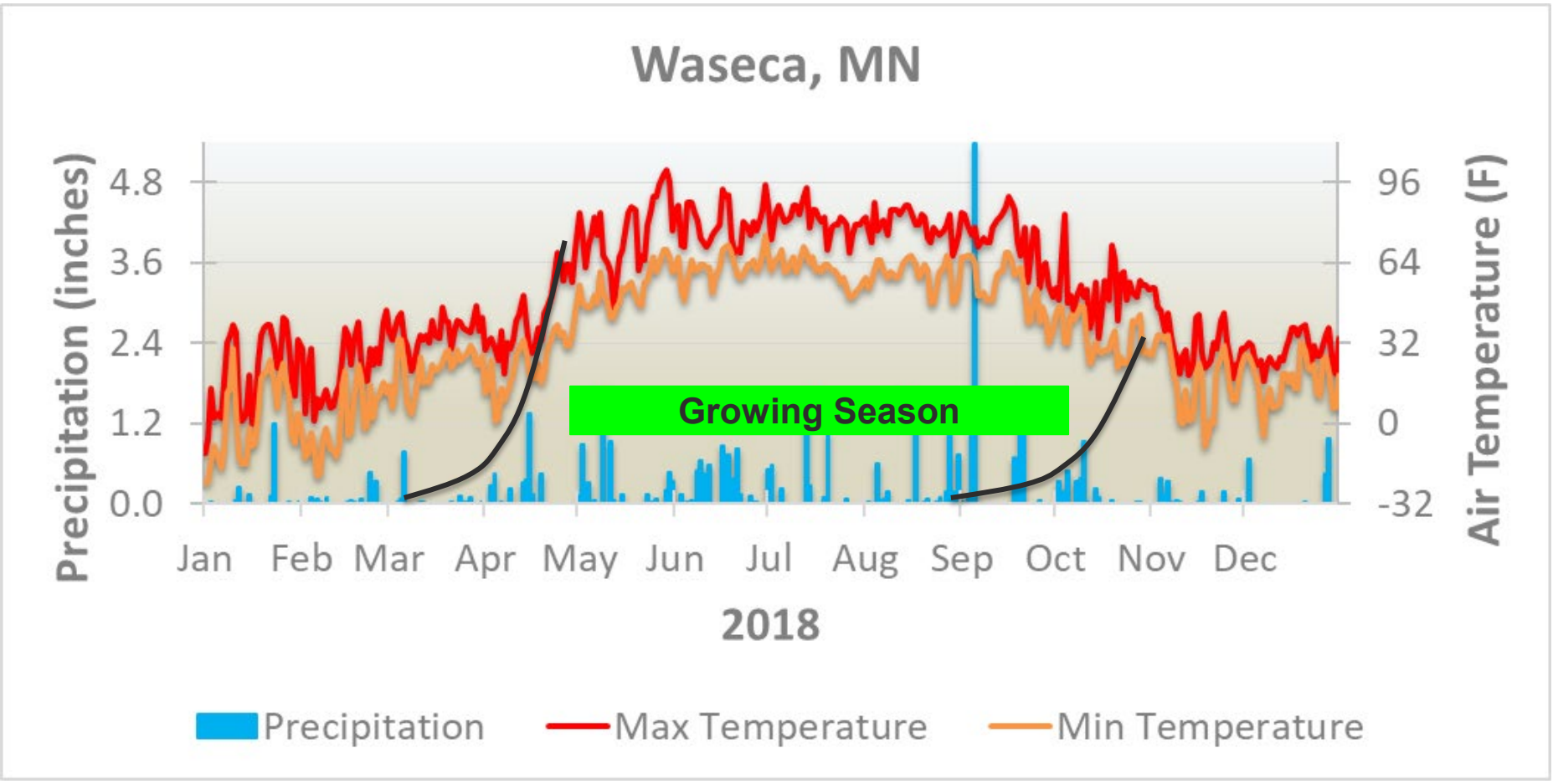


Source: University of Nebraska - Lincoln



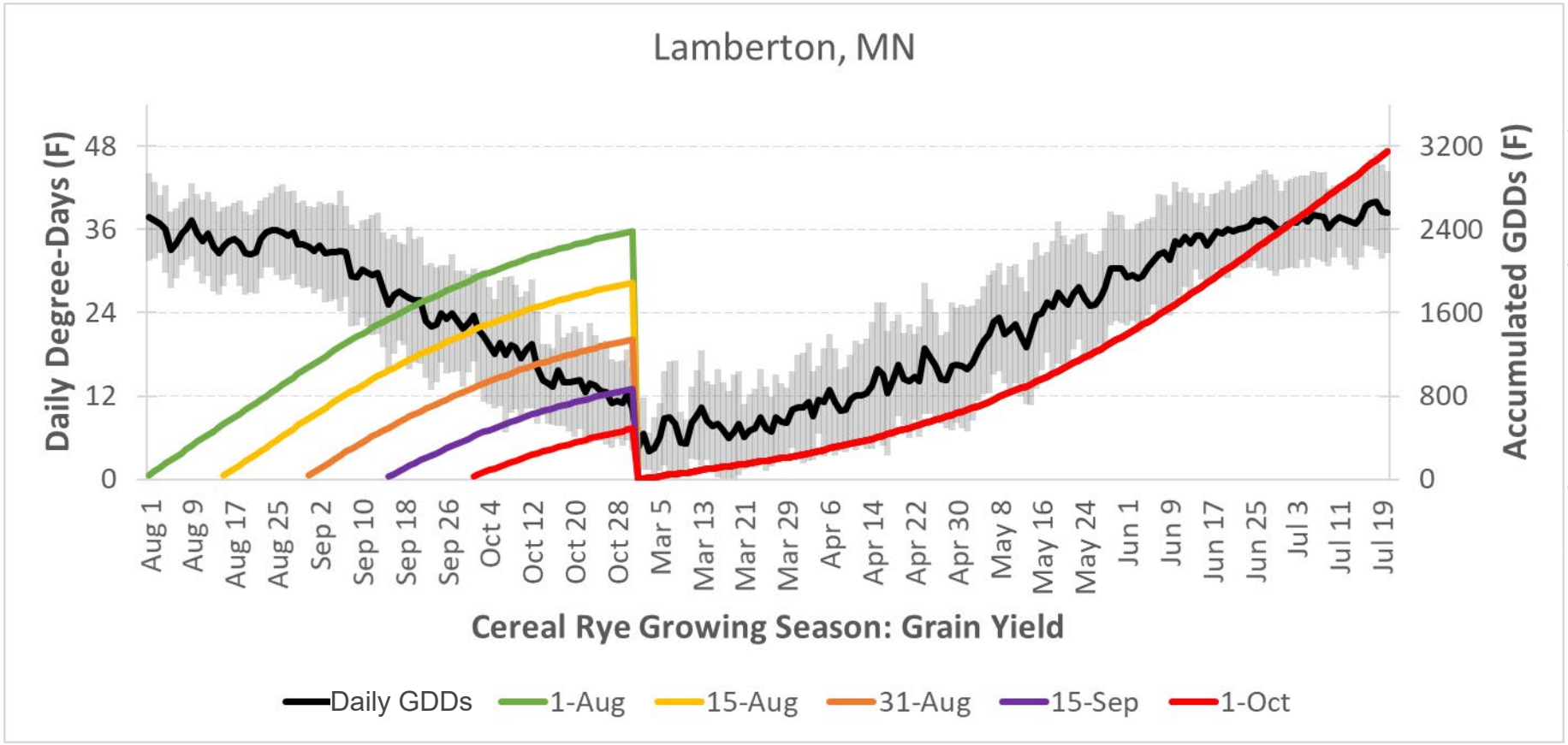
Cover Crops in Minnesota…

growing season

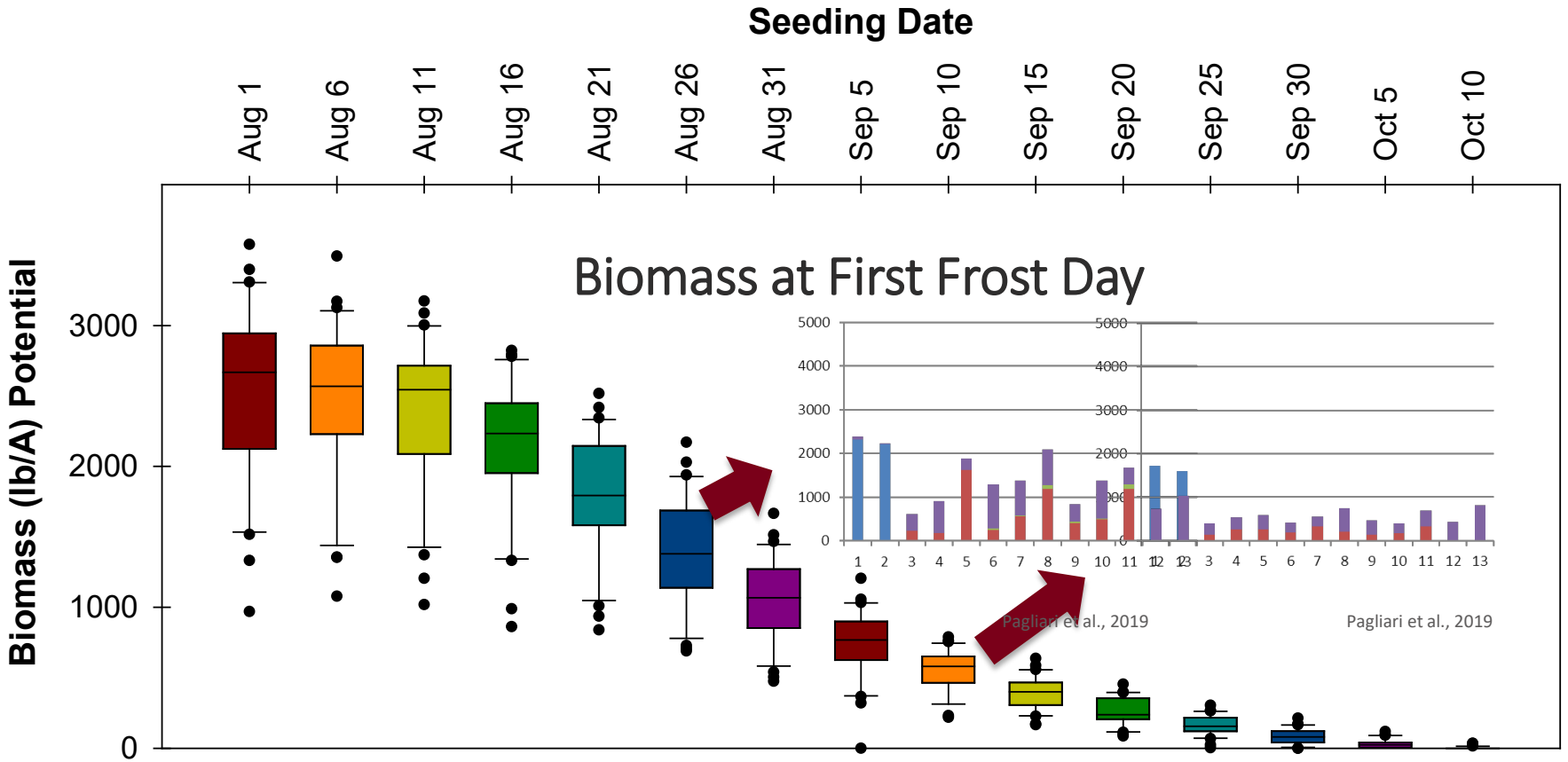


Cover Crops Use in MN…

heat units for winter rye



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



Anar et al., 2019 (work in progress)

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

How Cover Crops Could Improve ΠUE

Background on Nutrient Use

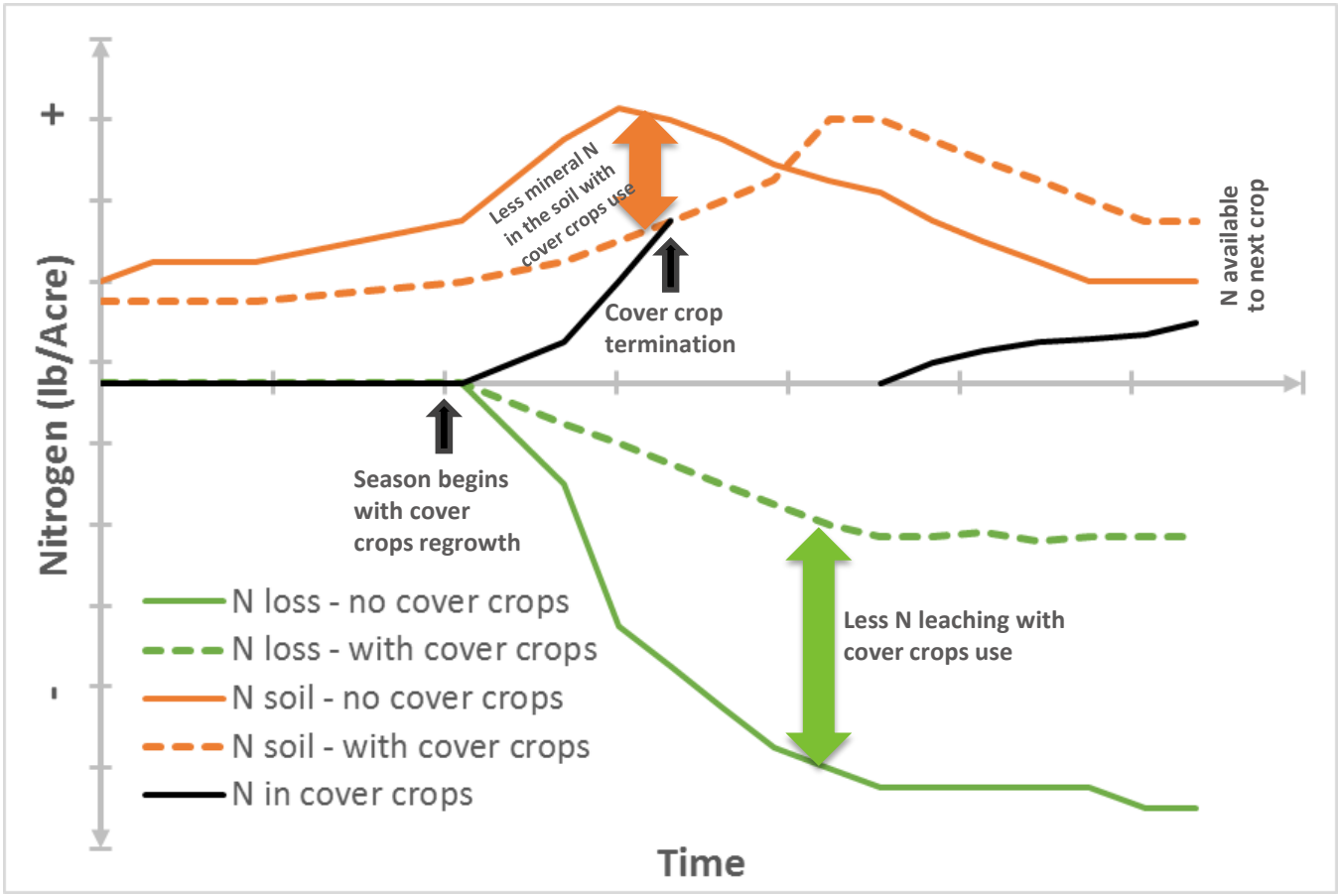
- Given to crops from fertilizers (synthetic sources) and organic amendments, and by ***building soil health*** to maintain nutrients in the soil for plants to use
- Most of ***nutrients applied aren't immediately taken up by crops***
- Excess nutrients stay in the soil, are emitted as gases, leach into groundwater, or run-off into surface waters
- Our objective: to improve ΠUE (***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 ΠUE

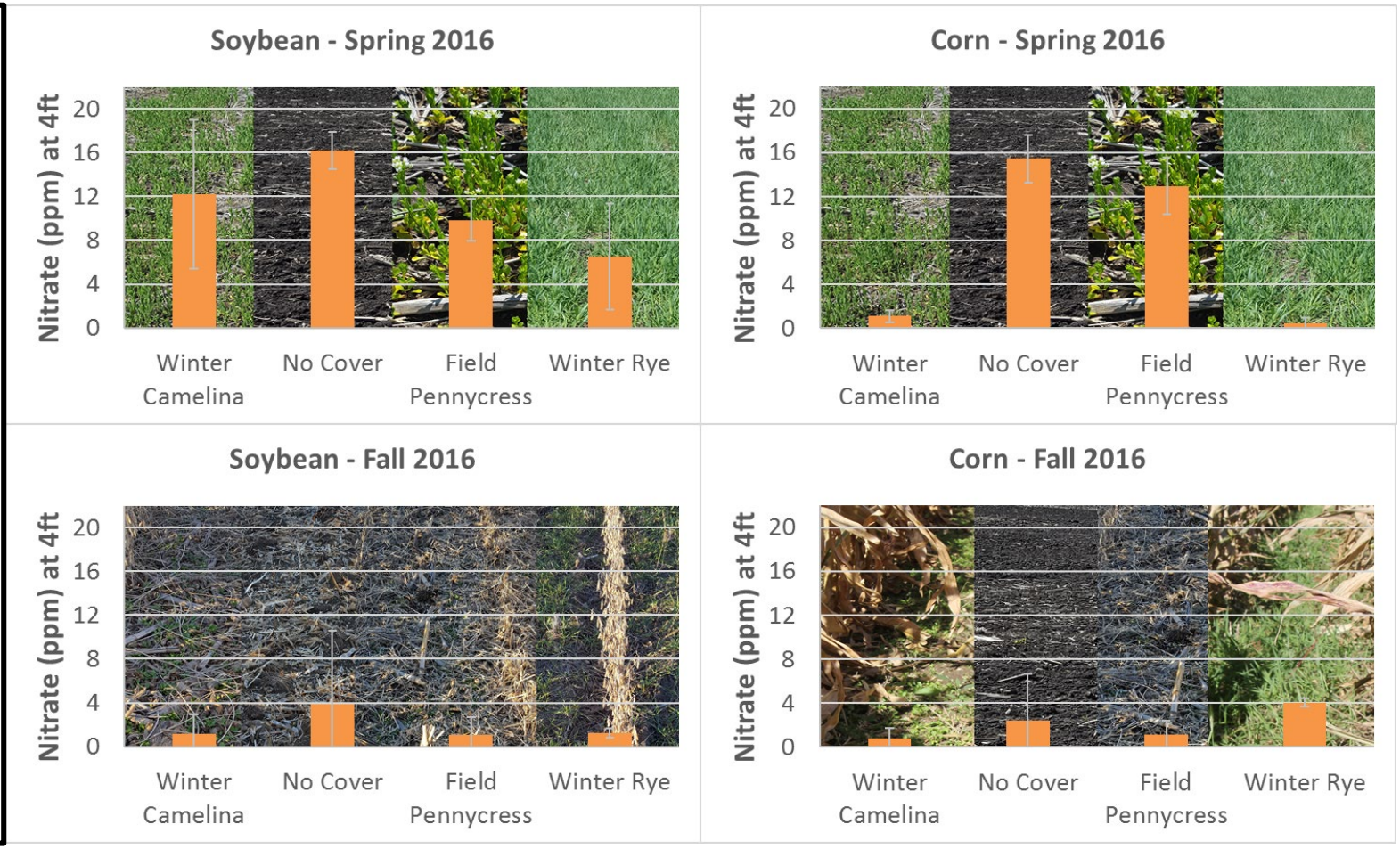
- Smart use of fertilizers (e.g.: 4Rs)
- Sufficient water
- Control of pests, diseases, weeds…
- ***Nutrients cycling*** through the use of ***cover crops***

How Cover Crops Could Improve ΠUE



How Cover Crops Could Improve ΠUE

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



Research on Cover Crops and ΠUE…

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 ΠUE… *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 ΠUE… *early-interseeded cover crops*

- Crimson clover (*Trifolium incarnatum* L.)

Origin: Europe

- 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

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

Research: Cover Crops and ΠUE… *late-interseeded cover crops*

- Cereal rye (*Secale cereale* L.)

Origin: Southwest Asia

- 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

- 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

Research: Cover Crops and ΠUE… *late-interseeded cover crops*

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

Origin: Mediterranean Europe

- 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

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

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 ΠUE…

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 ΠUE…

summer-seeded cover crops

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

- 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

Origin: Central Africa

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

www2.ca.uky.edu

Research: Cover Crops and ΠUE…

summer-seeded cover crops

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

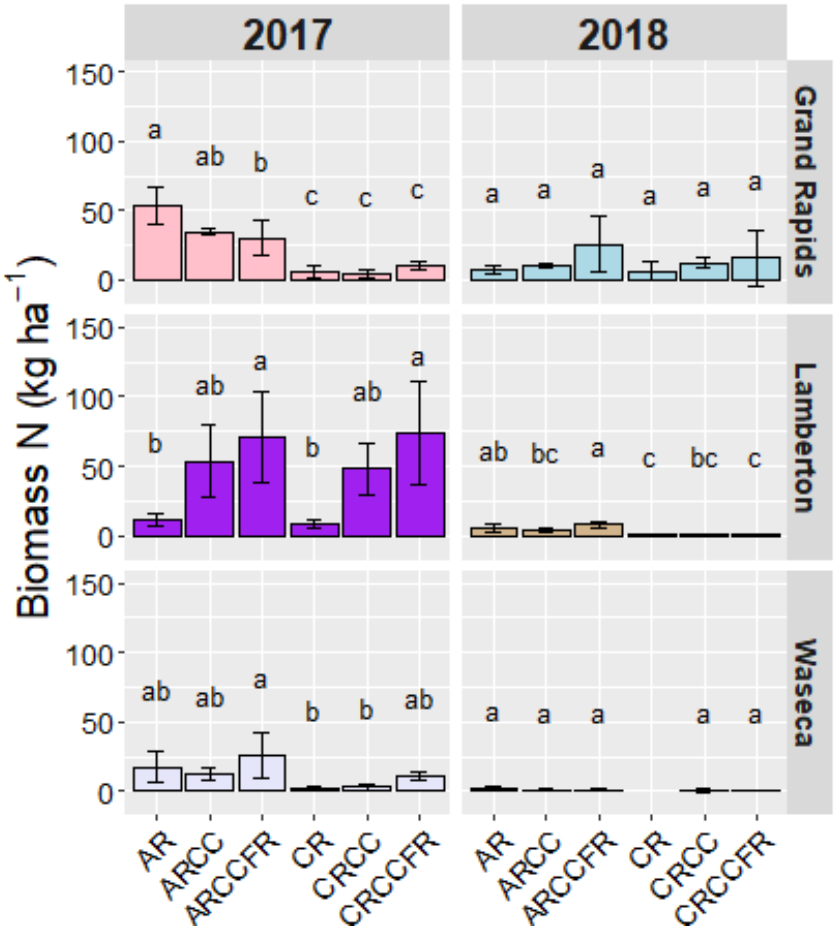
Origin: Northeast Africa

- 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

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

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. Rusch[1¶], Jeffrey A. Coulter[1¶], Julie M. Grossman[2&], Gregg A. Johnson[1,3&], Paul M. Porter[1&], Axel Garcia y Garcia[1,4*¶]

(*in review*)

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

Enter keywords, authc

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

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, 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

103 Views 0 CrossRef citations to date 3 Altmetric

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	3.0	18.0	0.50
	ARCC	10.0ab			
	ARCCFR	**14.0**a			
	CR	4.0b			
	CRCC	8.0ab			
	CRCCFR	16.0a			
Waseca	AR	-	4.0b	16.0	2.50
	ARCC		5.0b		
	ARCCFR		**10.0**a		
	CR		2.5bc		
	CRCC		2.3c		
	CRCCFR		5.0bc		

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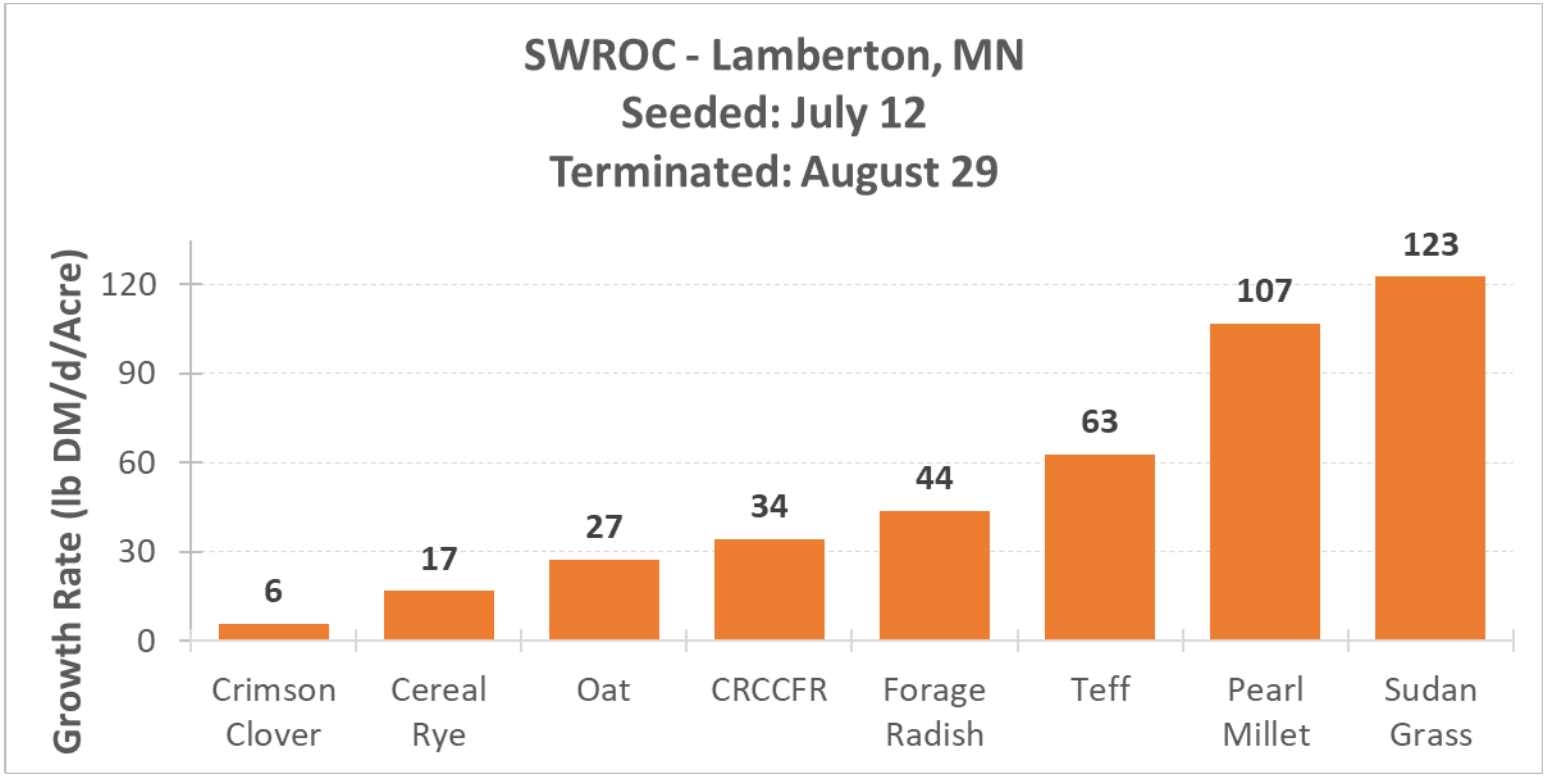
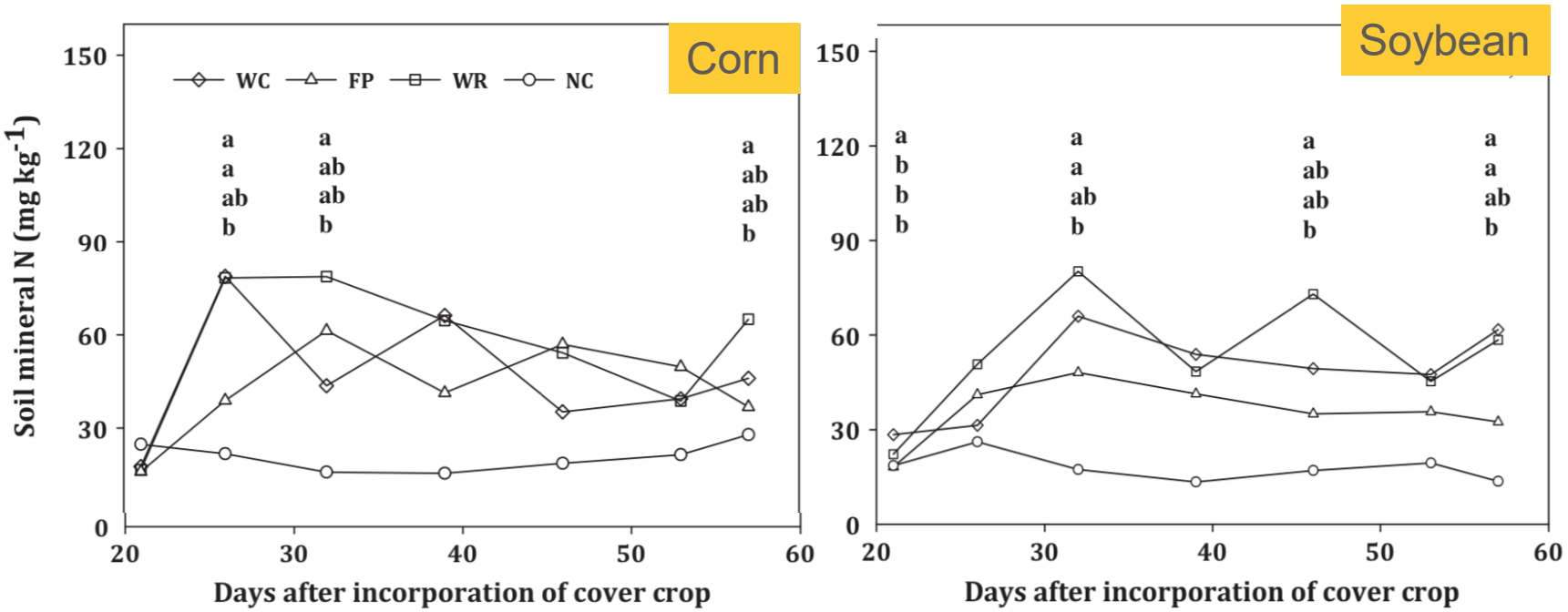
In Context: N Use of Summer-Seeded Cover Crops



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

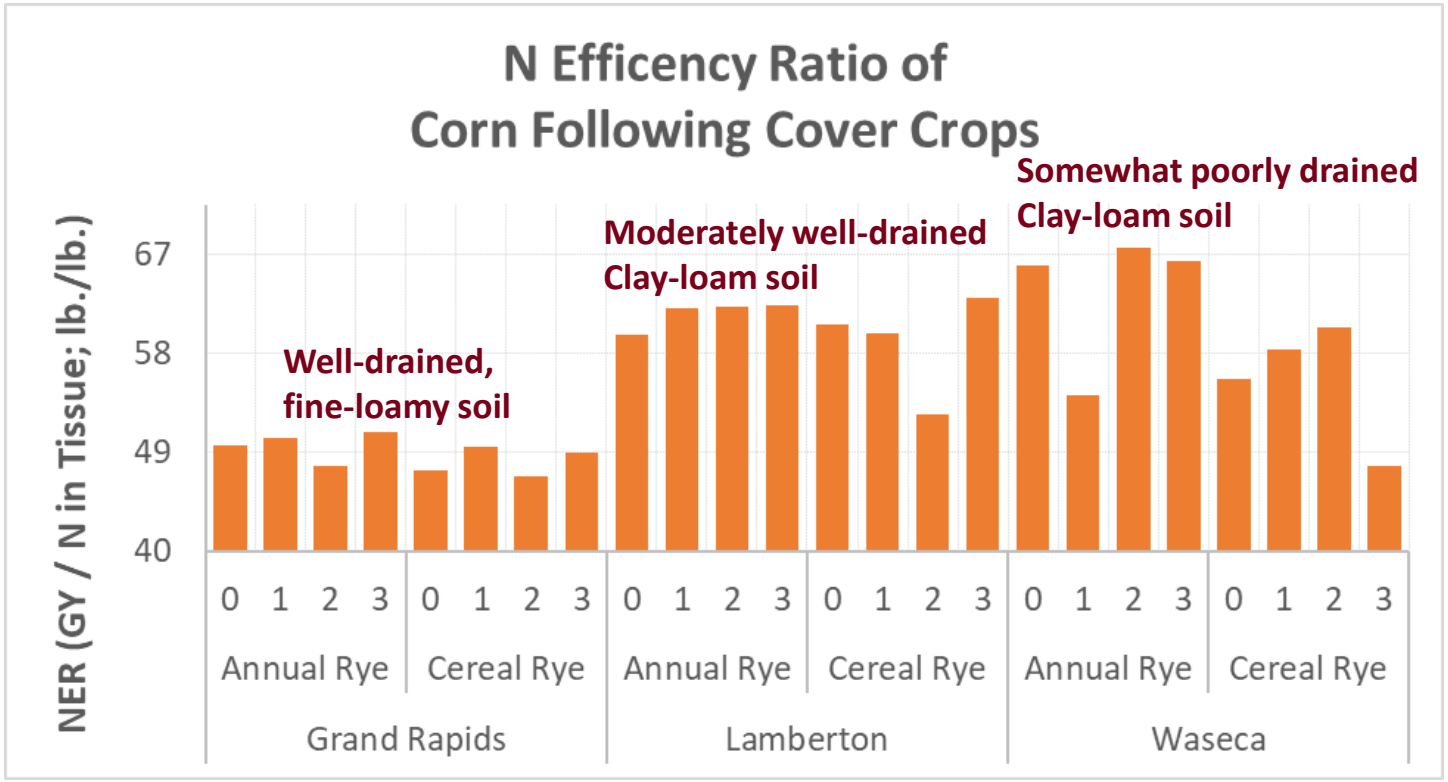
Research: Cover Crops and ΠUE… *when is N from residue released?*

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



ΠUE of Corn Following Cover Crops

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

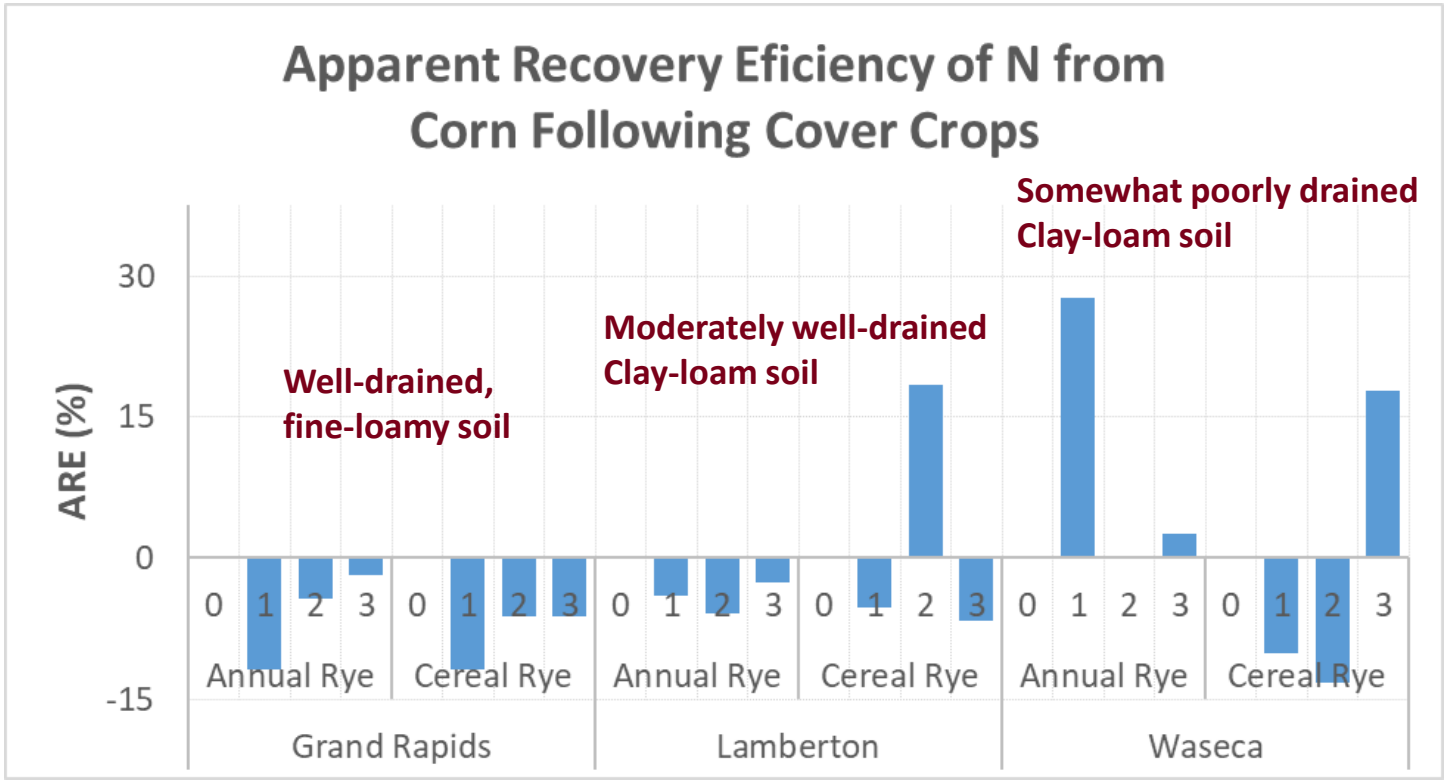


CLEAN WATER LAND & LEGACY AMENDMENT

MinnesotaCorn

ΠUE of Corn Following Cover Crops

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

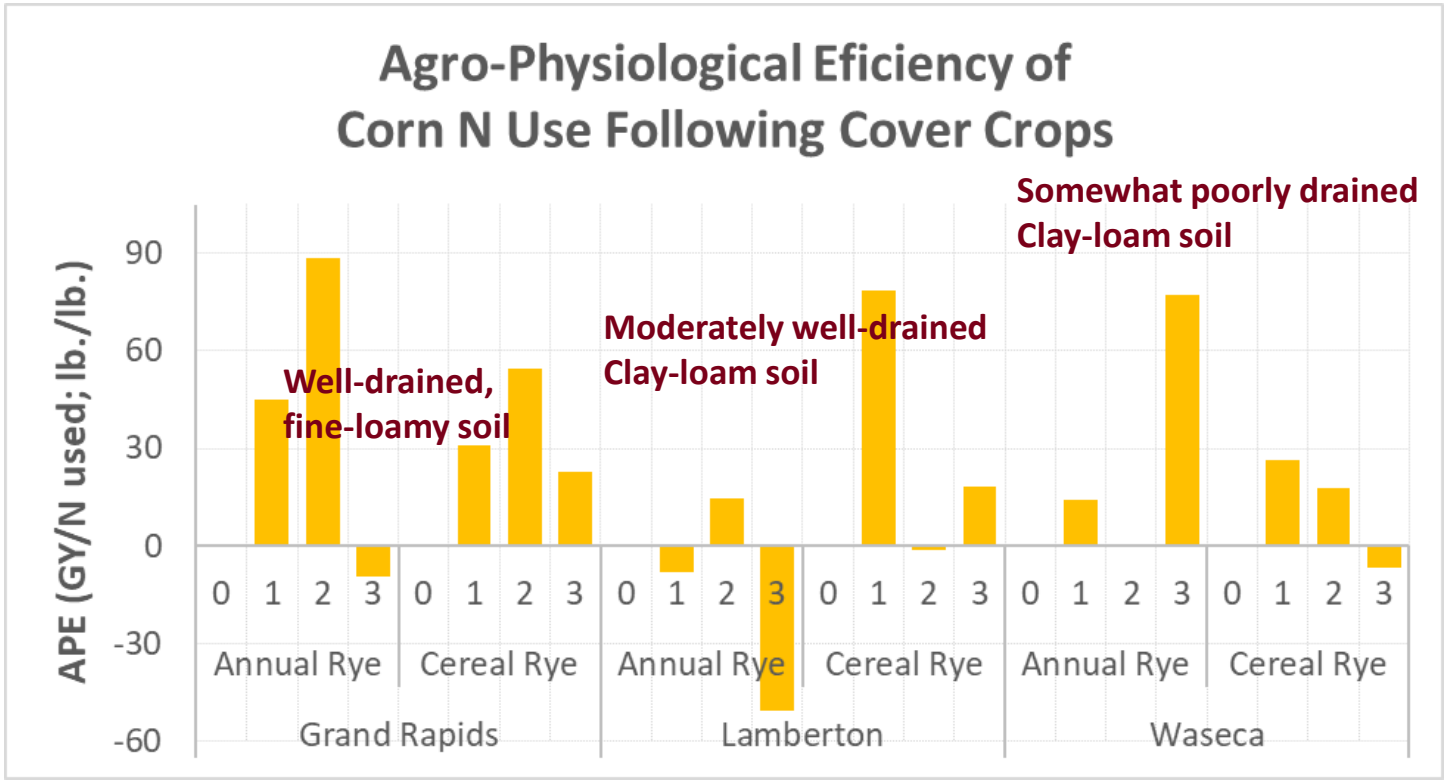


CLEAN WATER LAND & LEGACY AMENDMENT

MinnesotaCorn

ΠUE of Corn Following Cover Crops

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



CLEAN WATER LAND & LEGACY AMENDMENT

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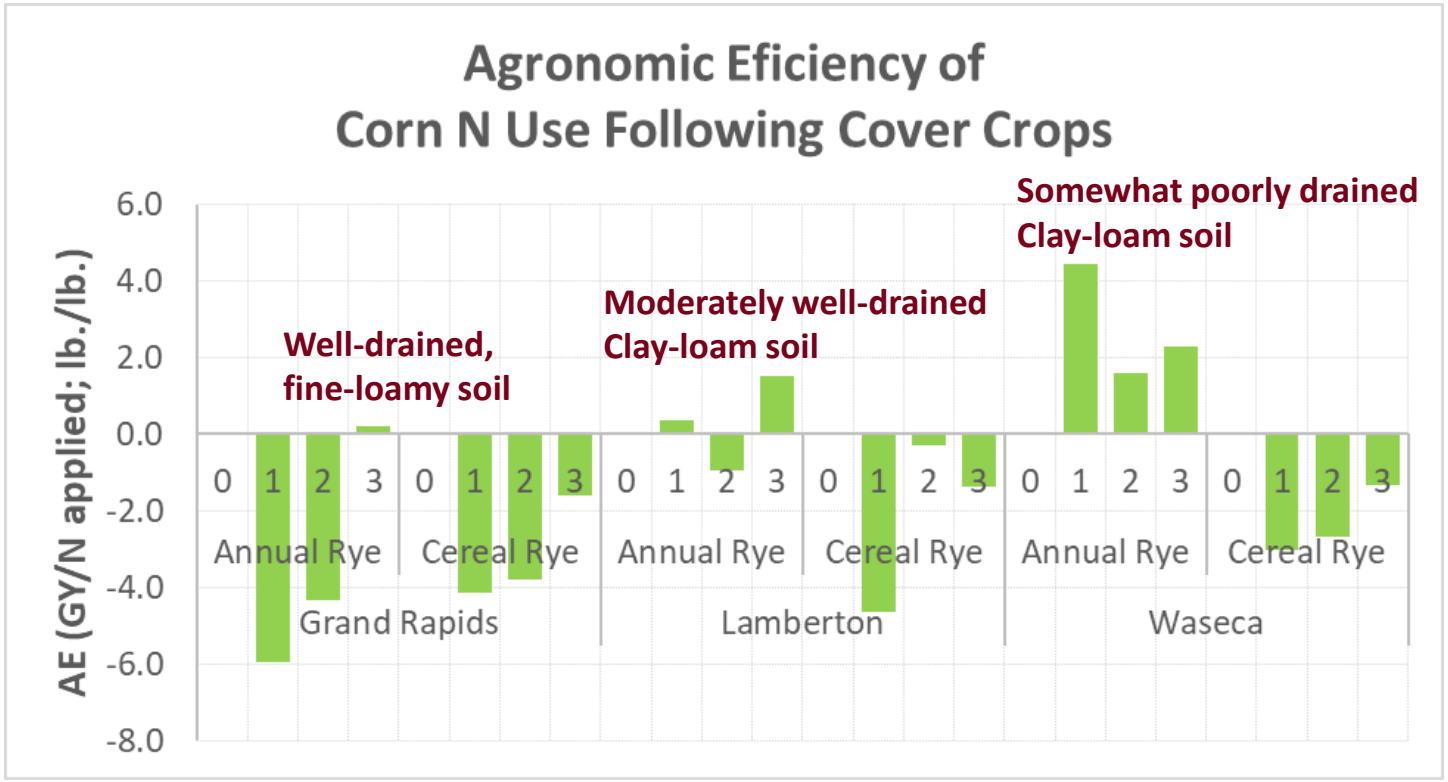
ΠUE of Corn Following Cover Crops

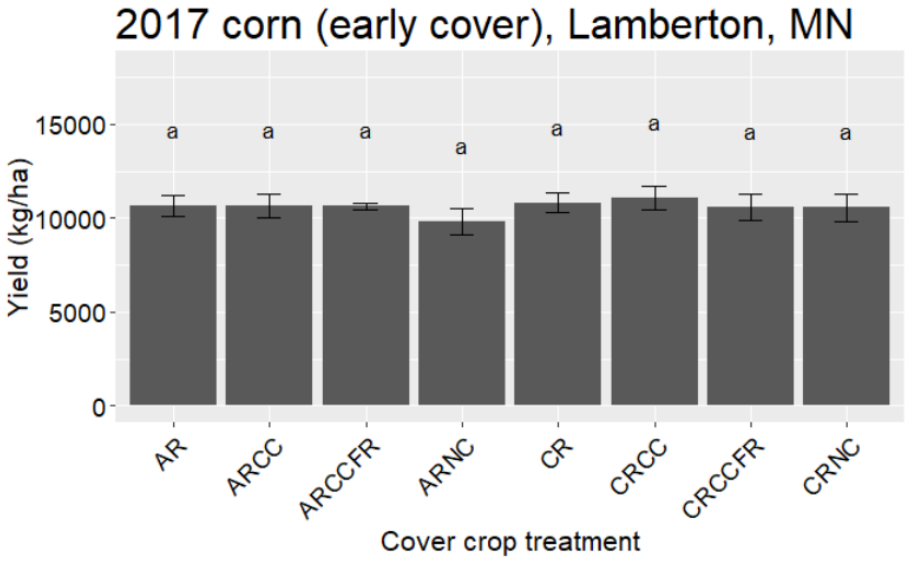
AE is the additional yield produced per unit of nutrient applied

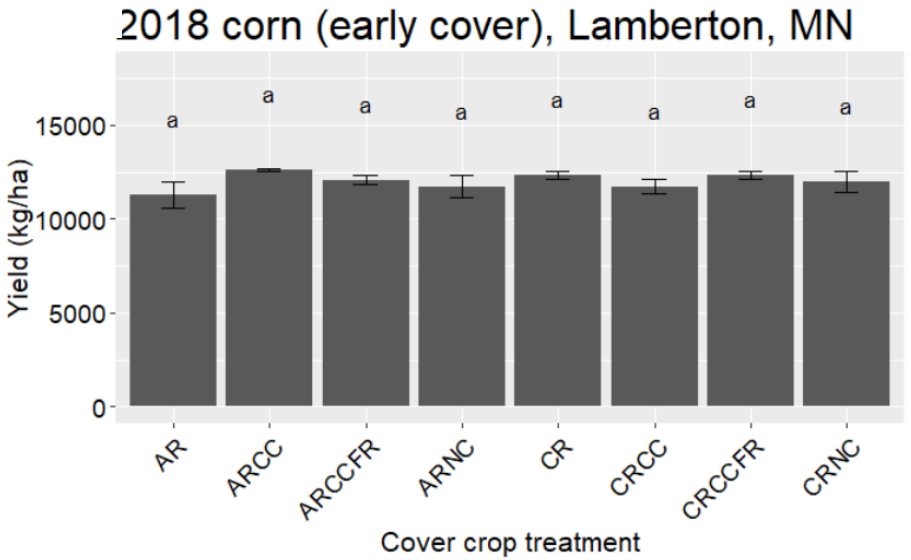


CLEAN WATER LAND & LEGACY AMENDMENT

MinnesotaCorn

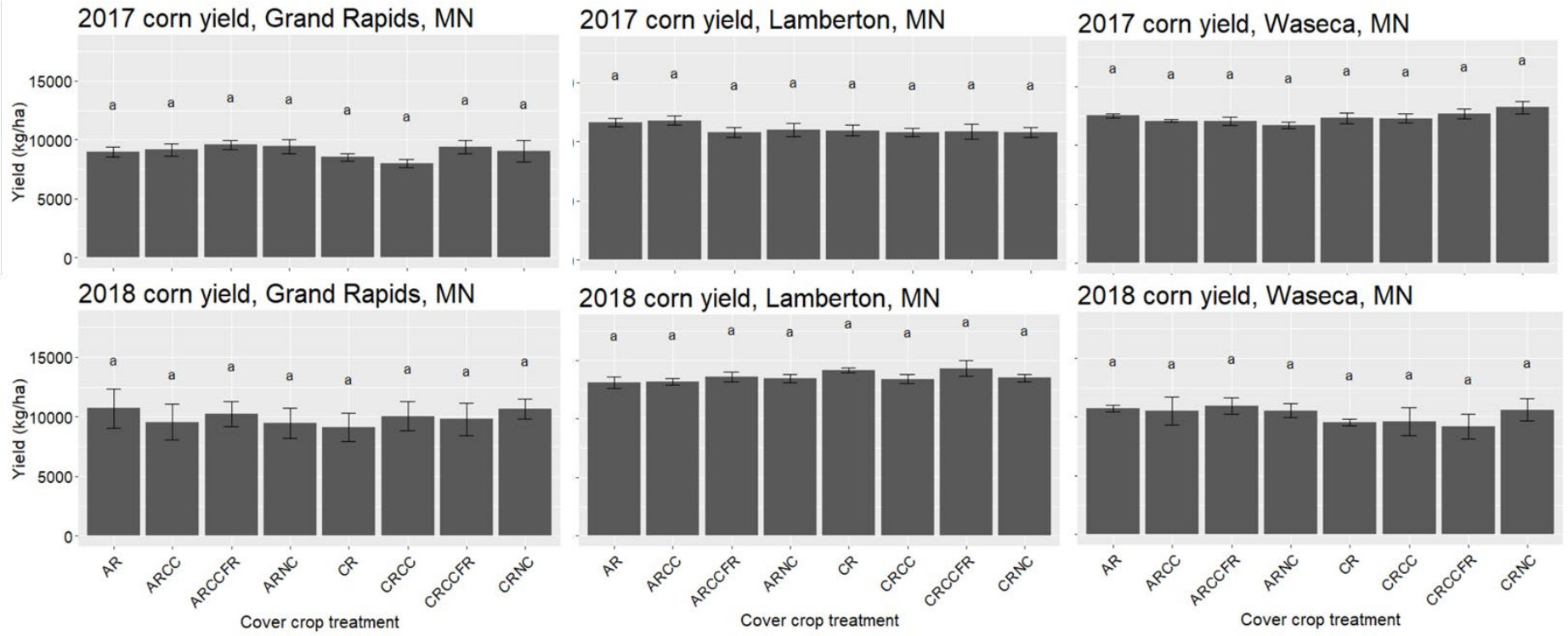
Do Cover Crops Affect Yield of Corn?





Rusch, HL. 2019. MS student

Do Cover Crops Affect Yield of Corn?



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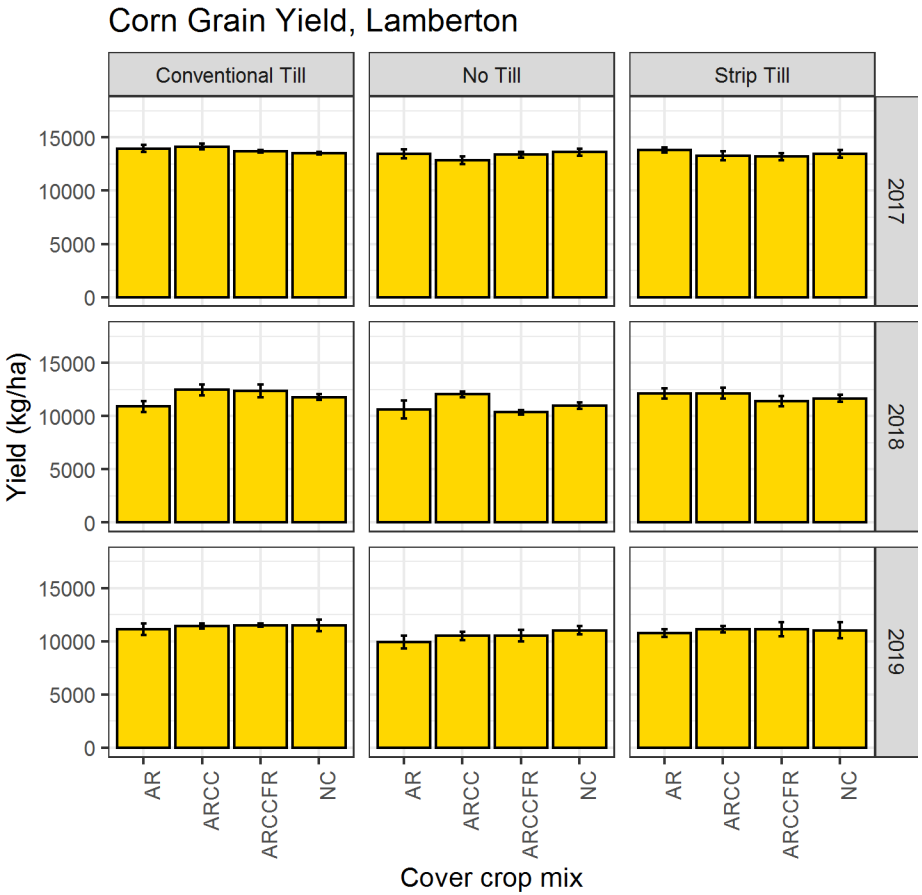

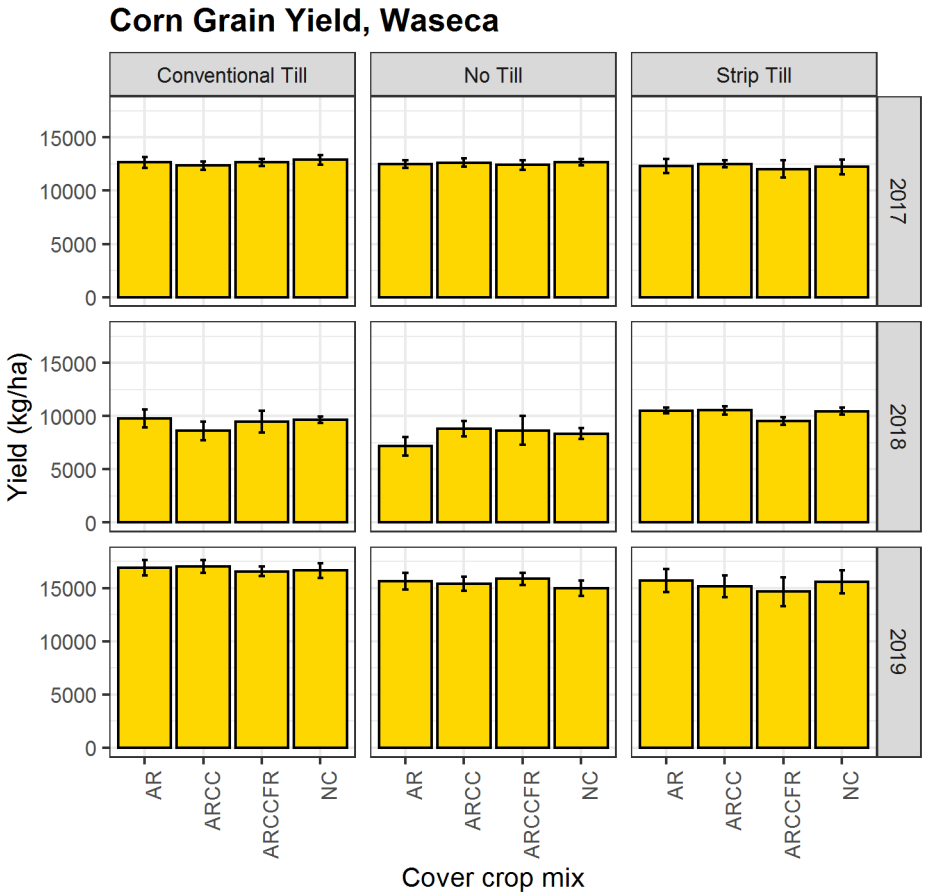

MinnesotaCorn

KC, R. 2019. MS student

Final Remarks

- Improved ΠUE 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 NO_3-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!

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