Combining 4R Nutrient Management and Ecological Intensification to Advance Corn Production

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Grand challenge

- Global crop production must increase substantially to meet the needs of a rapidly growing human population
  - 7.7 billion now, 9.7 billion by 2050 (+26%)

- Constraints to increasing crop production:
  - Availability of land, nutrients, water, energy, etc.
  - Variability & change in climate & pests
  - Soil degradation

Photo: businessinsider.com

Grand challenge

- Society desires cropping systems that are both productive and environmentally responsible
  - Demand for locally-sourced food
  - Documented production practices
- Collectively, these issues represent one of the greatest challenges of the 21st century
- Examine if 4R nutrient management and sustainable intensification can improve yield, profitability and environmental stewardship of current cropping systems.

Global network of experiments

Compare **normal** vs. **intensive agronomics** with **standard** vs. **advanced fertilizer management**

20 experiments in 9 countries

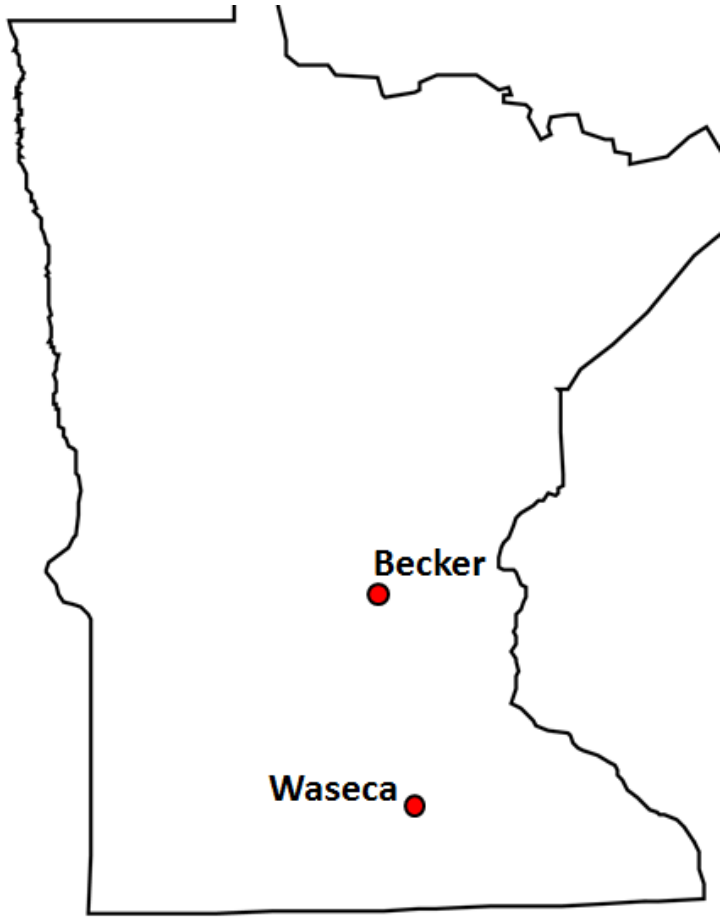
Research Questions

- What yield levels are possible?
- How far are current yields from these levels?
- Is standard fertilizer management capable of attaining yields at levels close to yield potential?

Sustainability Questions

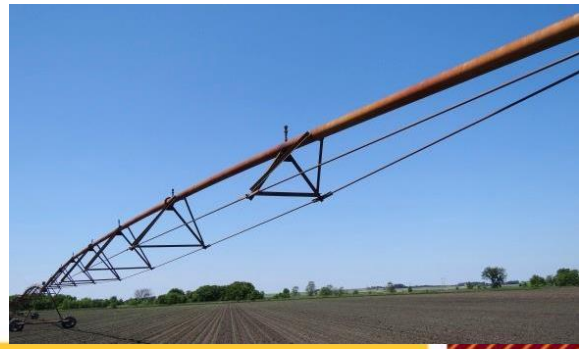
- How does managing for high yields affect profitability?
- What are the environmental effects?

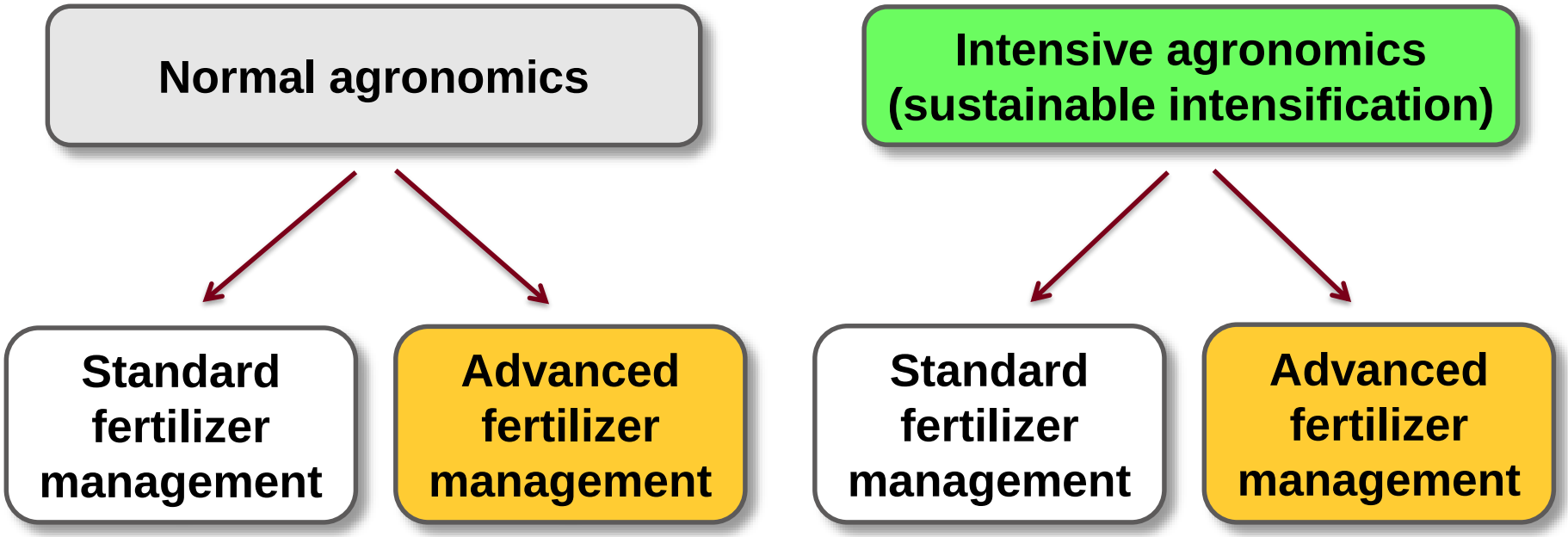
- **Waseca** (2013 – 2020)
  - Nicollet clay loam
  - Patterned tile drainage
- **Becker** (2014 – 2019)
  - Irrigated
  - Hubbard-Mosford loamy sand



AFREC
Agricultural Fertilizer Research & Education Council

- **Continuous corn**
  - Requires top management for high yields
  - Greater risk of nutrient losses
- **Irrigated sands**
  - High yield potential
  - Greater risk of crop nutrient deficiency
  - Greater risk of nutrient losses





- **'Systems' treatments developed at the start of the project & upgraded for the 2018 growing season**
  - Input from crop advisors, industry agronomists & farmers

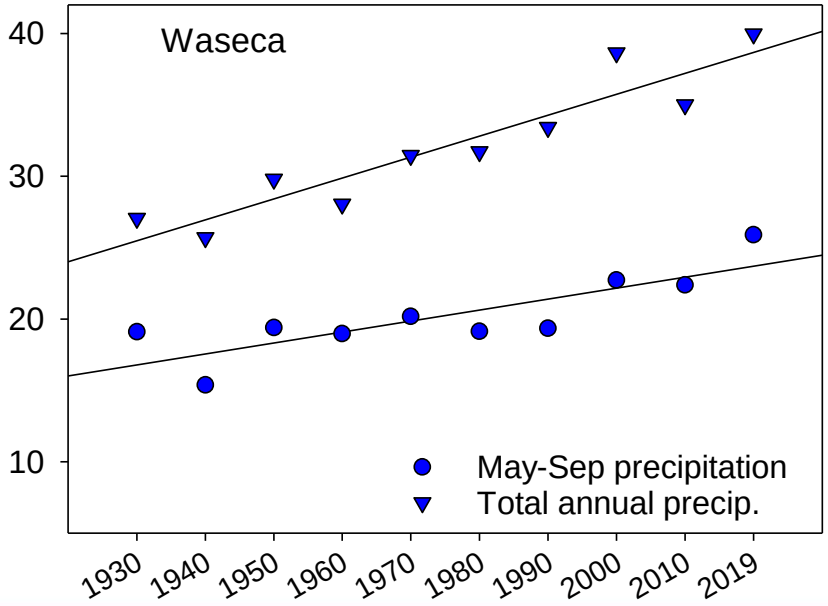
Agronomic treatments – Waseca

	Normal	Intensive
Corn stover harvested (%)	0	40
Hybrid maturity (CRM)	101	105
Planting rate (seeds/acre)	36,000	41,000
Fungicide at tasseling	No	Yes*

* Fungicide application began in 2018

Nitrogen

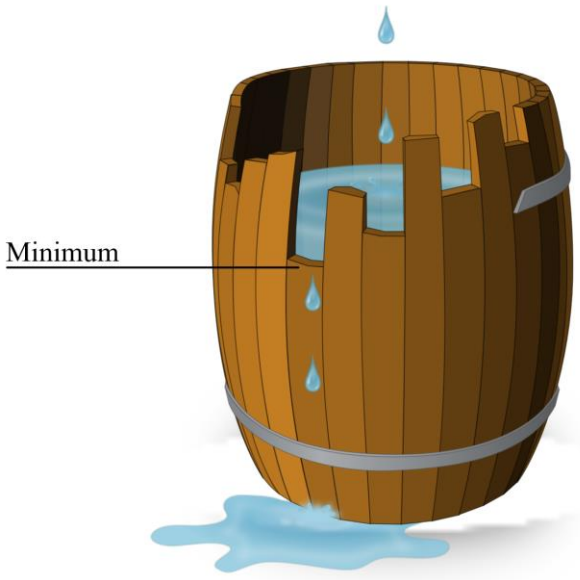
- Often the most limiting nutrient for corn
- Application in excess of corn requirements reduces risk of yield loss, but with economic & environmental consequences
- Increasing precipitation making N management difficult



Rate of Increase

0.15 inch/year

0.08 inch/year



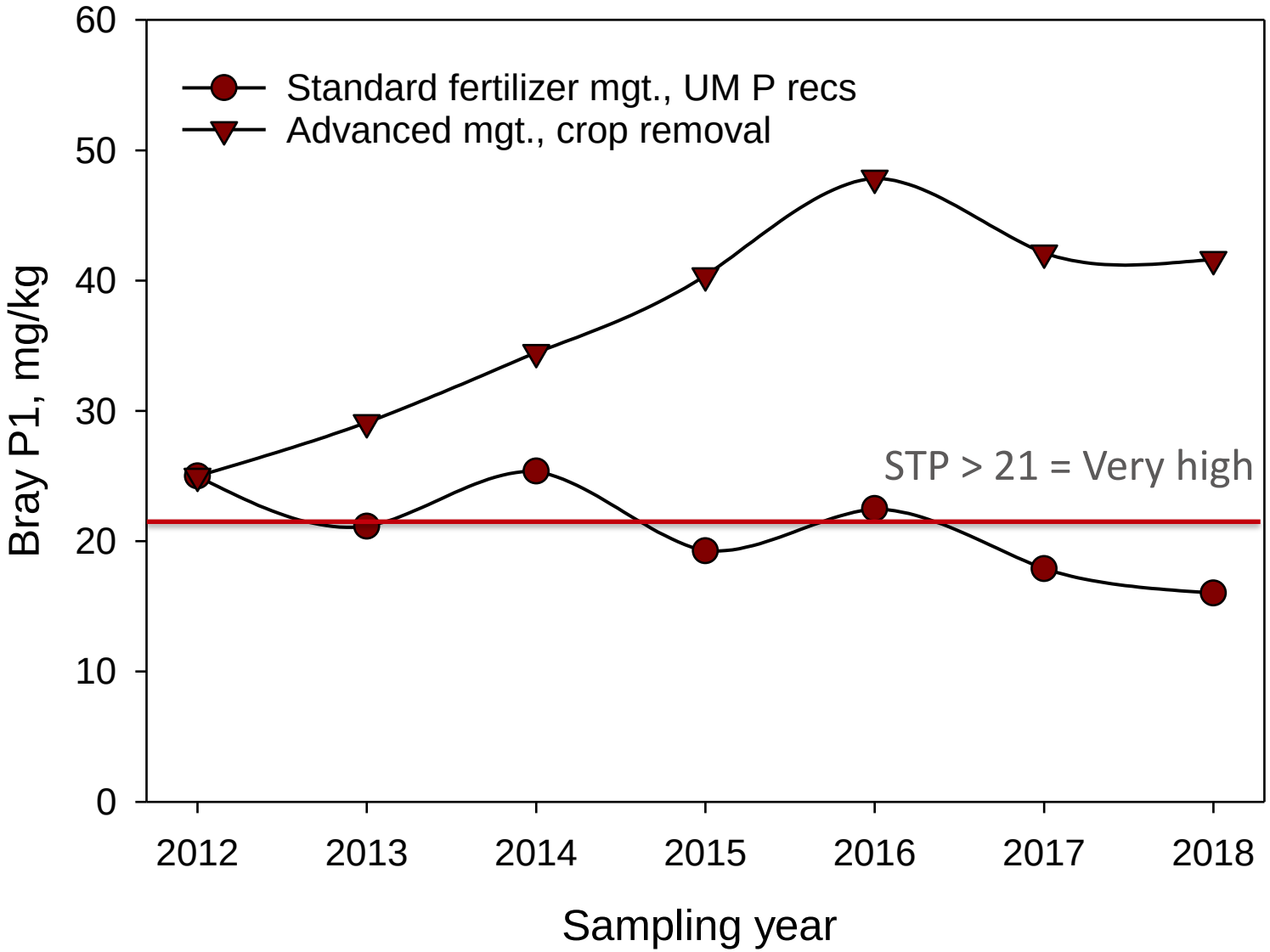
wikipedia.org

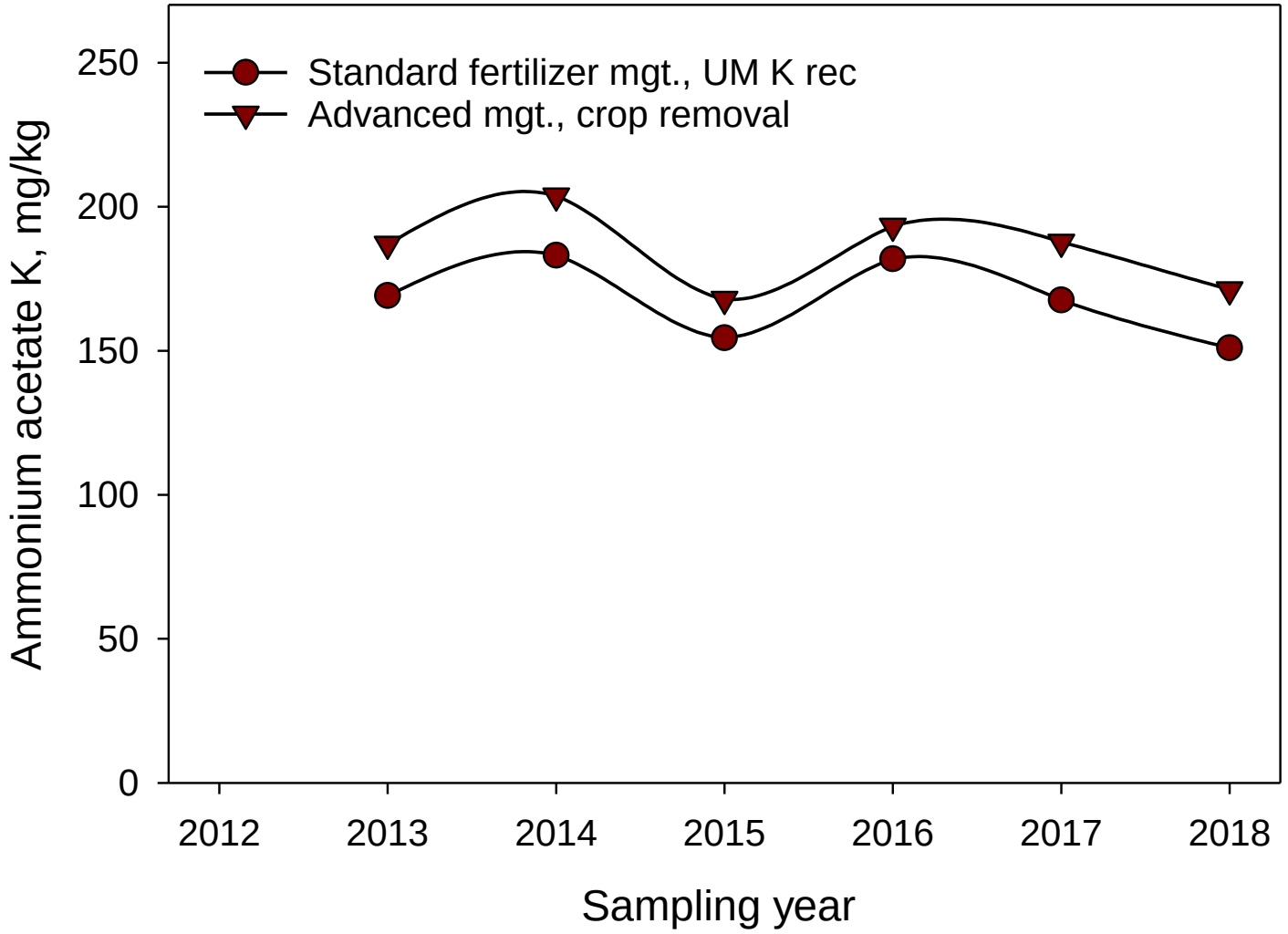
Fertilizer treatments	Standard	Advanced
S	20 lb SO_4/ac	20 lb SO_4/ac
P	U of M guidelines^	50% grain removal *
K	U of M guidelines^	100% grain removal*
10-34-0 in furrow	4 gal/ac	4 gal/ac
Surface-banded starter (2" x 0")	---	7 gal/ac 28-0-0 + 2 gal/ac 12-0-0-26
Pre-plant N (urea)	175 lb N/ac	111 lb N/ac
V6 N (28-0-0, injected)	---	40 lb N/ac
V14 N (28-0-0, Y-DROPs)	---	40 lb N/ac +
Total N *	180 lb N/ac	220 lb N/ac

^ **U of M:** P-only starter (16 lb P_2O_5/ac), K-broadcast (30 lb K_2O/ac)

* **Advanced:** P rate reduced from 100% to 50% of grain removal in 2018, grain removal was 86 lb P_2O_5/ac and 69 lb K_2O/ac (assumed 240 bu/ac)

+ V14 N application added in 2018


Standard fertilizer mgt., UM P recs
Advanced mgt., crop removal
STP > 21 = Very high
Bray P1, mg/kg
Sampling year
0
10
20
30
40
50
60
2012
2013
2014
2015
2016
2017
2018


Standard fertilizer mgt., UM K rec
Advanced mgt., crop removal
Ammonium acetate K, mg/kg
250
200
150
100
50
0
2012
2013
2014
2015
2016
2017
2018
Sampling year

- **Yield gap = 16 to 64 bu/ac (average = 31 bu/ac)**

LSD (0.05)

- **Greatest yield = advanced fertilizer mgt. + intensive agronomics**
- **Moderate yield = advanced fertilizer mgt. or intensive agronomics**

Agronomic management	Normal	Normal	Intensive	Intensive
Fertilizer management	Standard	Advanced	Standard	Advanced
--------- year ---------	---------- grain yield (bu/ac) ----------			
2013	193 c	215 b	210 b	233 a
2014	92 c	121 b	124 b	156 a
2015	203 c	220 b	234 a	242 a
2016	214 c	220 b	233 a	239 a
2017	209 c	230 b	228 b	238 a
2018	213 b	224 a	218 b	229 a
2019	177 c	192 ab	186 b	199 a
7-year average	186 c	203 b	205 b	219 a

Agronomic management	Normal	Normal	Intensive	Intensive
Fertilizer management	Standard	Advanced	Standard	Advanced
Cost of treatments for partial budget analysis	---------- $/ac ----------			
Raking, baling, & moving stover (2.7 round bales/ac)	-	-	27.81	27.81
Seed ($3.50/1,000 seeds)	126.00	126.00	143.50	143.50
Fungicide + application ($15.00/ac)	-	-	15.00	15.00
P_2O_5 pre-plant + application ($0.54/lb P_2O_5)	-	23.22	-	23.22
K_2O pre-plant + application ($0.31/lb K_2O)	9.30	21.39	9.30	21.39
Urea pre-plant + application ($0.44/lb N)	77.00	48.40	77.00	48.40
28-0-0 at planting ($0.44/lb N)	-	9.24	-	9.24
12-0-0-26 at planting ($1.32/gal)	-	2.64	-	2.64
28-0-0 at V6 ($0.44/lb N)	-	17.60	-	17.60
Custom rate for 28-0-0 at V6 ($10.45/ac)	-	10.45	-	10.45
28-0-0 at V14 ($0.44/lb N)	-	17.60	-	17.60
Custom rate for 28-0-0 at V14 ($6.90/ac)	-	6.90	-	6.90
Total	212.30	283.44	272.61	343.75

Cost of drying grain = $0.045/point/bu

Value of grain = $3.50/bu

Revenue from stover (2.7 bales/ac) for intensive agronomics = $94.50/ac

- **Greatest net return in all years & on average with intensive agronomics + standard fertilizer mgt.**
- **In the last 2 years with intensive agronomics, net return for advanced fertilizer mgt. was only $23-31 less than that with standard fertilizer mgt.**

LSD (0.05)

Agronomic management	Normal	Normal	Intensive	Intensive
Fertilizer management	Standard	Advanced	Standard	Advanced
--------- year ---------	---------- partial net return ($/ac) ----------			
2013	399 b	381 b	523 a	507 a
2014	72 b	68 b	262 a	268 a
2015	473 c	441 d	645 a	586 b
2016	521 c	455 d	654 a	589 b
2017	479 c	455 c	600 a	553 b
2018	480 ab	436 c	493 a	462 b
2019	373 b	349 c	428 a	405 a
7-year average	400 c	369 d	515 a	481 b

- **Agronomic NUE & corn N recovery efficiency were greatest with intensive agronomics & either level of fertilizer mgt.**

- **With intensive agronomics, advanced fertilizer mgt. did not improve agronomic NUE or corn N recovery efficiency (due to the additional 40 lb N/ac)**

		7-year average	6-year average
Agronomic management	Fertilizer management	Agronomic NUE (increase in yield (bu/ac) per lb N/ac applied)	Corn N recovery efficiency (increase in N uptake (lb N/ac) per lb N/ac applied)
Normal	Standard	0.58 b	0.53 b
Normal	Advanced	0.55 b	0.53 b
Intensive	Standard	0.66 a	0.62 a
Intensive	Advanced	0.61 ab	0.56 ab

LSD (0.05)

Agronomic treatments – Becker (irrigated)

	Normal	Intensive*
Hybrid maturity (CRM)	96	103
Planting rate (seeds/acre)	36,000	41,000

* Partial removal of corn stover discontinued in fall 2017

Fertilizer treatments	Standard	Advanced
S	25 lb SO_4/ac	25 lb SO_4/ac
P	U of M guidelines ^	50% grain removal *
K	U of M guidelines ^	UM, UW Research *
10-34-0 in furrow	4 gal/ac	4 gal/ac
V2 N (urea)	40 lb N/ac	40 lb N/ac +
V6 N (urea)	185 lb N/ac	70 lb N/ac
V12 N (urea)	---	70 lb N/ac
VT N (urea)	---	45 lb N/ac
Total N	230 lb N/ac	230 lb N/ac

^ **U of M:** P-only starter (16 lb P_2O_5/ac), K-broadcast (35 lb K_2O/ac)

* **Advanced:** P rate reduced from 100% to 50% of grain removal in 2018, grain removal was 90 lb P_2O_5/ac; K rate was 100 lb K_2O/ac, currently 75-lb

+ Surface-banded starter N replaced with V2 N application in 2018

- **Yield gap = 14 to 59 bu/ac (average = 42 bu/ac)**

LSD (0.05)

- **Greatest yield = advanced fertilizer mgt. + intensive agronomics**

- **Moderate yield = advanced fertilizer mgt. or intensive agronomics**

Agronomic management	Normal	Normal	Intensive	Intensive
Fertilizer management	Standard	Advanced	Standard	Advanced
---------- year ----------	---------- grain yield (bu/ac) ----------			
2014	159 c	192 ab	180 b	205 a
2015	163 d	183 c	197 b	222 a
2016	190 c	189 c	209 b	229 a
2017	169 c	192 b	171 c	224 a
2018	169 c	207 a	190 b	190 b
2019	192 b	206 a	204 a	204 a
6-year average	174 c	195 b	192 b	212 a

Agronomic management	Normal	Normal	Intensive	Intensive
Fertilizer management	Standard	Advanced	Standard	Advanced
Cost of treatments for partial budget analysis	---------- $/ac ----------			
Seed ($3.50/1,000 seeds)	126.00	126.00	143.50	143.50
P_2O_5 pre-plant + application ($0.54/lb P_2O_5)	-	25.38	-	25.38
K_2O pre-plant + application ($0.31/lb K_2O)	10.85	23.25	10.85	23.25
Urea at V2 + application ($0.44/lb N)	17.60	17.60	17.60	17.60
Urea at V6 + application ($0.44/lb N)	81.40	30.80	81.40	30.80
Urea at V12 + application ($0.44/lb N)	-	30.80	-	30.80
Urea at VT + application ($0.44/lb N)	-	19.80	-	19.80
Total	235.85	273.63	253.35	291.13

Cost of drying grain = $0.045/point/bu

Value of grain = $3.50/bu

- **Greatest net return with advanced fertilizer mgt. + intensive agronomics in 4 of 6 years & advanced fertilizer mgt. + normal agronomics in 2 of 6 years**

- **On average, greatest net return with intensive agronomics & either level of fertilizer mgt.**

LSD (0.05)

Agronomic management	Normal	Normal	Intensive	Intensive
Fertilizer management	Standard	Advanced	Standard	Advanced
-------- year --------	---------- partial net return ($/ac) ----------			
2014	264 c	309 b	359 a	367 a
2015	339 b	355 b	490 a	507 a
2016	425 b	371 c	522 a	534 a
2017	337 c	356 b	355 b	474 a
2018	319 bc	392 a	338 b	302 c
2019	389 b	489 a	382 b	348 c
6-year average	346 d	379 b	408 a	422 a

- **Agronomic NUE & corn N recovery efficiency were greatest with advanced fertilizer mgt. & either level of agronomic mgt. (due to greater yield than standard fertilizer mgt. with the same N rate)**

		6-year average	5-year average
Agronomic management	Fertilizer management	Agronomic NUE (increase in yield (bu/ac) per lb N/ac applied)	Corn N recovery efficiency (increase in N uptake (lb N/ac) per lb N/ac applied)
Normal	Standard	0.65 c	0.46 b
Normal	Advanced	0.76 ab	0.60 a
Intensive	Standard	0.74 b	0.50 b
Intensive	Advanced	0.80 a	0.61 a

LSD (0.05)

Summary

- **Experiments established with 10-year horizon**
  - Continue Waseca through 2020 (no AFREC funding for Becker in 2020)
    - Weather & crop response are dynamic over time
    - Long-term treatment effects on soil tests are expected at Waseca, had to move Becker site in 2018
  - Current yield levels are less than potential (weather)
  - Found a significant yield gap among treatments
    - >40 bu/ac in some years
    - UM recs did reduce yields some years
  - Profitability: intensive agronomics vs fertilizer management (N vs P)

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IPNI
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Thank you!

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