

Why is Corn Nitrogen Fertilization More Than the Economic Optimal Rate (EONR) Not the Best Idea?

Newell R. Kitchen and Curtis Ransom Cropping Systems and Water Quality USDA-ARS, Columbia, Missouri

The Fertilizer Industry and Market Updates

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December 29, 2021

Crop Prices Have Improved from Lows



Crop prices have improved significantly due to below trend global production and strong demand in China

Corn Avg. Realized Price



Wheat Avg. Realized Price

USD/bushel



Soybean Avg. Realized Price

USD/bushel



Cotton Avg. Realized Price USD/lb



Note: 2022 futures prices reference Sep 2022 Wheat, Nov 2022 Soybean, Dec 2022 Corn, Dec 2022 Cotton. Source: Bloomberg, USDA

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US corn and soybean supply tightened significantly, resulting in the lowest stocks-to-use ratios in over 7 years for 2020/21E; Tight fundamentals expected to continue into the next marketing year

US Soybean Ending Stocks & Stock/Use Ratio US Corn Ending Stocks & Stock/Use Ratio **Million Bushels** Million Bushels Percent Percent 2,500 18% 25% 1,000 Ending Stocks 16% Stocks to Use 2,000 20% 800 14% 12% 1,500 600 15% 10% 8% 400 1,000 10% 6% Ending Stocks 4% 500 200 5% Stocks to Use 2% 0% 0% 0 $\mathbf{0}$ 14/15 15/16 16/17 17/18 18/19 19/20 20/21E21/22F 14/15 15/16 16/17 17/18 18/19 19/20 20/21E 21/22F USDA USDA USDA USDA

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Source: USDA



US corn export sales remain at near-record highs, however soybean exports sales are at near-average levels to-date

US Soybean Export Sales¹

US Corn Export Sales¹ Million Tonnes



Note: Shading represents a 20-year range of export sales. Data as of October 28, 2021. 1. Represents cumulative sales for each period for the current marketing year. Source: USDA-FAS Alan Blaylock, Ph.D., Senior Agronomist, Nutrien Inc

Structural Changes in Chinese Demand



Jan-21

The rebuild of China's hog herd combined with structural shift in feed rations and corn production shortages has resulted in record import demand and historically high domestic prices

China Soybean & Corn Price

US\$/Bushel

China's Grain Production Surplus/Deficit Million Tonnes



Note: China's grain production surplus/deficit calculated by subtracting domestic consumption from annual production. / December 29, 2021 Source: USDA, Bloomberg Alan Blaylock, Ph.D., Senior Agronomist, Nutrien Inc

Global Natural Gas and Coal Prices



Record natural gas prices in Europe have contributed to plant shut-downs and reduced operating rates, supporting increased prices of all nitrogen products, while the combination of export restrictions and higher coal prices could pressure Chinese urea production in the coming months



Presented on a US\$/MMBtu equivalent basis.
Source: Fertecon, US EIA, Canadian Gas Price Reporter, CRU, Nutrien

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Strong global demand for commodities supporting high crop prices

China push for higher yields/grain imports to rebuild swine herds

Energy volatility has returned

Production curtailments resulting from high energy costs

Skyrocketing energy costs in Europe

Low fertilizer-commodity inventories in key global markets

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Why is it important to improve on what is "acceptable" for corn N Rate decisions?





Why put a focus on corn?

- Of the 5 leading grain crops, corn accounts for > 40% of global grain production.
- Contains over 16 million metric tons of N, which amounts to ~37% of the N of the five leading grain crops.
- From global N budgets, corn fertilizer NUE ranges from 30-40%.



What is EONR and why do we use it?

Phase 1: Don't Limit Yield (pre-1980's)

- Add enough or optimal yield, plus some for insurance
- As genetics improved yield, N rates increased to match crop need
- Documented environmental problems began to emerge

Transition Decade: (1980's)

Phase 2: Focus on Right Rate (1990's-now)

- Guard against N overfertilization
- EONR (Economic Optimal N Rate) emerged. At this fertilization rate the increased return from grain equals the increased fertilizer cost.
- Development of many N rate decision tools



Tools For How Much Nitrogen

Yield Goal-Based

Empirical-Based



Proximal Canopy Sensing





Soil Nitrate Tests

PPNT Pre-Plant Soil Nitrate Test

PSNT Side-dress Soil Nitrate Test

LSNT Late Spring Soil Nitrate Test

Crop Growth and N Transformation Models

Granular Maize-N Climate Adapt-N Sentera FieldApex WinField SCAN

Rates and Charts

State: Iowa Number of sites: 226 Rotation: Corn Following Soybean

MRTN: Maximum Return To N

The N rate where the economic net return to N application is maximized.

5,	
Nitrogen Price (\$/lb): 0.40
Corn Price (\$	/bu): 4.00
Price F	Ratio: 0.10
MRTN Rate (Ib N/a	cre): 140
Profitable N Rate Range (Ib N/acre):	
Net Return to N at MRTN Rate (\$/acre):	
Percent of Maximum Yield at MRTN Rate:	
Anhydrous Ammonia (82% N) at MRTN Rate (lb product/acre):	
Anhydrous Ammonia (82% N) Cost at MRTN Rate (\$/acre):	



PUBLIC-PRIVATE PARTNERING FOR IMPROVING PERFORMANCE OF CORN NITROGEN FERTILIZATION TOOLS



Economic Optimal Nitrogen Rate (EONR)



Corn N Recommendation Tool Performance

Mean difference recommendation tool and EONR



Ransom, C.J. et al., Corn Nitrogen Rate Recommendation Tools' Performance Across Eight U.S. Midwest Cornbelt States. Agron. J.

Corn N Recommendation Tool Performance

Mean difference recommendation tool and EONR





Ransom, C.J. et al., Corn Nitrogen Rate Recommendation Tools' Performance Across Eight U.S. Midwest Cornbelt States. Agron. J.

Corn N Recommendation Tool Performance

% within: ± 30 ("Good"), ± 60 ("Mediocre"), and > or < 60 ("Poor") kg N ha⁻¹ of EONR.



Ransom, C.J. et al., Corn Nitrogen Rate Recommendation Tools' Performance Across Eight U.S. Midwest Cornbelt States. Agron. J.

Crop Canopy Sensing





Bean, G.M., et al. 2018. Improving an Active-Optical Reflectance Sensor Algorithm Using Soil and Weather Information. Agron. J. 110:2541-255.

EONR (lbs N ac⁻¹)

Multiple Tools into a Split Decision Tree



Commercial Nitrogen Management Tools



R7° Field Forecasting

Granular Agronomy





	_						_				
	Pool/Processes/Losses					Other Factors					
ΤοοΙ	Residual	Mineralization	Fixation	Denitrification	Volatilzation	^{Leaching}	Sail Productivity	Management	Writhin-Field Spatial	^{Tem} poral (YR)	^T emporal (within YR)
/ield Goal											
PPNT (YG+)											
PSNT or LSNT											
MRTN											
Canopy Reflectance Sensing											
Crop Growth Models											

Is EONR the Right Target For Corn Nitrogen Fertilizer Management?

- One dimensional objective, an economic production function.
- Ignores other implications, most notably the environmental costs or the unintended negative side effects of N fertilization.

• Evidence that "insurance N" is alive and well under an EONR era. Why? Conditions with too much rainfall and/or uneven rainfall are easily recognized by producers. This uncertainty by weather largely drives insurance fertilizer additions.

How do we balance economics with environmental challenges?

Phytoplankton bloom in the Gulf of Mexico, May 20-25, 2019 Mexico Chlorophyll concentration (mg/m3) NOAA Climate.go Data: NOAAView 0.001 0.173 30.0

Promote Awareness through Nitrogen Use Efficiency (NUE) Metrics

- Producer Efficiency
- Partial Factor Productivity (PFP)
- Agronomic Efficiency (AE)
- Partial N Balance (PNB)
- Recovery Efficiency (RE, plant/grain)

(lb N fertilizer/bu grain)

(lb grain/lb N fertilizer)

(lb grain - check grain)/lb N fertilizer)

(lb grain N/lb N fertilizer)

(lb N - check N)/lb N fertilizer

Attempts to Add Environmental Outcomes

- Workshops, Conferences, and Educational programs
- Integrate environmental with economic (e.g., SONR, Socially Optimal N Rate- EONR is adjusted to include the social cost of remediating N fertilizer pollution (Tyler J. Nigon)
- Government fertilizer allocations or use tax
- Government cost share and other incentive programs offered to producers





Organized by the UMRSHNC (Upper Mississippi River Sob-basin Hypoxia Nutrient Committee

> Sponsored by Iowa State University, the United StatesDepartment of Agriculture (USDA), and the U.S. Environmental Protection Agency (EPA)

"Remember that N use in corn is part of a complex biological system that interacts with everything under the sun and is difficult to model with computer programs. We cannot accurately predict the weather. We cannot accurately predict soil N supply or availability throughout the year. Yet, we cannot afford, financially or environmentally, to simply apply "more than enough" N."

(Applied Crop Research Update, Purdue Univ., Camberato, Nielson, Quinn, 2021)

Successful people (and societies) are humble, and this produces high self-esteem, and from such they have an instinctive attitude to learn from others what to change, even to be corrected.



Clayton Christensen (1952-2020), Harvard Business Professor

Concept of Incremental Nitrogen Use Efficiency



A.R. Dobermann, Nitrogen Use Efficiency- State of the Art, 2005

Incremental Grain N Recovery Efficiency



Nitrogen Rate

A.R. Dobermann, Nitrogen Use Efficiency- State of the Art, 2005

Incremental Grain N Recovery Efficiency

- Greatest incremental NUE averages ~80%
- Incremental NUE ends at EONR
- Incremental NUE at EONR is low (6.4%), defined by prices



Unrealized Profit (or Forgone Profit) Relative to Incremental NUE

• Unrealized profit is alike at low incremental NUE.

• With minor sub-EONR fertilization, profit loss is minimal yet eliminates low incremental NUE.



With modest sub-EONR fertilization, average NUE improvements of ~10% can be realized.



Concluding Thoughts

- We shouldn't be satisfied with where we're at for managing N fertilizer.
- Better tools that integrate site-specific conditions of soil and weather are needed.
- Examining NUE incrementally helps expose the need for exploring more sustainable N fertilizer practices at or even below EONR.
- Since all society would be beneficiaries of improved crop NUE by mitigating against low incremental NUE, programs that provide incentive payments to producers seem appropriate when:
 - Proven practices are used that improve overall NUE through 4R stewardship
 - To match anticipated foregone profit from sub-EONR applications

