UPDATING NITROGEN, PHOSPHATE AND POTASH RATE RECOMMENDATIONS (AGR-1) FOR KENTUCKY GRAIN GROWERS

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ABSTRACT

For University of Kentucky (UK) soil test lab users, soil test phosphorus (P) and potassium (K) have been slowly declining for several decades, suggesting recommended ‘maintenance’ rates (initiated in 1992) were insufficient. Adjusting for modern grain P and K concentrations and increasing yield-driven nutrient removal, we raised corn, soybean and wheat maintenance rates by 10 to 20 lb P_2O_5 and 10 to 30 lb K_2O per acre, depending on the individual crop. Corn nitrogen (N) rate recommendations had not been deeply reexamined in 20 years. In response to a ‘data call’, 174 grain yield N response data sets/entries, from the 2013 to 2023 production seasons, were submitted by UK Plant and Soil Science faculty. Metadata for each entry (previous crop, tillage, soil drainage class, cover crop use, N loss inhibitor use, irrigation, manure use, N timing, N placement) were used to ‘bin’ the data in support of a meta-analysis. Several of the bins were insufficiently populated and unable to support meta-analysis. For 152 of the entries there were sufficient N rates (≥ 3) to determine the maximum yield (YAONR) and the corresponding agronomic optimum N rate (AONR), as well as the maximum economic yield (YEONR) and corresponding economic optimum yield (EONR). For the latter the partial factor productivity (PFP) was set to 0.1 bu/lb N. The AONR, YAONR, EONR and YEONR values were subject to the binning meta-analysis. Compared to the prior recommendations, some bin categories declined (e.g., soil drainage classes dropped from 3 to 2), and certain bin categories increased (e.g., previous crop categories rose from 3 to 4). New bin categories/scenarios were found to impact corn N response and resulted in new recommendations (e.g. without/with a cereal rye cover crop; without/with a N loss inhibitor). Current N rate recommendations, depending on the given scenario, are given as rate range. The new recommendations generally compress these rate ranges, usually by raising the low end of the rate range without greatly increasing the high end of that same range.

INTRODUCTION

Fertilizer P and K maintenance rate recommendations in AGR-1 (Ritchey and McGrath, 2020) have not been reexamined since inception - 1992. Others (G. Schwab, pers. comm.; B. Lee, pers. comm.) have reported that soil test P and K levels are declining in row-crop acres in some areas of Kentucky, even when AGR-1 (Ritchey and McGrath, 2020) fertilizer P and K rate recommendations are followed. This analysis was caused by those observations. The declines imply either that: a) that there has been an expansion in row crop acreage to areas with lower initial soil test P and K levels; or b) that P and K row crop maintenance rate recommendations are not adequate.

Additionally, there had been no substantial change to AGR-1 corn N management recommendations since the 2004-2005 version of the document.

Information about use of urease inhibitors was added at that time. Other N management recommendations last changed in the 2002-2003 edition, when text supporting use of management alternatives to surface urea application after May 1 were added. This does not mean that research results regarding corn N rate recommendations have not been considered. These later evaluations did not find enough evidence supporting the need to make a change. Corn producers and extension personnel voiced concern that current corn N management recommendations were not sufficiently modern = nuanced for more of the alternative practices available to producers.

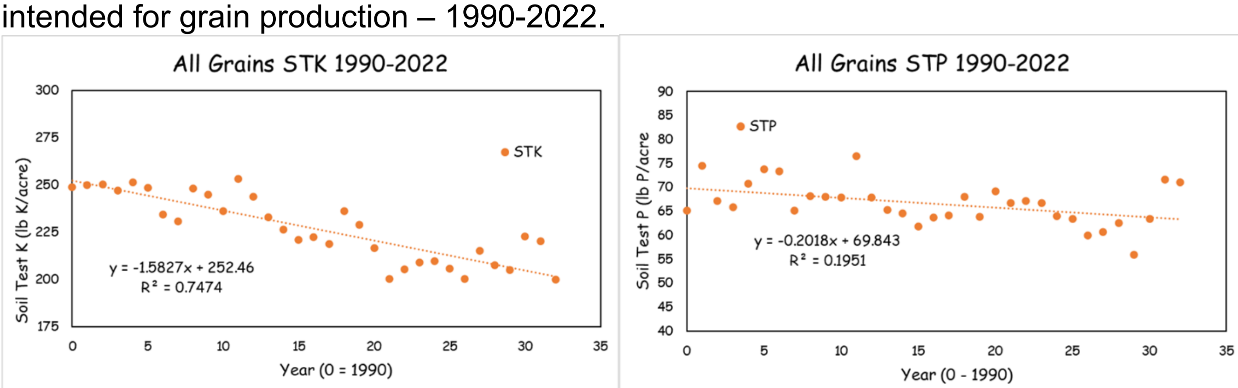
INFORMATION ANALYSES

Soil Test P and K (Mehlich III) Values Over Time

There was a need to verify soil test P (STP) and/or K (STK) changes. The UK soil test lab provided STP and STK data for the 1990 to 2022 period. The data was sorted according to the commodity to be fertilized, as noted on the sample submission sheet, and then by year. Corn, soybean, and winter small grain (barley, canola, oat, rye, wheat) soil test data were separated from other soil test information. Annual sample numbers were around 9300, but considerable fluctuation was observed (not shown).

Across all grain commodities, STK has declined over the entire period (Figure 1a). The annual STK mean values were determined using all values remaining after removal of individual STK values greater than one standard deviation above the mean - to remove samples from manured fields or soils naturally high in STK. The fraction of samples removed, per year, ranged from 9.6 to 15.7%, averaging 12.4%. Annual average STK values fell with time, about 1.6 lb STK/acre/year. Over the past three decades, STK has fallen by about 47 lb STK/acre.

Figure 1. Annual average: a) soil test K (STK); and b) soil test P (STP) values from soils intended for grain production – 1990-2022.



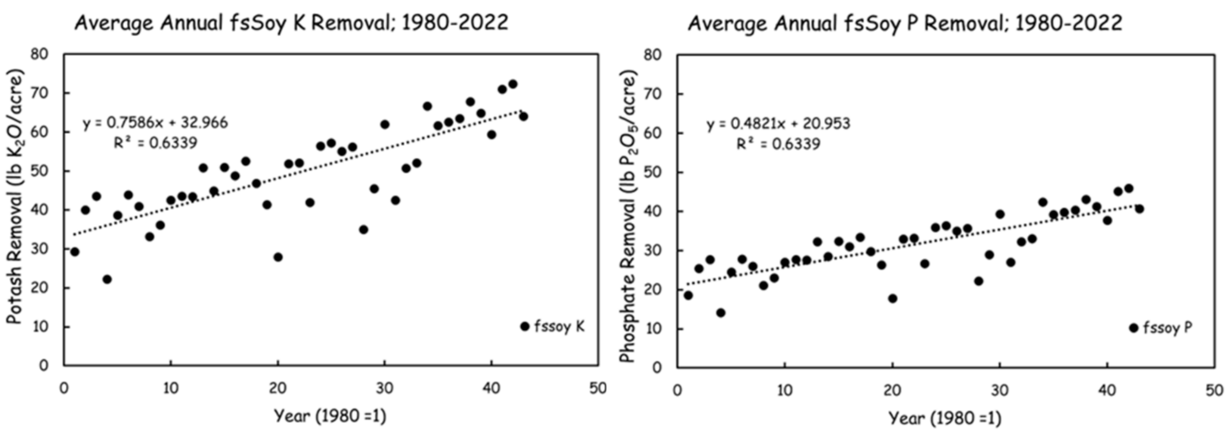
Across the grains, STP has hardly declined (Figure 1b). As was done for STK, the annual STP mean values were determined using all values remaining after removal of individual STP values greater than one standard deviation above the mean - to remove samples coming from manured fields or soils naturally high in STP. The fraction of samples removed, per year, ranged from 7.1 to 12.4%, averaging 9.8%. There was a modest decline, about 0.2 lb STP/acre/year. Over 33 years, STP has fallen by 7 lb STP/acre across this group of samples.

Grain P and K Removal

After a close look at the individual soil test data for corn and soybean, there was little support for the idea that soybean area expansion into less fertile fields caused the temporal decline in STP and STK values. This does not preclude the fact that recent expansion in both corn and soybean acreage has contributed to some of the decline in STP and STK values, but the amount of that contribution is not discernable.

It was known that soil test P and K declines could be related to increasing grain yield, and coincidently greater grain P and K removal. Kentucky's annual average corn, wheat, and soybean grain yield data for 1980 to 2022 were gathered from the National Agricultural Statistics Service (NASS, 2023). A recently published analysis of Illinois corn, soybean and wheat grain P and K composition by Villamil et al. (2019) was used with the annual yield data to compile annual average P and K removal for corn, full-season soybean, wheat and double crop soybean. Figure 2 illustrates that rising full-season soybean yield is driving P and K removal.

Figure 2. Average annual full-season soybean: a) potash; and b) phosphate removal – 1980-2022.



Maintenance P and K Rate Recommendations

Current AGR-1 grain crop P and K rate recommendations are shown in the three tables that constitute Figure 3. The maintenance portion of the recommendations is contained in the red boxes within each table. Mehlich III soil test values are in lb/acre.

Using the generated removal data, proposed grain crop P and K rate recommendations are shown in the three tables shown in Figure 4. The expanded maintenance portion of the recommendations is contained in the green boxes within each table. As in Table 3, Mehlich III soil test values are in lb/acre. Note that there is no proposed change to the Mehlich III soil test values at which no phosphate or no potash are recommended (60 lb STP/acre and 300 lb STK/acre, respectively). Rates below the proposed/expanded maintenance phosphate and potash rates also remain unchanged.

Figure 3. Current AGR-1 grain crop phosphate and potash rate recommendation tables.

Table 13. Phosphate and potash recommendations (lb/A), corn.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
Very high			>420	0
High	>60	0	355 - 420	0
			336 - 354	0
			318 - 335	0
			301 - 317	0
Medium	46 - 60	30	282 - 300	30
	41 - 45	40	264 - 281	30
	37 - 40	50	242 - 263	30
	33 - 36	60	226 - 241	40
	28 - 32	70	209 - 225	50
			191 - 208	60
Low	23 - 27	80	173 - 190	70
	19 - 22	90	155 - 172	80
	14 - 18	100	136 - 154	90
	9 - 13	110	118 - 135	100
	6 - 8	120	100 - 117	110
Very low	1 - 5	200	<100	120

Table 18. Phosphate and potash recommendations (lb/A), small grains.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	48 - 60	30	213 - 300	30
	45 - 47	40	187 - 212	40
	41 - 44	50		
	38 - 40	60		
	34 - 37	70		
	31 - 33	80		
Low	24 - 30	90	159 - 186	50
	17 - 23	100	132 - 158	60
	10 - 16	110	104 - 131	70
Very low	<10	120	<104	80

Table 15. Phosphate and potash recommendations (lb/A), soybean.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	40 - 60	30	242 - 300	30
	34 - 39	40	226 - 241	40
	28 - 33	50	209 - 225	50
			191 - 208	60
Low	22 - 27	60	173 - 190	70
	16 - 21	70	155 - 172	80
	11 - 15	80	136 - 154	90
	9 - 10	90	118 - 135	100
	7 - 8	100	100 - 117	110
	6	110		
Very low	1 - 5	120	82 - 99	120
			64 - 81	130

Figure 4. New AGR-1 grain crop phosphate and potash rate recommendation tables.

Table 13. Phosphate and potash recommendations (lb/A), corn.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
Very high			>420	0
High	>60	0	355 - 420	0
			336 - 354	0
			318 - 335	0
			301 - 317	0
Medium	46 - 60	50	282 - 300	50
	41 - 45	50	264 - 281	50
	37 - 40	50	242 - 263	50
	33 - 36	60	226 - 241	50
	28 - 32	70	209 - 225	50
			191 - 208	60
Low	23 - 27	80	173 - 190	70
	19 - 22	90	155 - 172	80
	14 - 18	100	136 - 154	90
	9 - 13	110	118 - 135	100
	6 - 8	120	100 - 117	110
Very low	1 - 5	200	<100	120

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High	>60	0	>300	0
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	45 - 47	40	187 - 212	40
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	38 - 40	60		
	34 - 37	70		
	31 - 33	80		
Low	24 - 30	90	159 - 186	50
	17 - 23	100	132 - 158	60
	10 - 16	110	104 - 131	70
Very low	<10	120	<104	80

Table 15. Phosphate and potash recommendations (lb/A), soybean.

Category	Test Result: P	P_2O_5 Needed	Test Result: K	K_2O Needed
High	>60	0	>300	0
Medium	40 - 60	40	242 - 300	60
	34 - 39	40	226 - 241	60
	28 - 33	50	209 - 225	60
			191 - 208	60
Low	22 - 27	60	173 - 190	70
	16 - 21	70	155 - 172	80
	11 - 15	80	136 - 154	90
	9 - 10	90	118 - 135	100
	7 - 8	100	100 - 117	110
	6	110		
Very low	1 - 5	120	82 - 99	120
			64 - 81	130

Corn N Nutrition Research Data Sets

In response to a ‘data call’, 174 grain yield N response data sets/entries, from the 2013 to 2023 production seasons, were submitted by UK Plant and Soil Science faculty. Each entry consisted of two or more N rates and the same number of yield values and was accompanied by meta-data that permitted ‘binning’ of the data. Bins permit comparisons guided by existing AGR-1 N rate recommendations, but additional interesting comparisons were also done. Bins were related to soil drainage; tillage; previous crop; a cereal rye cover crop; manure use; irrigation use; N timing; N placement of the largest N fraction; N loss inhibitor use with largest N fraction; and location (grower farm vs. research farm).

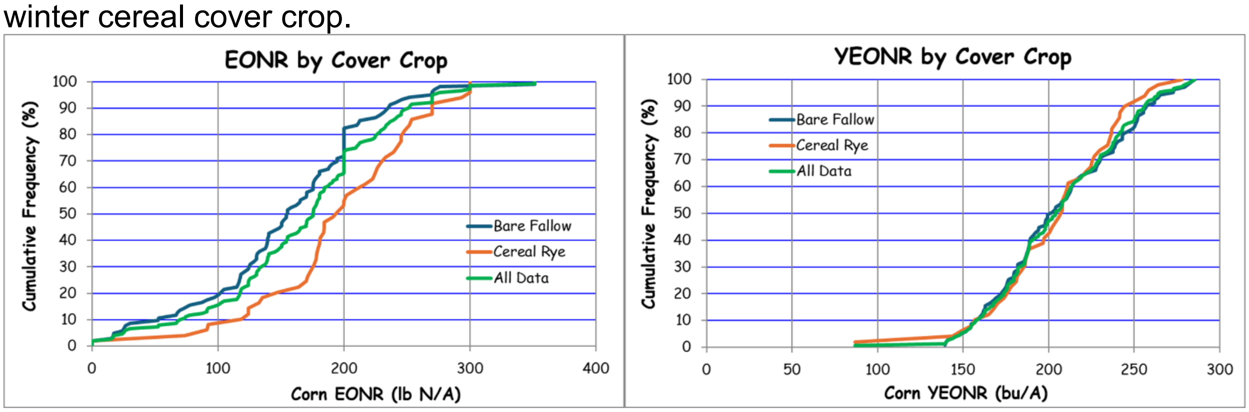
Each entry’s N rate and yield values were used to calculate a corn yield versus N production function, if possible. The quadratic-plateau function was favored, but some entries required linear-plateau, quadratic or linear functions. The production functions were used to determine the parameters that were binned: maximum yield (YAONR), the corresponding agronomic optimum N rate (AONR), the maximum economic yield (YEONR), and the corresponding economic optimum yield (EONR). For the latter the partial factor productivity (PFP) was set at 0.1 bu/lb N. There were enough N rates (n ≥ 3) to determine production function parameters for 152 entries.

Once the parameters were binned, population analysis was done to evaluate differences in bin populations for a given parameter. First, the normality of each bin population was established using measures of skew and kurtosis. All bin populations were found to be normally distributed. Then, one-way ANOVA (PROC UNIVARIATE, PROC GLM) was used to evaluate bin population differences. Cumulative frequency distributions were developed to visualize the parameter bin populations.

Figure 5 illustrates the cumulative frequency distributions for EONR and YEONR depending upon whether a winter cereal cover crop (usually rye) was present (n = 49) or not (n = 103) prior to corn planting. In general, there was a greater spread in EONR values (0 to 352 lb N/acre) than in YEONR values (87 to 286 bu/acre). The EONR populations were significantly different with median values of 155 and 193 lb N/acre in the absence and presence of the cover crop, respectively. The YEONR populations were not significantly different, with median values of 201 and 207 bu/acre in the absence and presence of the cover crop, respectively.

The EONR and YEONR value distributions for the different previous cash crops

Figure 5. The EONR (a) and YEONR (b) value distributions as related to the use of a winter cereal cover crop.



(Figure 6) both exhibited some significant differences. Where corn was the previous crop (n = 49), median EONR was 186 lb N/acre but where either soybean (n = 90) or wheat/double crop soybean (n = 11) were grown previously the median EONR was 161 lb N/acre. The shapes of the EONR cumulative probability distributions differed, while those for YEONR were more similar. Mean YEONR values were not quite significantly different (p>F =0.1449), being 199 and 219 bu/acre where corn followed corn and wheat/double crop soybean, respectively. That said, yield differences were more pronounced at the higher end of the yield spectrum.

Figure 6. The EONR (a) and YEONR (b) value distributions as related to the previous cash crop.

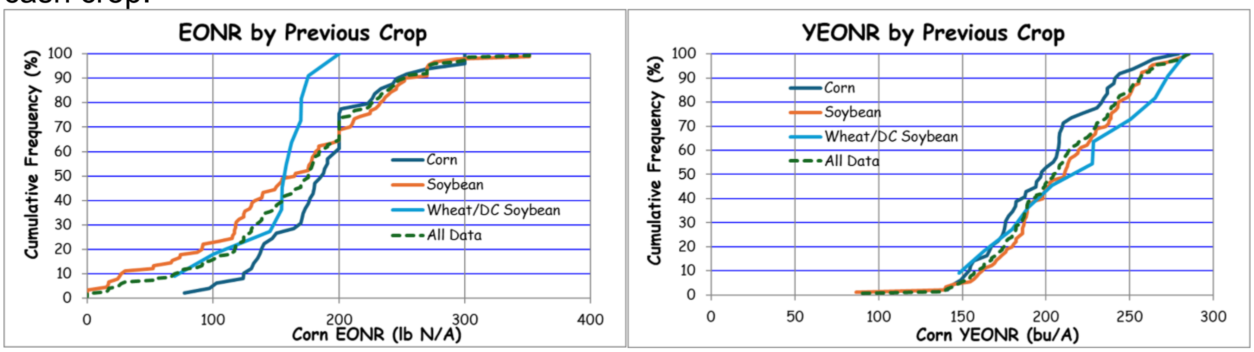
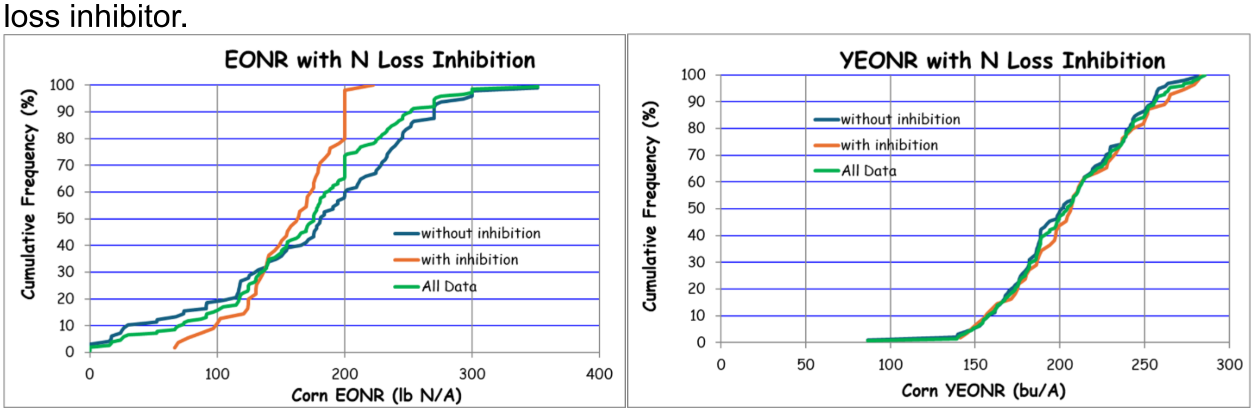


Figure 7 illustrates the impact of N loss inhibitor (usually urease inhibitor) use on EONR and YEONR value distributions. The YEONR values were similar across the distribution and averaged 201 bu/acre where no inhibitor was used (n = 97), and 207 bu/acre where an inhibitor was present (n = 55). The EONR value distributions were not similar, pulling away from each other when the situation required more N nutrition (at higher EONR values). In these cases, the use of the inhibitor reduced EONR values even more.

Figure 7. The EONR (a) and YEONR (b) value distributions as related to the use of an N loss inhibitor.



The previous corn N rate recommendations (Figure 8) were binned according to previous crop, tillage and soil drainage class. There were three previous crop categories (corn was lumped with the other grain crops), tillage differences were established according to the degree of residue cover, and soil drainage classes did not include the somewhat poorly drained class. Other N rate influencing factors are noted.

Figure 8. Current AGR-1 corn N rate recommendations.

Table 12. Recommended application of nitrogen (lb N/A), corn.[1]

Cover Crop	Tillage[3]	Soil Drainage Class[2]: Well-Drained	Soil Drainage Class[2]: Moderately Well-Drained[4]	Soil Drainage Class[2]: Poorly Drained
Corn, sorghum, soybean, small grain, fallow	Intensive	100 - 140	140 - 175	175 - 200
	Conservation	125 - 165	165 - 200	
Grass, grass-legume sod (4 years or less), winter annual legume cover	Intensive	75 - 115	115 - 150	150 - 175
	Conservation	100 - 140	140 - 175	
Grass, grass-legume sod (5 years or more)	Intensive	50 - 90	90 - 125	125 - 150
	Conservation	75 - 115	115 - 150	

[1] Nitrogen rate for irrigated corn should be increased to 175 to 200 lb N/A.
[2] Soil drainage class examples are given on Page 2.
[3] Intensive tillage has less than 30% residue cover, and conservation tillage has more than 30% residue cover on the soil at planting.
[4] Poorly drained soils that have been tile drained should be considered moderately well- drained.

New recommendations (Figure 9) separate corn/sorghum from other prior grown grain crops, simplify "Tillage" as no-till versus any tillage prior to planting, and split the four soil drainage classes into two bins. Table 12a assumes no inhibitor or rye cover crop use. Table 12b clarifies the impact of those two practices on the recommended N rate.

Figure 9. New AGR-1 corn N rate recommendations.

Table 12a. Recommended nitrogen application rate (lb N/A) for dryland corn.[1]

Previous Crop	Tillage[3]	Soil Drainage Class[2]: Well and Moderately Well Drained[4]	Soil Drainage Class[2]: Somewhat Poorly and Poorly Drained
Corn, Sorghum	No-Till	160-190	175-205
	Tilled	150-180	165-195
Soybean, Small Grain, Fallow	No-Till	140-170	155-185
	Tilled	130-160	145-175
Grass, Grass-Legume (≤ 4 years), Winter Annual Legume Cover Crop	No-Till	110-140	125-155
	Tilled	85-115	100-130
Grass, Grass-Legume (≥ 5 years)	No-Till	85-115	100-130
	Tilled	60-90	75-105

[1] Assumes no cereal rye cover crop ahead of corn planting. Assumes no N loss inhibitor used.
[2] Soil drainage class examples are given on Page 2.
[3] No Till = no primary or secondary tillage, fall or spring, prior to planting the crop. Tilled = any primary or secondary tillage, fall or spring, prior to planting the crop.
[4] Somewhat poorly or poorly drained soils that have been tile drained should be considered moderately well drained soils.

Table 12b. ***Cereal rye cover crop and/or urease inhibitor use:***[1] Recommended total nitrogen application rate (lb N/acre) for no-till dryland corn grown on well and moderately well drained soils and where two-thirds or more of the total N rate top/side-dressed with surface applied urea-containing fertilizer in the absence/presence of a cereal rye cover crop without/with use of a urease inhibitor.

Previous Crop	Cereal Rye Cover Crop[3]	Recommended Total N Rate (lb N/acre): No Inhibitor	Recommended Total N Rate (lb N/acre): With Inhibitor[2]
Corn, Sorghum	No	160-190	150-180
	Yes	185-215	165-195
Soybean, Small Grain, Fallow	No	140-170	135-165
	Yes	165-195	150-180

REFERENCES

McGrath, J, and E. Ritchey. 2022. 2020-2021 Lime and Nutrient Recommendations, AGR-1. Univ. Kentucky Coop. Extn. Svc., Lexington, KY.

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