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Fertilizing Corn Grown on Irrigated Sandy Soils

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Most irrigated corn grown in Minnesota is on soils derived from sand and gravel outwash deposits. Sub-soils are sandy while the surface soil's textures can range from sand to silty clay loam. With irrigation, these soils are very productive but nutrient application is necessary to get the most economical production from them. These soils also require high levels of management to control nutrient loss and related environmental degradation and profitability concerns.

NITROGEN BEST MANAGEMENT PRACTICES

Currently, the use of best management practices (BMPs) for nitrogen (N) is voluntary. Corn growers on irrigated sandy soils should implement BMPs to optimize N use efficiency, profit, and protect against increased losses of nitrate-N to groundwater aquifers. The focus of this publication is to present recent findings for N fertilizer use, especially related to rate of application and time of application. For more detailed discussion on time of application, selection of N source, placement of fertilizer N, and decisions regarding the use of nitrification inhibitors please see Extension publications listed under Related Publications.

Rate of N Application

Because of environmental risks and profitability concerns, N is the most important nutrient input for irrigated corn. The corn fertilizer guidelines established in 2006 were based on the use of the Maximum Return To Nitrogen (MRTN) concept. This concept incorporates the productivity of the soil, the cost of N fertilizer, the price received for corn, and the grower's attitude towards risk associated with insufficient N for the crop and risk of environmental degradation.

When the MRTN concept was developed, there was relatively little current information for corn N response on irrigated sandy soils. A decision was made to use data from highly productive fine-textured soils for the irrigated sandy soils until an adequate amount of data was collected under irrigation. Here we discuss N rates based on field research conducted since 2007 on irrigated sandy soils. The corn market and fertilizer costs do affect the economic optimum N rate. To account for this, the ratio of the price of N fertilizer per pound to the value of a bushel of corn is used in the N rate decision. An example calculation of the price/value ratio is if N fertilizer costs $0.50 per lb N or $830 per ton of anhydrous ammonia, and corn is valued at $5.00 per bushel, the ratio would be 0.50/5.00 = 0.10. Once the soil productivity, in this case irrigated sandy soils, and price/value ratio have been determined, a producer's attitude towards risk must be factored into the process. The acceptable range listed in **Table 1**, was calculated as the difference in return of $1 per acre around the MRTN value. Choosing the lowest N rate in the acceptable range, a producer would only reduce profit $1 per acre compared to the MRTN N rate. A producer who is risk adverse and cannot tolerate risk associated with less-than-maximum yield in some years, even though economic return to N may not always be the greatest, may want to use the N rates near the high end of the acceptable range shown in **Table 1**. On the other hand, if input money is tight and/or other risk factors are a concern, producers may choose N rates near the low end of the acceptable range in Table 1. This acceptable range gives the producer flexibility in arriving at an acceptable and profitable N rate. The MRTN value shown in **Table 1** is the N rate that maximizes profit to the producer based on the results of experiments supporting these guidelines.

The N rate guidelines in **Table 1** are used if corn is grown in rotation with corn on irrigated sandy soils.

Table 1. Guidelines for use of N fertilizer for corn after corn grown on irrigated sandy soils.

N price/Crop value ratio	MRTN	Acceptable range
	------------- lb N/acre -------------	
0.05	233	214 – 252
0.10	209	192 – 225
0.15	191	177 – 206
0.20	177	164 - 190

To arrive at a guideline following other crops, an adjustment (credit) is made to the corn following corn guidelines. The adjustments can be found in Table 2. In **Table 2**, several crops are divided into Group 1 and Group 2. The crops for each group are listed in **Table 3**.

The N rates listed in **Table 1** define the total amount of fertilizer N that should be applied to maximize returns on the N investment. Any N applied in a starter fertilizer, weed and feed program, DAP (di-ammonium phosphate) or MAP (mono ammonium phosphate) should be included in the calculation of the total amount of N applied during the growing season.

Table 2. Nitrogen credits for different previous crops for first year corn.

Previous crop	1st year N credit
	lb N/acre
Soybean	30
Harvested alfalfa	100
Group 1 crops	75
Group 2 crops	0
Edible bean	20
Field pea	20

Table 3. Crops in Group 1 and Group 2.

Group 1 crops	Group 2 crops	
alsike clover	barley	potatoes
birdsfoot trefoil	buckwheat	rye
grass/ legume hay	canola	sorghum-sudan
grass/ pasture	corn	sugar beet
fallow	grass hay	sunflower
red clover	grass pasture	sweet corn
	oats	vegetables
		wheat

If your irrigation water has more than 10 ppm of nitrate-N in it, you should account for the amount supplied by the irrigation water above 10 ppm when determining the amount of N to apply. Irrigation water below 10 ppm nitrate-N is considered background N.

Table 4. Nitrogen credits for some forage legumes if corn is planted two years after the legume.

Legume crop	2nd year N credit
	lb N/acre
Harvested alfalfa	50
Red clover	35

It's generally accepted that legume crops provide N to the next crop in the rotation. Some forage legumes provide some N in the second year after the legume was grown. These second year N credits are listed in **Table 4.** If corn is grown in the second year following alfalfa and red clover, these N credits should be subtracted from the N rates in **Table 1.**

Time of N Application

The impact of timing of fertilizer N application for irrigated corn has been the focus of considerable research. Results of these research efforts lead to the conclusion that split applications are superior to a single application. Results from recent studies, **Table 5**, confirm this conclusion with modern corn production. The value of the split application is especially influenced by the amount and frequency of rainfall during the growing season. In 2012, there was considerable rainfall (5 to 6 inches) between planting and the first split application. Corn yield data confirms the superiority of split applications of urea in a wet year. While 2013 was not as wet, split application corn yields were still superior.

Table 5. The effect of split N applications on corn yields. Nitrogen was applied at 160 lb N/A. Rosen and Lamb 2014.

Method	2012		2013	
	Site 1	Site 2	Site 1	Site 2
	---- Corn grain yield (bu/A) ----			
Check (no N)	119	75	110	46
Urea pre-plant	164	106	190	172
BMP V2, V4	193	198	221	159
4 way split V2, V4, V6, and V8	210	220	228	190

When leaching is a potential problem, either a two or four equal side-dress N applications after emergence produced the greatest grain yields. Yields were low when all of the N fertilizer was applied before planting.

Based on the results of research trials conducted over the years, pre-plant applications are not recommended. There are several options for split applications on irrigated sands. These are:

- N in starter plus side-dress N
- N in the starter plus split side-dress N
- N in the starter plus side-dress N plus N injected in the irrigation water
- N in the starter plus N injected in the irrigation water
- N in the starter plus pre-emergence herbicide applied with UAN plus side-dress N
- N in the starter plus pre-emergence herbicide applied with UAN plus N injected with the irrigation water.

From both an agronomic and environmental perspective, split application of fertilizer N is a good management practice. There are many choices and the grower can choose the one that fits the farming enterprise. When planning a system for split application for corn, the last application of N should take place before the silks turn brown.

Nitrogen Sources and Additives

Responding to the recognition that loss of nitrate-N caused by leaching is a universal concern enhanced efficiency products have been developed to reduce the potential for loss. The use of these products can be especially important in irrigated sandy soils where N loss potential is great.

Table 6. The effect of N products applied pre-plant on corn grain yield that reduce potential for N loss in sandy soils. Nitrogen was applied at a 160 lb N/A rate. Rosen and Lamb 2014.

Product/Method	2012		2013	
	Site 1	Site 2	Site 1	Site 2
	Corn grain yield (bu/A)			
Check (no N)	119	75	110	46
ESN* preplant	165	160	232	187
Instinct**preplant	136	132	233	191
Super U***preplant	182	116	231	190
Urea preplant	164	106	190	172
BMP V2, V4	193	198	221	159
4 way split V2,V4, V6, V8	210	220	228	190

* ESN is urea coated with a polymer that slows N release.
** Instinct is a formulation of nitrapyrin for urea, UAN, and manure.
*** Super U is a combination of a nitrification inhibitor (DCD) and urease inhibitor (NBPT).

In a recent study comparing several different enhanced efficiency products, the products produced greater corn grain yields than untreated urea applied pre-plant, **Table 6**. When compared to a two or four way split in-season application of urea, the enhanced efficiency products were not superior. In only 1 of 9 site years, N products produced better corn yields than the 2 way split application and in the 9 site years, the products produced either equal or less corn grain yield than the 4 way split application of urea.

Application Below the Soil Surface

Although the risk is minimal with acid sandy soils, there can be some loss of N via volatilization if fertilizer N is placed on the soil surface and not incorporated. It is suggested to incorporate any N (28-0-0, 46-0-0, etc.) that is applied to the soil surface. Cultivation or irrigation water can be used for this incorporation. Application just prior to rain would also be acceptable. Studies conducted in other states in the Corn Belt have shown that 0.25 inches of irrigation water or rainfall is necessary to incorporate either 46-0-0 or 28-0-0 that has not been previous incorporated.

PHOSPHATE AND POTASH GUIDELINES

When needed, the use of phosphate and/or potash fertilizer can produce profitable increases in corn yields. The guidelines for phosphate use are summarized in **Table 7** and for potash in **Table 8**.

Phosphate

The phosphate guidelines provided in **Table 7** change with phosphorus (P) soil test level, expected yield, and placement. In general, the results of the Olsen test should be used if the soil pH is 7.4 or higher. Because at those pH levels the bray test tends to underestimate the amount of plant-available P. However, there are some situations when soil pH values are higher than 7.4 where the results of the Bray test are higher than the results of the Olsen test. In these cases, base the phosphate application off the higher value.

Measurement of P by the Mehlich-III procedure is not recommended in Minnesota. However, if the soil testing laboratory uses this analytical test, follow the category guidelines for the Bray procedure as long as the soil pH is less than 7.5. The Olsen test is suggested when the soil pH is higher than 7.4 because while the Mehlich-III test is correlated to the Olsen test, the Olsen P categories in **Table 7** do not match the Mehich-III test.

Table 7. Phosphate guidelines for corn production in Minnesota.*

Expected yield		Soil test P (ppm)									
	Category:	v. low		low		medium		high		v. high	
	Bray:	0-5		6-10		11-15		16-20		21+	
	Olsen:	0-3		4-7		8-11		12-15		16+	
	Placement:	Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band
bu/acre		---------- lb P_2O_5 per acre to apply ----------									
175 – 199		110	55	75	40	45	30	15	10-15	0	10-15
200 – 219		130	65	90	45	55	30	20	10-15	0	10-15
220 – 239		145	75	100	50	60	3o	20	10-15	0	10-15
240 +		160	80	115	60	70	35	25	10-15	0	10-15

** Use one of the following equations to determine the amount of P_2O_5 if a specific soil test value and a specific expected yield is desired.*

lb P_2O_5 per acre = [0.700 - 0.035 (Bray P ppm)] (expected yield)

lb P_2O_5 per acre = [0.700 - (0.044 (Olsen P ppm)] (expected yield)

No phosphate fertilizer should be applied if the soil test for P is greater than 25 ppm (Bray) or 20 ppm (Olsen).

Rate Changes with Placement

A combination of band and broadcast applications is suggested when the soil test for P is very low (0-5 ppm for Bray; 0-3 ppm for Olsen). In these situations, use the suggested band rate in a band at planting, subtract this amount from the suggested broadcast rate, then broadcast and incorporate the remainder before planting.

Phosphate fertilizer can be applied either as a broadcast application or in a band if the soil test value for P is in the low (6-10 ppm for Bray; 4-7 ppm for Olsen) or medium (11-15 ppm for Bray; 8-11 ppm for Olsen) categories.

Broadcast applications of phosphate fertilizer have a low probability of increasing corn yields when the soil test or P is in the high category (16-20 ppm for Bray; 12-15 ppm for Olsen) but a banded application can be more advantageous. No phosphate fertilizer is needed (broadcast or banded) if the soil test is higher than 25 ppm (Bray), or 20 ppm (Olsen), in conventional tillage systems.

Potash

As with phosphate, the guidelines for potash vary with the potassium (K) soil test level, expected yield, and placement (**Table 8**). A combination of band and broadcast applications is suggested when the soil test for K is very low (0-40 ppm). In these situations, use the suggested band rate in a band at planting, subtract this amount from the suggested broadcast rate, then broadcast and incorporate the remainder before planting.

Potash fertilizer can be applied either as a broadcast application or in a band if the soil test value for K is in the low (41-80 ppm) or medium (81-120 ppm) categories.

Broadcast applications of potash have a low probability of increasing corn yields when the soil test value for K is in the high category (121-160 ppm), but a banded application can be more advantageous.

There is a low probability of response to broadcast applications of potash if the soil test for K is higher than 160 ppm. No potash fertilizer is needed (broadcast or banded) if the soil test is greater than 175 ppm in conventional tillage systems.

Potassium can be considered a mobile nutrient in very sandy soils that have low nutrient holding capacity. Split application of K has been proposed as a way to maintain K availability through the growing season. However, field studies over two growing seasons showed no yield advantage to split applied K in irrigated sandy soils.

Table 8. Potash guidelines for corn production in Minnesota.*

	Soil test K (ppm)									
Category:	v. low		low		medium		high		v. high	
Expected	0-40		41-80		81-120		121-160		160+	
yield	Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band	Bdcst	Band
bu/acre	lb K_2O per acre to apply									
175 - 199	185	90	135	70	80	50	25	10-15	0	10-15
200 - 219	210	105	165	80	90	55	30	10-15	0	10-15
220 -239	235	120	165	85	100	60	30	10-15	0	10-15
240 +	255	130	180	90	110	65	35	15-20	0	10-15

** Use one of the following equations to determine the amount of* K_2O if *a specific soil test value and a specific expected yield is desired.*

lb K_2O per acre = [1.166 - 0.0073 (soil test K, ppm)] (expected yield)

No potash fertilizer should be applied if the soil test for K is 175 ppm or higher.

The study showed no differences in K availability in the soil or plant K uptake when K was applied in a single pre-plant application pre-plant, side-dress at V5, or in a split application at pre-plant and at V5. The study illustrated that targeting the appropriate rate of K_2O is more important than the timing of application.

Special Considerations

Because of the diversity in Minnesota's soils and climate, land rental and lease arrangements, and goals of individual growers, the phosphate and potash recommendations listed in **Tables 7 and 8** cannot be rigid across the entire state. There are some special situations where rates might be changed. Some, but not all, of these situations are described in the following paragraphs.

East Central Minnesota

Soils in this region of the state usually have high native levels of soil test P and strict interpretation of the recommendations suggests that no phosphate is needed in a fertilizer program. Yet, many have observed responses to phosphate when applied in a band at planting. Soils in this region are frequently cool and wet in the spring and these conditions can lead to a requirement for phosphate fertilizer early in the growing season. Therefore, regardless of soil P level, a rate of 10-20 lb. P_2O_5 per acre in a band close to the seed is suggested for corn production in these situations.

Broadcasting Low Rates

Some of the guidelines for phosphate and potash use listed in **Tables 7 and 8** are small and fertilizer spreaders cannot be adjusted to apply these low rates. In some situations, the suggested broadcast rate of phosphate can be blended with the suggested broadcast rate of potash and the mixture could then be applied with available equipment.

In other situations, broadcast applications of low rates of only phosphate or potash may be suggested. For these fields, it may be more practical to double the suggested broadcast rate and apply on alternate years.

Changes in Soil Test Values

Many growers would prefer to maintain soil test values for P and K in the medium to high categories. This is especially true if they own, rather than rent, the land. There is justified concern that soil test levels for either P or K will drop substantially if low rates of phosphate or potash fertilizers are applied year after year.

Research in Minnesota has shown that soil test levels for P and K do not change rapidly with time. Yearly decreases have been small for situations where no phosphate or potash fertilizer has been applied.

A small decrease in soil test levels for P and K can be expected when phosphate and potash are used repeatedly in a banded fertilizer application. Likewise, some reduction can be expected when low rates of phosphate and potash are used year after year. When soil test values drop, broadcast applications of higher rates of phosphate and/or potash fertilizers are justified if profitability and cash flow is favorable and the grower wants to maintain soil test values in the medium or high categories.

Unless long-term leases or rental arrangements are used, a banded application of phosphate and/or potash may be the most profitable management system for rented land. It is difficult to economically justify the use of high rates of phosphate and/or potash to build soil test levels on rented acres.

ADJUSTING FOR MANURE USE

The plant nutrients used in a fertilizer program for corn should be reduced if manure is used. The nutrient value of manure, however, varies with type of livestock, handling system, and method of application. Old general rules are no longer appropriate when calculating the nutrient value of manure. Manure nutrient credits should be subtracted from the fertilizer guideline. There are several extension publications that describe in detail the use of manure. These publications are listed at the end of this folder.

BANDING FERTILIZER

The use of a banded fertilizer at planting is an excellent management tool for corn production in Minnesota especially when soil conditions are cold and wet at planting. Yield increases are not always guaranteed with the use of a starter when soil test values are in the very high category. Recent research shows frequent response to banded fertilizer when soil test values for P and/or K are in the high category and yield potential is high. Banding P and/or K can be considered a good insurance policy.

The rate of fertilizer that can be applied in a band below and to the side of the seed at planting varies with the nutrient and type of fertilizer used, the distance between seed and fertilizer, and soil texture. See Use of Banded Fertilizer for Corn Production (FO-74250) for more information.

CAUTION! Do not apply urea (46-0-0), ammonium thiosulfate (12-0-0-26) or fertilizer containing boron in contact with the seed.

SULFUR USE

The addition of sulfur (S) to a fertilizer program should be a major consideration when corn is grown on sandy soils, reduced tillage systems or in a long continuous corn rotation.

The use of a soil test for S is not a reliable predictor of the need for sulfur in a fertilizer program. If the soil texture is a loamy sand or sandy loam, either apply 12 to 15 lb. S per acre in a banded fertilizer or broadcast and incorporate 25 lb. S per acre before planting. The optimal amount of S may vary based on the organic matter concentration in the top six inches of the soil surface. If organic matter concentrations are greater than 4.0% the amount of S required to maintain high yields may be as little as 10-15 lb S per acre.

There are several materials that can be used to supply S. Any fertilizer that supplies S in the sulfate (SO_4^{2-}-S) form is preferred. Elemental S is cost effective but must be oxidized to SO_4^{2-}–S to be available for corn uptake. The oxidation process is slow and is dependent on soil temperature. Elemental S should not be applied as the soil S source in situations where a deficiency is expected. Because the greatest need for S occurs early in the growing season, application of any needed S in a starter fertilizer is preferred. Keep in mind that ammonium thiosulfate should not be placed in contact with the seed. This material will not harm germination or emergence if there is 1 inch of soil between the seed and the fertilizer.

Is there a benefit from split application of S for irrigated corn?. Sulfate is mobile in the soil but the mobility depends on soil texture. Movement can be rapid on very sandy soils but decreases as the relative amount of clay in the soil increases. Research found no yield benefit from split applications of S on irrigated fields even in situations with heavy precipitation totals in May and June. This research also indicated that a significant portion of corn uptake, (10-20 lbs SO_4^{2-}-S per acre) could be applied through the irrigation water during the growing season. It is critical to have some available S early in the growing season when no irrigation water is applied.

MAGNESIUM NEEDS

Most Minnesota soils have an adequate natural supply of with magnesium (Mg), thus this nutrient is not usually needed in a fertilizer program. There are some exceptions, however. The very acid soils of east-central Minnesota might need Mg. There should be no need for the addition of Mg if dolomitic limestone has been applied for legume crops in the rotation. There is a soil test that can be used to predict the need for Mg. The guidelines for using Mg in a fertilizer program are summarized in **Table 9**.

Table 9. Guidelines for magnesium use for corn production.

Magnesium soil test	Relative level	Mg to apply	
		Band	Broadcast
ppm		------- lb per acre -------	
0 – 50	Low	10 - 20	50 - 100
51 – 100	Medium	Trial*	0
101 +	Adequate	0	0

*Apply 10 -20 lb. Mg per acre in a band only if a Mg deficiency is suspected or if a deficiency has been confirmed by plant analysis.

MICRONUTRIENT NEEDS

Table 10. Zinc guidelines for corn production in Minnesota.

	Zinc to apply	
Zinc soil test*	Band	Broadcast
- ppm -	------------- lb per acre -------------	
0.0 – 0.25	2	10
0.26 – 0.50	2	10
0.50 – 0.75	1	5
0.76 – 1.00	0	0
1.01 +	0	0

* Zinc extracted by the DTPA procedure.

Research trials conducted throughout Minnesota indicate that zinc (Zn) is the only micronutrient that may be needed in a fertilizer program for the corn production. This nutrient, however, is not needed in all fields. The soil test for Zn is very reliable and will accurately predict the needs for this essential nutrient. The guidelines for Zn are summarized in **Table 10.** Because corn is the only agronomic crop that will consistently respond to Zn fertilization, the use of Zn in a banded fertilizer is highly recommended. However, carryover to succeeding years will be better with broadcast applications. There are several fertilizer products that can be used to supply Zn. Except for large particles of zinc oxide, all commercially available sources of this nutrient are equally effective so cost should be a major consideration in product selection.

The use of iron (Fe), copper (Cu), manganese (Mn), and boron (B) is not suggested for corn fertilizer programs in Minnesota.

Additional information about nutrient management in all crops can be found at: www.extension.umn.edu/agriculture/nutrient-management.

The Corn Nitrogen Rate Calculator can be found at: http://extension.agron.iastate.edu/soilfertility/nrate.aspx

For more information: www.extension.umn.edu/agriculture/nutrient-management/