Corn fertilization

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Profitable corn production requires an adequate soil fertility program. Insufficient nutrients will lower yields; excess nutrients will lower profit margins and may damage the environment through nutrient runoff and leaching. Corn must receive adequate amounts of nutrients to fully realize yield benefits from other management practices such as early planting dates, selection of adapted hybrids, and effective weed and insect control. This publication will help you supply the optimum nutrient level for your fields.

Determining nutrient needs

Corn uses substantial amounts of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) and relatively small amounts of secondary nutrients and micronutrients. Table 1 lists specific amounts of each nutrient removed from the soil by corn stover and grain at a yield level of 150 bushels/acre. The nutrients taken up by the plants must be supplied either from soil reserves or by adding nutrients. A deficiency of any of these nutrients can reduce yields.

The best way to determine the level of nutrients available in the soil and the kinds and amounts of supplemental fertilizer needed is through soil testing and using locally calibrated fertilizer recommendations based on soil test results. Optimum soil test levels on various Wisconsin soils are shown in table 2.

Soil sampling procedures for all nutrients except nitrogen are outlined in Extension publication *Sampling Soils for Testing* (A2100). Soil sampling for nitrogen tests is described in *Soil Nitrate Tests for Wisconsin Cropping Systems* (A3624). Detailed information on fertilizer recommendations based on soil test results can be found in *Soil Test Recommendations for Field, Vegetable and Fruit Crops* (A2809).

If insufficient nutrients are available to the corn plant, it will often develop an abnormal

Table 1. Nutrient content of corn grain and stover at 150 bu/acre yield

Nutrient	Grain	Stover	Total
	lb/acre		
Nitrogen (N)	120	51	171
Phosphorus (P_2O_5)[a]	57	14	71
Potassium (K_2O)[b]	37	150	187
Calcium (Ca)	1	29	30
Magnesium (Mg)	8	21	29
Sulfur (S)	9	7	16
Zinc (Zn)	0.10	0.15	0.25
Boron (B)	0.03	0.10	0.13
Manganese (Mn)	0.07	0.33	0.40
Iron (Fe)	0.06	1.10	1.16
Copper (Cu)	0.02	0.09	0.11

[a]Divide by 2.3 to convert to P.
[b]Divide by 1.2 to convert to K.
Calculated from data compiled at Wisconsin and at the Indiana Agricultural Experiment Station.

Table 2. Optimum Wisconsin soil test levels for corn

Nutrient	Sandy soils	Medium-textured soils		
		Southern and western	Eastern red	Northern
	ppm			
Phosphorus	23–32	11–20	16–20	13–18
Potassium	66–90	81–110	81–100	101–130
Calcium	401–600	601–1000	601–1000	601–1000
Magnesium	51–250	101–500	101–500	101–500
Sulfur	30–40	30–40	30–40	30–40
Manganese	11–20	11–20	11–20	11–20
Zinc	3.1–20	3.1–20	3.1–20	3.1–20

appearance or symptoms characteristic of deficiency for the specific nutrient. Deficiency symptoms for several nutrients are listed in table 3. When corn shows these symptoms, especially during the early to mid-season growth stages, the deficiency is probably severe and yield reductions are likely. Color photographs illustrating deficiency symptoms on corn and other crops are shown in the publication *Nutrient Deficiencies and Application Injuries in Field Crops* (IPM-42, July 1994), available from Iowa State University Extension.

Table 3. Visual symptoms of nutrient deficiency in corn

Nutrient	Deficiency symptom
Nitrogen	Yellowing of the lower leaves. Yellowing occurs along the midrib. Leaf margins may remain green.
Phosphorus	Purpling of the leaves early in the growing season. The purple or reddish color appears first on older leaves and usually disappears before the plant reaches 18 to 24 inches.
Potassium	Yellowing or browning of the lower leaves. Yellowing occurs along the edges of the leaf with the midrib remaining green.
Sulfur	The entire plant is stunted and light green in color. Yellowing between veins in leaves is sometimes apparent.
Zinc	Broad bands of bleached or yellow tissue on either side of the midrib beginning at the base of the leaf. Leaf midrib and margins remain green. Symptoms usually appear on mature leaves near the top of the plant.

Plant analysis or visual deficiency symptoms can be used during the growing season to identify nutrient deficiencies that may limit crop growth. Information on use of plant analysis to diagnose fertility problems is provided in publication *Sampling for Plant Analysis: A Diagnostic Tool* (A2289). Table 4 shows the generally accepted sufficiency ranges of most essential nutrients at several corn growth stages. Recognize, though, that site-specific factors such as soil characteristics, climatic conditions, and corn hybrid affect the concentration of nutrients in corn leaves and will influence plant analysis results.

If visual symptoms are used to diagnose nutrient deficiencies, note that weather-related stress, insect or disease damage, and inappropriate pesticide or fertilizer applications can also produce abnormal appearance in corn. Use plant analysis and soil testing to confirm apparent nutrient deficiency symptoms.

Liming for corn production

Aglime recommendations are based on the target pH level of the most acid-sensitive crop in a crop rotation or sequence. The optimum or target pH for corn grown on mineral soils in Wisconsin is 6.0. When corn is grown in rotation with alfalfa the target pH is 6.8 due to the greater sensitivity of alfalfa to soil acidity.

Nitrogen recommendations

Nitrogen fertilizer program

Corn yields are more often limited by inadequate supplies of nitrogen than by deficiencies of other essential nutrients. This is because corn has a high nitrogen requirement and losses of applied nitrogen can occur during the growing season by leaching, denitrification, or other processes. Thus, it is important to accurately determine corn nitrogen requirements and to use effective management practices to minimize losses of applied nitrogen.

Corn requires annual additions of nitrogen from fertilizer, manure, or previous legume crops because the amount of soil-supplied nitrogen is usually less than the total crop requirement. Table 5 gives soil-specific nitrogen recommendations for Wisconsin corn based on soil yield potential, soil texture, and soil organic matter content. Once the organic matter content for a field is known from soil test results, it is not likely to change significantly from year to

Table 4. Nutrient sufficiency ranges for corn at several growth stages

Nutrient	Seedlings, 24–45 days[a]	Third leaf, 45–80 days[b]	Ear leaf at silking
	%		
Nitrogen	4.0–5.0	3.5–4.5	2.76–3.75
Phosphorus	0.40–0.60	0.35–0.50	0.25–0.50
Potassium	3.0–5.0	2.0–3.5	1.75–2.75
Calcium	0.51–1.6	0.20–0.80	0.30–0.60
Magnesium	0.30–0.60	0.20–0.60	0.16–0.40
Sulfur	0.18–0.40	0.18–0.40	0.16–0.40
	ppm		
Zinc	25–60	20–60	19–75
Boron	6–25	6–25	5.1–40
Manganese	40–160	20–150	19–75
Iron	40–500	25–250	50–250
Copper	6–20	6–20	3–15

[a]*Seedlings 6 to 16 inches tall; 24 to 45 days after planting.*
[b]*Third leaf from top; plants over 12 inches tall, before silking.*
Source: Schulte and Kelling, University of Wisconsin-Madison, 1986.

Table 5. Annual nitrogen recommendations for corn

Soil organic matter	Sands and loamy sands		Other soils—yield potential[a]	
	Irrigated	Non-irrigated	Medium/low[b]	Very high/high
%	lb N/acre			
<2.0	200	120	150	180
2.0–4.9	160	110	120	160
5.0–20.0	120	100	90	120
>20.0	80	80	80	80

[a] *To determine soil yield potential, consult Extension publication* Soil Test Recommendations for Field Vegetable, and Fruit Crops *(A2809) or contact your agronomist or county agent.*
[b] *Irrigated non-sandy soils with a medium or low yield potential should receive the nitrogen recommendation for very high/high yield potential soils.*

year. Yield potential ratings are given for essentially all soil names used in Wisconsin in Extension publication *Soil Test Recommendations for Field, Vegetable, and Fruit Crops* (A2809).

The nitrogen recommendations in table 5 differ for sandy soils (sands and loamy sands) depending on whether or not they are irrigated. The lower recommendations for non-irrigated sandy soils reflect the lower corn yield potential in an environment where moisture is often inadequate. For medium- and fine-textured soils, nitrogen recommendations are based on soil yield potential and organic matter content. The yield potential ranking for each soil series is based on soil characteristics such as drainage, depth of root zone, and water holding capacity. Soils with very high or high yield potentials receive higher nitrogen recommendations than those with a medium or low yield potential ranking. Yield goals are not a factor in making nitrogen recommendations. Numerous studies have shown that optimum nitrogen rates for corn are not closely tied to yield. In fact, the optimum nitrogen rate for corn on a given soil is similar in high and low yielding years. Yields are more variable than optimum nitrogen rates because corn recovers nitrogen more efficiently in favorable growing conditions and less efficiently in poor growing conditions.

The nitrogen recommendations in table 5 should usually be considered the maximum amount of nitrogen needed for economically optimum corn yields. These recommendations must be adjusted for manure and legume nitrogen contributions; additional adjustments based on soil nitrate test results will often be appropriate.

Nitrogen credits for manure and legumes. Where manure has been applied or where previous legume crops were grown, refer to tables 6 and 7 to determine the appropriate credits to subtract from the total nitrogen recommendations in table 5. Research in Wisconsin and other states shows that manure can provide the total nitrogen needs of corn and that a good or fair alfalfa stand prior to growing corn can provide most or all of the corn's nitrogen requirement. Using appropriate nitrogen credits for these common agricultural practices is essential for efficient nitrogen use in corn production and minimizing the environmental risk to groundwater associated with overapplications.

Adjustments for high corn residue cover. When corn is planted in fields with at least 50% residue cover from the previous corn crop, increase the nitrogen application by 30 lb/acre. This additional nitrogen is not needed where the previous crop was soybean or a forage legume. To increase nitrogen efficiency, inject the nitrogen below the surface residue. The added nitrogen is needed mainly to offset the lower annual amount of nitrogen mineralized from soil organic matter in high corn residue systems, and possibly to compensate for nitrogen that may be immobilized in surface residues.

Table 6. Expected first-year available nitrogen from manure[a]

Manure source	Nitrogen credit			
	Solid (lb N/ton)		Liquid (lb N/1000 gal)	
	incorp.[b]	not incorp.	incorp.[b]	not incorp.
Dairy	4	3	10	8
Beef	4	4	12	10
Swine (finish)	5	4	28	22
Swine (farrow)	5	4	15	12
Poultry	15	13	41	35

[a] *Residual credits are also expected for the second and third years (see A2809).*
[b] *Injected or incorporated into the soil within 72 hours after spr eading*

Nitrogen fertilizer management

The nitrogen recommendations in table 5 assume that appropriate management practices are used to minimize nitrogen losses. The nitrogen application rate decision is the most important management factor affecting the profitability of nitrogen use in corn production and the risk of nitrate loss to groundwater. The key initial step in arriving at the nitrogen rate decision is to use the appropriate recommendations for the soil and to credit the amounts of nitrogen provided from non-fertilizer sources. Soil nitrate tests can often help to identify optimum nitrogen rates for corn on a site-specific basis.

In addition to the rate applied, other nitrogen management options can also influence fertilizer effectiveness. These options include the nitrogen fertilizer source used, the method and timing of nitrogen application, and use of a nitrification inhibitor with ammonium forms of fertilizer nitrogen. For more information about nitrogen management for corn production refer to Extension publication *Nutrient Management Practices for Wisconsin Corn Production and Water Quality Protection* (A3557).

Soil nitrate tests. The recent development of soil tests for assessing soil nitrogen levels has provided new tools for improving the efficiency of nitrogen fertilizer applications to corn. Soil nitrate tests allow nitrogen fertilizer recommendations to be adjusted for field-specific conditions that can influence crop nitrogen needs. In fields where a soil nitrate test has been used, nitrogen fertilizer recommendations can often be reduced to reflect the soil's residual nitrate content and the nitrogen that will be released from organic sources.

Two soil nitrogen tests are currently available. The preplant soil nitrate test (PPNT) assesses nitrogen requirements by measuring the residual soil profile nitrate before planting corn. The pre-sidedress soil nitrate test (PSNT) estimates nitrogen availability mainly from organic nitrogen sources and predicts the amount needed for a sidedress or in-season nitrogen application.

Preplant soil nitrate test samples are usually collected too early in the growing season to measure nitrogen released from fall or spring manure applications, previous legume crops, and soil organic matter. To credit manure and legume nitrogen where preplant soil nitrate tests are taken, provide field management information on these practices with the soil samples. This information will be used to adjust nitrogen recommendations for legume and manure nitrogen in addition to the adjustments for soil nitrate. The preplant nitrate test is most useful where corn follows corn in a rotation. The preplant test is not useful if corn follows a forage legume (alfalfa). In this situation, take the standard nitrogen credit for the previous legume crop or use the pre-sidedress soil nitrate test. Sampling procedures for the preplant soil nitrate test are described in Extension publication *Soil Nitrate Tests for Wisconsin Cropping Systems* (A3624).

Table 7. Nitrogen credits for previous legume crops

Crop	Sandy soils		Other soils	
	<8" regrowth	>8" regrowth	<8" regrowth	>8" regrowth
	lb/a			
Alfalfa[a]				
good stand (>70%)	100	140	150	190
fair stand (30–70%)	70	110	120	160
poor stand (<30%)	40	80	90	130
Red clover or birdsfoot trefoil				
good stand (>70%)	80	110	120	150
fair stand (30–70%)	50	90	90	130
poor stand (<30%)	30	60	70	100
Soybean	—	0	—	40

[a]*For second-year, a 50 lb credit is given on non-sandy soils if the stand is fair or good.*

The pre-sidedress soil nitrate test should be taken when corn plants are 6 to 12 inches tall, usually 4 to 6 weeks after planting. Conversion (mineralization) of organic nitrogen to the plant-available nitrate form has usually occurred by the time pre-sidedress samples are collected. Consequently, this soil test can estimate the amount of nitrogen released from previous legumes, fall/spring manure applications, and soil organic matter as well as residual nitrate in the top 12 inches of soil. The pre-sidedress soil nitrate test can be a valuable tool for confirming the amount of nitrogen credited from manure or previous legume crops. For more information on both the preplant and pre-sidedress soil nitrate tests, see Extension publication *Soil Nitrate Tests for Wisconsin Cropping Systems* (A3624).

Fall nitrogen application. Fall nitrogen applications have a higher risk of nitrogen loss than other timing options. Fall-applied nitrogen has more time to leach into groundwater or to denitrify before the crop can use it. Nitrogen losses between application and uptake the following growing season mean less nitrogen is available for crop recovery, reducing corn yield. An increased risk of nitrogen loss during the fall and early spring should be weighed against any advantages associated with fall-applied nitrogen.

Fall to spring precipitation, soil texture, and soil moisture conditions influence the potential for fall-applied nitrogen losses. Thus, the relative effectiveness of fall nitrogen applications varies widely from one year to the next depending on climatic conditions. Wisconsin research has shown fall applications on medium-textured soils to be 10 to 15% less effective than the same amount of nitrogen applied preplant in the spring.

Fall application of nitrogen fertilizer is not recommended on coarse-textured soils or on shallow soils over fractured bedrock. If fall applications are to be made on other soils, they should be limited to the application of ammonium-nitrogen sources such as anhydrous ammonia, and should be applied only after soil temperatures at the 6-inch soil depth are below 50°F. Use of a nitrification inhibitor (discussed later) with ammonium forms of nitrogen is likely to improve the effectiveness of fall applications. Research indicates, however, that fall applications of nitrogen with an inhibitor are still not likely to be as effective as spring-applied nitrogen.

Sidedress or delayed nitrogen application. Sidedress applications 4 to 6 weeks after planting are an effective method of applying nitrogen to corn on all soils. Benefits from sidedress applications are likely to be greatest on sandy soils and fine-textured, poorly drained soils where the risks of nitrogen loss through leaching or denitrification are high. Delaying nitrogen application for 4 to 6 weeks after planting will avoid early season nitrogen losses and provide available fertilizer nitrogen to the crop when it needs it most. Research on sandy irrigated soils shows consistently higher corn yields with sidedress applications than with nitrogen applied before planting. Spring preplant applications are usually as effective as sidedress treatments on medium-textured, well-drained soils because the risk of early season nitrogen loss on these soils is low. The optimum rate for the sidedress nitrogen applications can often be determined using the pre-sidedress soil nitrate test (see earlier discussion).

The timing of sidedress nitrogen applications for corn is critical. Corn takes up nitrogen rapidly beginning about 6 weeks after planting and continuing until 10 to 12 weeks after planting. To provide adequate amounts of nitrogen to corn during this period, make sidedress applications no later than 6 weeks after planting. Multiple applications of nitrogen through irrigation systems are also effective. These applications should be timed so that some nitrogen is applied by the sixth week after planting, and most of the nitrogen requirement is applied by the tenth week after planting.

Sidedress or delayed postemergence fertilizer nitrogen applications can be made where these nitrogen additions were planned or where early season weather conditions prevented preplant nitrogen applications. The priority for postemergence applications should be those fields most likely to respond to nitrogen. This usually will be fields that do not have forage legume or manure nitrogen credits. Corn following a forage legume or where substantial amounts of manure have been applied may not need additional nitrogen.

Postemergence broadcast applications of urea-ammonium nitrate solution (UAN) or urea over growing corn will cause burning of the plants, and may reduce yields if high nitrogen rates are used. Minnesota research showed that leaf burn increased in severity as rates of UAN increased and as corn plants aged. However, postemergence UAN can be applied at rates up to 90 lb N/acre at the four- to five-leaf corn growth stage or up to 60 lb N/acre at the eight-leaf stage without reducing yields. These maximum application rates may need to be reduced if herbicides are applied with the UAN.

Broadcast application of dry urea fertilizers over growing corn is an alternative postemergence application option. Some burning of corn plants is likely where urea particles stick to the leaves or are trapped in the whorl of the plants. Although the maximum rates of broadcast urea that can be applied to corn without reducing yields are not known, the rate suggestions for UAN shown above may be reasonable guidelines for urea-nitrogen rates.

Use of nitrification inhibitors. A nitrification inhibitor such as nitrapyrin (N-Serve) or dicyandiamide (DCD) can be used with ammoniacal fertilizer nitrogen to reduce nitrogen losses under some conditions. Nitrification inhibitors slow the conversion of ammonium to nitrate by soil bacteria. More information on nitrogen reactions in soils is provided in Extension publication *Soil and Applied Nitrogen* (A2519). Because leaching and denitrification losses occur through the nitrate form of nitrogen, use of an inhibitor to maintain fertilizer nitrogen in the ammonium form should reduce these losses.

Nitrification inhibitors used with fertilizer nitrogen typically increase corn yields only when there is a high risk of nitrogen loss through leaching or denitrification. For example, fall or spring preplant nitrogen applications on fine-textured, poorly drained soils are at a high risk of nitrogen loss through denitrification. Similarly, nitrogen losses through leaching are probable when spring preplant applications are made to sandy soils. In both these situations, a nitrification inhibitor applied with the fertilizer will increase yields. However, sidedress applications without an inhibitor may be more effective than a spring preplant application with an inhibitor. Nitrification inhibitors are not likely to increase corn yields when used with sidedress nitrogen applications because the risk of nitrogen loss with this application method is low on all soil types.

Ammonia loss from surface-applied urea-containing fertilizers. Urea and urea-containing nitrogen solutions (28% UAN) are important nitrogen fertilizer sources in Wisconsin. More than half of the fertilizer nitrogen used in the state is applied as urea or a urea-containing material. When urea-containing fertilizers are surface applied but not incorporated into the soil, significant amounts of the applied nitrogen can be lost to the atmosphere as ammonia. Nitrogen losses through ammonia volatilization are promoted by crop residue cover on the soil surface, absence of rainfall following urea application, high temperatures, and high soil pH.

Research on silt loam soils indicates that 15 to 20% of the urea nitrogen surface-applied to corn can be lost as ammonia, and subsequent corn yield reductions are likely if these losses occur. Substantially higher losses can occur if urea is surface-applied on sandy soils. Rainfall (at least 0.2 inch) within 3 days following urea application will prevent significant ammonia loss. Nitrogen loss through ammonia volatilization can be eliminated on most soils by incorporating or injecting urea-containing fertilizers into the soil. Where urea must be surface-applied, use of urease inhibitors can reduce ammonia losses.

Urease inhibitors used with surface-applied urea-containing fertilizers have potential for reducing ammonia losses and improving nitrogen efficiency in high residue systems. However, they do not give consistent yield increases. A summary of recent research suggests that the urease inhibitor NBPT increases corn yields about 30 to 40% of the time where urea-containing fertilizers were surface applied. Yields can be reduced in 5 to 10% of the cases. The decision to use a urease inhibitor will depend upon the risk of nitrogen loss that could be controlled by a urease inhibitor, the cost of using the inhibitor, and the cost and convenience of other nitrogen sources or placement methods that are not subject to ammonia loss. These alternatives could include injecting or incorporating the urea-containing fertilizers or using non-urea nitrogen sources.

Phosphate and potash recommendations

Recommendations for annual phosphate (P_2O_5) and potash (K_2O) applications for corn grain and silage production are shown in tables 8 and 9, respectively. These fertilizer recommendations are based on anticipated crop phosphorus and potassium removal at various yield levels and on soil test results. At optimum soil test levels, the recommended phosphorus and potassium additions are approximately equal to anticipated crop removal. The recommendations are set to optimize economic return and maintain soil test levels in the optimum range. Additions of phosphorus and potassium are essential to prevent reductions in yields. At low and very low soil test levels, the recommended phosphorus and potassium additions reflect anticipated crop removal plus additional phosphorus and potassium

Table 8. Annual P_2O_5 and K_2O fertilizer recommendations for corn grain production

Yield goal	Soil test level[a]				
	VL	L	Opt	H	EH
bu/acre	K_2O to apply (lb/acre)				
71–90	60–90[b]	50–70[b]	30	15	0
91–110	70–100[b]	60–80[b]	40	20	0
111–130	75–105[b]	65–85[b]	45	25	0
131–150	85–115[b]	75–95[b]	55	25	0
151–170	90–120[b]	80–100[b]	60	30	0
171–190	100–130[b]	90–110[b]	70	35	0
191–210	105–135[b]	95–115[b]	75	40	0
	P_2O_5 to apply (lb/acre)				
71–90	50–80[c]	40–65[c]	25	15	0
91–110	55–85[c]	45–70[c]	30	15	0
111–130	60–90[c]	50–75[c]	35	15	0
131–150	65–95[c]	55–80[c]	40	20	0
151–170	70–100[c]	60–85[c]	45	20	0
171–190	75–105[c]	65–90[c]	50	20	0
191–210	80–110[c]	70–95[c]	55	25	0

[a] *Abbreviations: VL = very low, L = low, Opt = optimum, H = high, EH = excessively high.*
[b] *Use the higher values on sandy or organic soils.*
[c] *Use the lower values on sandy or organic soils.*

Table 9. Annual P_2O_5 and K_2O fertilizer recommendations for corn silage production

Yield goal	Soil test level[a]						
	Phosphorus			Potassium			
	Opt	H	EH	Opt	H	VH	EH
tons/acre	P_2O_5 to apply (lb/acre)			K_2O to apply (lb/acre)			
≤16	50	25	0	100	50	25	0
16.1–20	65	30	0	120	60	30	0
20.1–25	85	40	0	135	70	35	0
>25	100	50	0	150	75	40	0

[a] *Abbreviations: Opt = optimum, H = high, VH = very high, EH = excessively high.*

to raise the soil test levels to optimum over a 5- to 8-year period. Recommendations for soils testing high are reduced to half the anticipated removal. For soils testing excessively high, no phosphorus or potassium is recommended. The reduced rates allow a gradual lowering in above-optimum soil test levels and, for most soils, will not reduce soil test levels below the optimum range in 4 years of cropping.

Soil nutrient levels need to be monitored closely to detect changes in phosphorus and potassium status so that soil fertility levels can be maintained in the optimum range. Soil tests should be taken at least every 3 years and preferably every other year on sandy soils and other soils with low buffering capacity.

Manure can provide part or all of the phosphate and potash requirements for corn production. Recommended credits are 3 lb of P_2O_5/ton and 8 lb of K_2O/ton of solid dairy manure or 8 lb of P_2O_5/1000 gal and 21 lb of K_2O/1000 gal of liquid dairy manure. If manure analyses have been obtained, credit 55% of the total P_2O_5 and 75% of the total K_2O. Subtract appropriate nutrient credits for manure from fertilizer recommendations (see table 6).

Starter (row) fertilizer

In areas with short growing seasons, such as Wisconsin, a band or row application of fertilizer near the seed at planting provides a readily available supply of nutrients to corn seedlings early in the season when root growth and nutrient release from organic matter are slow.

Table 10. Maximum recommended starter fertilizer rates for corn.

Placement method	Sands	Silts & clays
	lb fertilizer/acre	
With seed (pop-up)	50*	50*
Side (2 inches x 2 inches)	300	500

[a]*Limit the N + K_2O to 10 lb/acre.*

Wisconsin research has shown that starter fertilizer often increases corn yields, and starter fertilizer is widely used in corn production in the state.

Numerous research trials have led to a series of recommendations on starter fertilizer composition, placement, rates, and factors affecting response. Corn yield benefits to starter fertilizer application are most consistently observed when a complete fertilizer containing all three of the major nutrients (nitrogen, phosphorus, and potassium) is used. Starter fertilizers containing potassium are particularly beneficial on compacted soils and in no-till systems. A side placement located about 2 inches below and 2 inches to the side of the seed (2 x 2) performs as well as or better than other placement alternatives such as with-seed placement (pop-up), surface broadcast, surface banded, or deep banded treatments.

All of the phosphorus and potassium needs for corn can be applied as starter when a side placement is used. However, rates of seed-placed starter must be carefully monitored to avoid stand and yield reductions. The maximum rates for side- and seed-placed starter fertilizer are listed in table 10. Never use fertilizers containing urea for seed placement because corn stand and yield reductions are likely.

Although corn response to starter decreases with increasing phosphorus and potassium soil test levels, profitable yield responses to starter sometimes occur on soils with excessively high soil tests. Results from numerous on-farm studies show that profitable yield responses occur about 30 to 40% of the time on soils with excessively high phosphorus and potassium soil tests.

The frequency of starter response increases as the combined effect of hybrid relative maturity (RM) and planting date result in an inadequate growth period to realize the crop's yield potential. To estimate the likelihood of response on soils with high to excessively high phosphorus and potassium soil tests, calculate the sum of the hybrid RM and the Julian date (day of year) of planting (PDRM). When PDRM values are in the 220 to 230 range, 30 to 40% of the sites will respond to starter fertilizer; response occurs 50 to 60% of the time when PDRM values range from 240 to 250.

The frequency of response to starter fertilizer is also influenced by soil test potassium level. More frequent responses occur where soil test potassium levels are in the optimum and high range;

response is less frequent when soil test potassium is excessively high (over 150 ppm). At high PDRM values, response to starter is much more frequent at soil test potassium levels less than 150 ppm. Where soil test potassium is excessively high, the frequency of response to starter is not affected by soil test phosphorus levels ranging from 24 to 125 ppm. Responses to starter at sites with soil test phosphorus values above 125 ppm are not likely.

Recommendations for starter fertilizer

Sites with excessively high soil tests. Apply a minimum rate of starter fertilizer of about 10+20+20 ($N+P_2O_5+K_2O$), which will produce the full starter benefit at responsive sites. The nutrients in a 10+20+20/acre application rate are substantially less than crop removal at normal yield levels. For example, corn yielding 150 bu/acre removes about 55 lb of P_2O_5/acre and 40 lb of K_2O/acre (table 1). If this minimal starter application of 10+20+20/acre is the only phosphorus and potassium applied for the crop, the excessively high soil test levels will be drawn down.

Sites with high or optimum soil tests. Soils with phosphorus and potassium tests in the high or optimum ranges will need more phosphorus and potassium than is provided in the minimum starter application of 10+20+20/acre (see removals at the 150 bu/acre corn grain yield level in table 1). Producers may wish to increase starter fertilizer application rates to provide the entire crop phosphorus and potassium requirement or use the minimum starter fertilizer rate at planting and supply the additional phosphorus and potassium needed with a broadcast application.

Manured sites. Where substantial amounts of manure are applied to meet part or all of the corn nitrogen requirement, phosphorus and potassium additions in the manure will often meet or exceed the plant needs. In these cases, starter fertilizer application rates should not exceed the minimum 10+20+20/acre application rate.

Crediting starter nutrients in nutrient management plans. Typical amounts of nitrogen in starter fertilizer (10 to 20 lb N/acre) are not credited against the crop nitrogen requirement. Where higher amounts of nitrogen are applied in starter, that portion of the nitrogen that exceeds 20 lb N/acre should be credited. All of the phosphate (P_2O_5) and potash (K_2O) in starter fertilizer should be credited against crop needs.

Secondary and micronutrient recommendations

Calcium and magnesium

The most economical method of applying calcium and magnesium for corn is through use of dolomitic lime to maintain soil pH levels above 6.0. This provides adequate amounts of calcium and magnesium for corn production on most Wisconsin soils. Magnesium deficiency on corn has been observed on some sandy soils following moderate to heavy applications of potassium fertilizer or ammonium forms of nitrogen fertilizer and where papermill lime sludge was used. High concentrations of potassium or ammonium in sandy soils with low magnesium content interfere with magnesium uptake by corn. This magnesium deficiency usually does not occur unless the potassium soil test level is higher than the magnesium soil test level. Under these conditions, magnesium deficiency in corn can be corrected or prevented by band application of 10 to 20 lb magnesium/acre as magnesium sulfate (Epsom salt).

Sulfur

Sulfur deficiency in corn is rare in Wisconsin, but isolated deficiencies have been observed, particularly in northern Wisconsin. Sulfur deficiency is most likely to occur on sandy soils, on soils with less than 3% organic matter, and on soils that have not received recent manure applications.

The sulfur availability index, described in Extension publication *Soil and Applied Sulfur* (A2525), reflects the amounts of sulfur provided from all sources. Use this index to determine the need for sulfur fertilization. Where sulfur fertilization for corn is necessary, apply 10 to 20 lb sulfur/acre either with the starter fertilizer or broadcast. Sulfate forms of sulfur or elemental sulfur may be used. Elemental sulfur should be applied before anticipated crop use to allow time for conversion to plant-available sulfate.

Zinc

Zinc is the micronutrient most likely to be deficient in corn, because corn has a relatively high requirement for this nutrient. Deficiencies usually occur on eroded or scalped soils with low organic matter content, on sandy soils, on organic soils with pH values above 6.5, and on soils with high levels of available phosphorus.

Use soil tests or plant analysis to determine if there is a need for added zinc. If these tests indicate a need for zinc fertilization, apply 2 to 4 lb zinc/acre in a band or 4 to 8 lb zinc/acre broadcast. Additional information on determining the need for and applying zinc fertilizers can be found in *Soil and Applied Zinc* (A2528).

Manganese

Manganese deficiencies in corn are rare in Wisconsin. They are most likely to occur on the high pH, red soils of eastern Wisconsin and on dark-colored, high pH soils in southeastern Wisconsin. Organic soils that have been burned can also be deficient in manganese. A band application of 5 to 10 lb manganese/acre effectively corrects manganese deficiencies when soil tests or plant analyses indicate manganese fertilization is necessary. Broadcast applications of manganese are not recommended. Extension publication *Soil and Applied Manganese* (A2526), contains additional information on diagnosing and correcting manganese deficiencies.

Copper

Copper deficiency is usually confined to acid soils, particularly mucks. It is unlikely that copper fertilization will be required for corn production on most Wisconsin soils. Copper fertilizer recommendations can be found in *Soil and Applied Copper* (A2527).

Boron

Boron deficiency in corn is rare in Wisconsin. Soil test interpretations for this element are based on alfalfa and other crops with higher boron requirements. Only 0.5 oz of boron is removed in 150 bushels of corn. However, too much boron applied close to the seed (e.g., in row fertilizer) may inhibit germination and reduce yields. Response to boron is most likely in high-yielding irrigated corn on sandy soils, but even here no documented responses to this element have been reported. Additional information on boron in soils and use of fertilizers containing boron can be found in *Soil and Applied Boron* (A2522).

Iron, molybdenum, chlorine

Fertilizer applications of these nutrients are not recommended since deficiencies have not been observed in Wisconsin corn crops.

Additional information

For information on related subjects, see the following publications available from Cooperative Extension:

Sampling Soils for Testing (A2100)

Soil Nitrate Tests for Wisconsin Cropping Systems (A3624)

Soil Test Recommendations for Field, Vegetable, and Fruit Crops (A2809)

Sampling for Plant Analysis: A Diagnostic Tool (A2289)

Nutrient Management Practices for Wisconsin Corn Production and Water Quality Protection (A3557)

Urea—Its Use and Problems (A2898)

Soil and Applied Nutrients:
- Nitrogen (A2519)
- Phosphorus (A2520)
- Potassium (A2521)
- Boron (A2522)
- Calcium (A2523)
- Sulfur (A2525)
- Manganese (A2526)
- Copper (A2527)
- Zinc (A2528)
- Iron (A3554)
- Molybdenum (A3555)
- Chlorine (A3556)

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