SDSU Extension

iGrow Corn

BEST MANAGEMENT PRACTICES

Chapter: 23

Estimating Yield Goals and Nitrogen, Phosphorus, Potassium, Iron, and Zinc Recommendations

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South Dakota nitrogen, phosphorus, and potassium fertilizer recommendations are based on soil test results, yield goals, and other credits. Directions for converting yield estimates and soil test results to nitrogen (N), phosphorus (P), and potassium (K) recommendations are provided below. The purpose of this chapter is to provide guidance on applying N, P, K, Fe, and Zn fertilizers. Recommendations for lime, sulfur, starter fertilizers, and band-applying fertilizer are provided in Chapters 25, 26, and 27.

Table 23.1 General guidelines for estimating corn yield goals should consider that:

- Corn yields in South Dakota over the past 20 years have been increasing at an annual rate of ≈2.0 bu/acre/year.
    - For example, 140 bu/acre + (10 years)×(2 bu/year) = 160 bu/acre today
- When estimating the yield goal, it is not recommended to consider more than 10 years of data.
- Abnormally high or low yield values should be excluded from yield goal estimates.
- Managing for an optimistic, yet realistic, yield goal is important. Underestimating the yield can contribute to a gradual yield decline.
- Achieving full yield potential depends on management, climate, soil, and will vary from field to field and year to year.

Fertilizer Recommendation Yield Goals

In South Dakota, fertilizer recommendations for nitrogen (N), phosphorus (P), and potassium (K) are based on the expected yield or "yield goal." Calculating yield goals should include adjustments for annual yields that have been increasing at a rate of 2 bu/(acre× year). Guidelines for calculating yield goals are provided in Tables 23.1 and 23.2. There are many different approaches used to estimate the yield goal. One approach uses field records to calculate the field's historical average yield followed by using the soil moisture content at planting to adjust the goal, other methods include removing unusually low or high values. Low yields could result from droughts, floods, hail, uncontrollable pest infestation, late harvest, or other extraordinary events, whereas unusually high yields can result from ideal growing conditions that are unlikely to regularly occur.

Nitrogen Recommendations

N Transformations

Nitrogen (N) applied to soil undergoes many transformations facilitated by soil microbes and chemical reactions (Fig. 23.1). These reactions influence how much is lost, retained in the soil, or utilized by the target plants. Nitrogen can be lost by volatilization, leaching, denitrification, and runoff. Nitrogen lost through these mechanisms increases costs and can reduce yields. Volatilization is the loss of ammonia gas (NH_3) from soil, fertilizer, and manure. Research reports that up to 100% of the ammonia-N contained in manure can be lost through volatilization if the manure is left on the soil surface (Lauer et al., 1975), whereas over 30% of the urea-N can be lost to volatilization when urea is left on the soil surface (Clay et al., 1990).

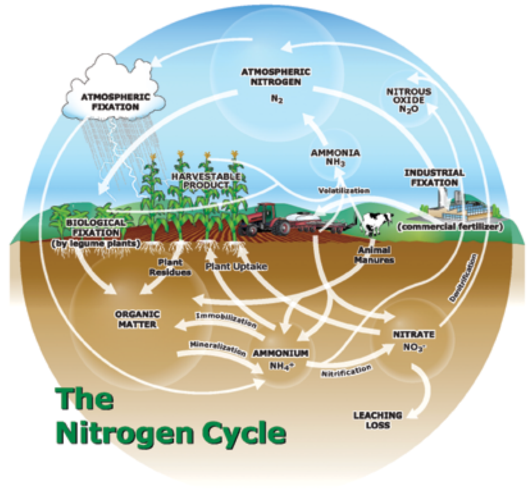

Figure 23.1 Important N transformations in agricultural soils. (Courtesy of IPNI)

Denitrification is a microbial conversion of nitrate (NO_3-) to nitrous oxide (N_2O) or nitrogen (N_2) gas, and it is the highest when the soils are warm and wet. If the soil is well-drained denitrification losses are relatively low. Denitrification can be reduced by treating the fertilizer with a nitrification inhibitor or splitting the N rate.

Nitrate leaching occurs because both the NO_3- molecule and soil have a negative charge. Nitrate losses can be high following a heavy rain and it is more rapid in sandy soil than in medium- and fine-textured soils. Nitrate leaching losses can be reduced by splitting the N application. Immobilization is the conversion of inorganic N into organic N by plants and soil microbes. Immobilization reduces the amount of inorganic N available to the crop and it can lead to early season N deficiencies. N immobilization is highest when crop residues with high carbon to nitrogen (C/N) ratio are left in the field. Immobilized N becomes available to the plant as microbes themselves die and decay. Reduced-tillage and no-tillage systems often have high immobilization.

Nitrogen fixation is the conversion of atmospheric N (N_2) to plant available N by bacteria. Common South Dakota rotations include soybeans and alfalfa where N fixation can provide up to 40 and 150 lbs N/acre, respectively, for the following corn crop (Gerwing and Gelderman, 2005). Nitrogen mineralization is the biological conversion of organic N to inorganic N, whereas nitrification is the biological oxidation of ammonia or ammonium to nitrite followed by the oxidation of the nitrite to nitrate. Nitrification inhibitors slow the conversion of ammonia to nitrate and they can reduce N losses in sandy soils from leaching and denitrification losses in high clay soils (Franzen, 2013). If a substantial amount of N has been lost, the plants may have N deficiencies. Under these conditions, it may be possible to add additional N as a split application or in the irrigation.

N Plant Uptake and Movement

In the soil, both nitrate and ammonia can be utilized up by the corn plant. These ions move to the root in the water transpiration stream and by diffusion. Once in the plant, N is mobile and will move from older parts of the plant to newer growth (translocation). Translocation results in deficiency symptoms appearing as yellow V-shaped patterns on lower leaves (Fig. 23.2). If crop growth stage allows, soil sampling and an injected sidedress application according to soil test results is recommended. In some states, active-optical sensor algorithms have been developed to direct in-season N application to corn (Franzen, 2014). Algorithms from other states should be used as a starting algorithm, with modifications from local grower field sensing and yield

Figure 23.2 Nitrogen deficiency in corn. Note the V-shaped chlorosis in older leaves and that the lowest leaves (oldest leaves on the plant) are dead. (Umesh M. Rangappa, University of Agricultural Sciences, Raichur, courtesy IPNI, Notes: The photo was taken at 67 days after planting. The soil was a sandy clay loam)

correlation considered as more local data is acquired. In irrigated systems, fertigation according to yield goal and soil test results is a viable option.

N Recommendation Model

The South Dakota N recommendation for grain and silage are:

N grain rec. (lbs/acre) = yield goal×1.2– soil NO_3-N- manure N + no-till adjustment

N silage rec. (lbs/acre) = (10.4 lbs N/ton silage) – soil NO_3-N- manure N + no-till adjustment

The South Dakota whole field N recommendation (1.2 lbs N/bu grain yield goal) was recently tested (Kim et al., 2013). This assessment showed that prior to 2012 the model was reasonably accurate. The multiplier (1.2 lbs/acre) used to determine the N recommendation is currently being assessed. Preliminary analysis suggests that the multiplier could be reduced to 1 lb N/bu. An example for determining the yield goal is below (Table 23.2).

Table 23.2 Estimating the corn grain yield goal:

1. Standardize your data. Over the past 10 years, genetic improvements have increased yields on average 2 bu/(acre year).
   a. For yields measured 5 years ago, add 10 bu/acre.
2. Remove the low and high value.
   a. Delete the 171 and 112 bu/acre yields.
3. Determine the average.
   a. The average yield of years 1, 2, 3, 4, 5, 6, 8, and 10 is 136bu/acre.
4. If the soil water content of soil profile is at field capacity add 10% to the average yield goal.
   a. Field capacity is the maximum amount of water that can be held in soil after excess drainage (Chapter 33).
   b. 136+136×0.10 =150 bu/acre
5. If the soil moisture content is poor, subtract 10%.
   a. 136 -136×0.10 = 123 bu/acre

Year	#Standardized yield (bu/A)	Conditions
1	136	Average
2	133	Average
3	126	Average
4	128	Average
5	126	Average
6	145	Average
7	*171	Excellent
8	163	Excellent
9	*112	Poor
10	129	Average

Base yield goal = 136

Recommendation =136 bu + 10%*136 = 149.6 ~150 bu

Estimating N Fertilizer Credits

Soil NO_3-N

Residual soil NO_3^--N is estimated by analyzing a 0- to 24-inch soil sample collected in the spring. Additional information for collecting soil samples is available in Chapter 21. To obtain accurate soil test results, the sampling technique should consider prior management, and should involve separately sampling areas such as wet spots, old homesteads, old fence lines, field entry points, hay piles, turnrows, or salt-affected patches. If a soil sample is not available, residual-soil N can be estimated using the long-term soil test average of 55 lbs/acre. If the field was summer fallowed the previous year and if a soil sample is not available, 100 lbs/N acre can be used to estimate residual nitrate-N. Soil testing for residual nitrate is most important for continuous corn and where manure is routinely applied (Fig. 23.3). In sensitive areas, such as over shallow aquifers, an additional sample from the 24- to 48-inch depth should be collected. If the soil test N exceeds 30 lbs nitrate-N/acre in the 24- to 48-inch depth, 80% of that amount of N should be added to the residual N credit (Gerwing and Gelderman, 2005).

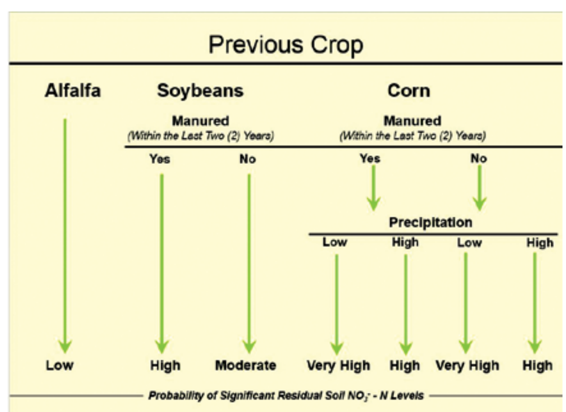

Figure 23.3 Probability of significant soil NO_3^- -N level. (Reitsma et al., 2008)

Manure N

Manure N credit estimates are best determined from a laboratory analysis of a sample of the manure. Samples should be representative of the source and should be collected after the manure has been well-mixed. If the manure is not sampled, N content can be estimated using values in Table 23.3.

Legume N Credit

Legume crops, which form symbiotic relationships with bacteria, can provide a significant amount of N to the following crop. In situations where corn follows soybeans, a credit of 40 lbs N/acre is recommended. Credits for other legume crops are provided in Table 23.4 (Reitsma et al., 2008).

Table 23.3 Estimated nitrogen content of liquid and solid manure. ***(Modified from Lorimor and Powers, 2004)***

Type of Livestock	Liquid Manure: Nitrogen (N) lbs/1000 gal		Solid Manure: Nitrogen (N) lbs/ton	
	$N_{ORGANIC}$	$N_{INORGANIC}$	$N_{ORGANIC}$	$N_{INORGANIC}$
Swine				
Farrowing	7	8	11	3
Nursery	11	14	8	5
Grow-Finish	-	-	10	6
Grow-Finish(deep pit)	17	33	-	-
Grow-Finish(wet/dry feeder)	21	39	-	-
Grow-Finish(earthen pit)	8	24	-	-
Breeding-Gestation	13	12	4	5
Farrow-Finish	12	16	8	6
Farrow-Feeder	10	11	5	5
Dairy				
Cow	25	6	8	2
Heifer	26	6	8	2
Calf	22	5	8	2
Veal calf	26	21	4	5
Herd	25	6	7	2
Beef				
Beef cows	13	7	4	3
Feeder calves	19	8	6	3
Finishing cattle	21	8	7	4
Poultry				
Broilers	50	13	34	12
Pullets	48	12	39	9
Layers	20	37	22	12
Tom turkeys	37	16	32	8
Hen turkeys	40	20	32	8
Ducks	17	5	13	4

These values should not be used in place of a regular manure analysis as true nutrient content varies drastically depending on feeding and manure storage and handling practices. Use only for planning purposes.

Table 23.4 Nitrogen credits from previous legume crop. ***(Gerwing and Gelderman, 2005)***

Crop	Population (Plants/ft^2)	[1,2]N Credit (lbs N/Acre)
Alfalfa or [3]Legume Green Manure	<1	0
	1-2	50
	3-5	100
	>5	150
Soybeans, edible beans, peas, lentils and other annual legumes		40

[1] No-till corn into alfalfa or green manure crop: use half credit first year. Other tillage systems: use full credit.

[2] For second year following alfalfa and green manure crops: use half credit.

[3] Includes sweet clover, red clover, and other similar legumes.

Tillage Adjustment

If no-tillage has been followed for less than 5 years, then the N rate should be increased 30 lbs N/acre. For fields that have been in no-tillage for more than 5 years, the adjustment should be zero. Examples are below.

> **Example 23.1 Example for estimating N requirement.**
>
> **Field A:** Estimate the corn grain N recommendation if the yield goal is 200 bu/acre, prior soybean yields was 60 bu/acre, and the nitrate-N amount in the surface 2 feet is 60 lbs/acre. The field is chisel plowed.
>
> N recommendation = 200×1.2- residual N credit – soybean credit
>
> Residual N credit is 60 lbs N/acre and the soybean credit is 40 lbs N/acre (Table 23.4)
>
> N recommendation = 240 lbs N/acre – 60 lbs N/acre – 40 lbs N/acre = 140 lbs N/acre
>
> **Field B:** No-tillage for 7 years, yield goal is 200 bu/acre, nitrate-N is 60 lbs/acre, and the previous crop was corn. For this field the recommendation is as follows:
>
> Nitrogen recommendation = 1.2×200 – 60 = 180 lbs N/acre. The field had been in no-tillage for 7 years and therefore a tillage adjustment is not used
>
> Field C: No-tillage for 3 years, yield goal 200 bu/acre, nitrate-N is 60 lbs/acre and soybeans was the previous crop.
>
> Nitrogen recommendation = 1.2×200 – 60 – 40 + 30 = 170 lbs N/acre

Phosphorus Recommendation

Phosphorus (P) exists in soil solution, mineral, and organic forms (Fig. 23.4). About 1% of P is in solution (plant available), 85% is in mineral form, and 14% is in organic form. It is not recommended to apply P to production fields if Olsen or Bray soil test P exceeds 100 ppm. Off-site movement of P generally occurs with runoff and erosion, as P is strongly attached to soil. The transport of P from production fields to streams and lakes can result in algal blooms, which impact fisheries and other wildlife. Transport is minimized when conservation-tillage practices are adopted. Concentrations of P in runoff waters can be reduced by:

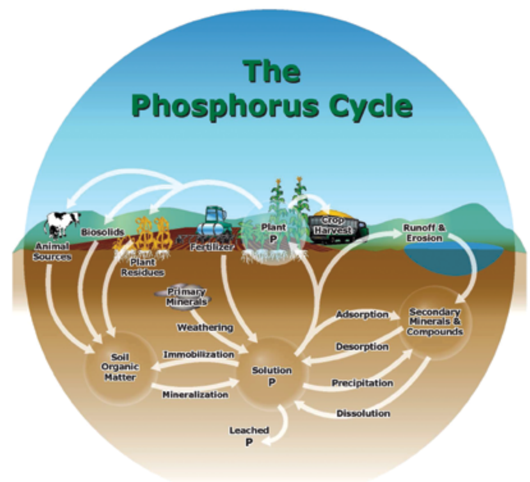

Figure 23.4 The phosphorus cycle. (Courtesy of International Plant Nutrition Institute)

1. Minimizing the exposure of manure and fertilizer to runoff water.
2. Only applying P where it is needed.
3. Maintain a buffer between "fertilized" and surface water or drainage.
4. Consider developing and maintaining "grassed" or "wooded" buffers or filter strip.
5. Avoid application of manure on frozen or snow-covered ground.
6. Maintain crop residues above 30% to reduce erosion and incorporate the P when possible.

The optimal pH value for P availability is about 6.8, and increasing or decreasing the soil pH values from this value reduces its plant availability. Clay soils in the western part of the state often have high soil calcium (Ca^{2+}) and magnesium (Mg^{2+}) levels that reduce soil test P levels. Irrespective of the soil test P values, these high clay soils may not respond to P fertilizer.

The soil test categories are an index that is correlated to a probability of a yield response from added fertilizer (Table 23.5). Soil samples analyzed during 2010 at the SDSU Plant Science Soil Testing Laboratory showed that 50% of the samples were in the medium or below soil test P categories (Gelderman and Ulvestad, 2010).

Phosphorus-deficiency symptoms appear in corn as "purpling" of leaves, most commonly seen during early growth stages (Fig. 23.5). New leaves may not show coloration and P-deficient plants are shorter. The symptoms may disappear as the plant matures. Some hybrids will not show coloration, even when limiting. Symptoms may appear even though soil test phosphorous (P) levels are high. Deficiency symptoms can result from cool or dry soil conditions, compacted soils, and root systems that have been reduced by tillage, cultivation, and insects.

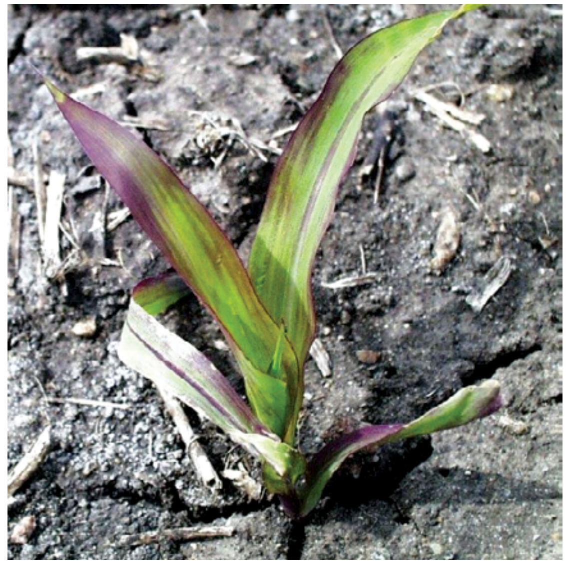

Figure 23.5 P-deficient corn symptoms appear as leaf "purpling" along leaf edges and slow and stunted growth. Symptoms most often appear early in the season, especially in low areas with high water tables (Courtesy: South Dakota State University). Phosphorus-deficient corn plants are always purple, but not all purple plants are P deficient, as the symptom can also be caused by anything interfering with early corn root development.

In soils that test high for P, banding 30 lbs P_2O_5/acre at planting may increase early growth but may not increase yield. In soils with low to medium soil test levels, banded P application at planting usually increases yields. Banding P is most effective when the yield is > 150 bu/acre, when < 40 lbs P_2O_5/acre is applied, and the soil test P level is < 10 ppm. Additional details on starter, pop-up, banding P is available in Chapter 26. A bushel of corn removes about 0.38 lbs of P_2O_5. Based on this estimate, a 150 bu/acre corn crop removes 57 lbs of P_2O_5.

Phosphorus recommendations are based on yield goals and laboratory results from a 0- to 6-inch soil sample (Table 23.5). In South Dakota, P fertilizer recommendations can be calculated from either the Bray-1 or Olsen P methods. The University of Minnesota soil-testing laboratory used the Bray-1 (B-P1) if the pH < 7.4 and the Olsen (O-P) method if the soil pH > 7.4. Findings from Iowa suggest that Olsen P can replace Bray P if the soil pH < 7.4 (Sawyer, Iowa State). However, at pH values < 5.5, the Olsen P test can overestimate P availability (http://www.soiltech.co.nz/articles/article13.pdf). Results from Mehlich III (MIII) soil tests are often similar to those obtained from the Bray-1 method, but in high pH soils, it cannot substitute for the Olsen test. Sample calculations are shown in Example 23.2. When calculating P fertilizer rates, assume that 100% of the fertilizer P is available and 90% of manure P is available.

Table 23.5 Soil test P levels for corn using the Bray and Olsen extraction methods.

Soil Test Method	Soil Test Level				
	Very Low	Low	Medium	High	Very High
	ppm				
Olsen	0-3	4-7	8-11	12-15	16+
Bray-P1	0-5	6-10	11-15	16-20	21+
Probability of a yield response	80%	50-80%	20-50%	10-20%	

Potassium Recommendation

Potassium-deficiency symptoms appear as leaf yellowing and burning that begins at the tip of older leaves and, unlike N deficiency symptoms, cause yellowing at the leaf margins first before intensifying later in the season to include the mid-rib (Fig. 23.7). These symptoms are often observed in: 1) plants where root growth is limited by adverse soil/soil moisture conditions; 2) sandy soils and organic soils; and 3) fields where the crop residues were harvested. Potassium deficiencies start in older tissues and may progress up the plant. Lodged corn plants (not root lodged) may be K deficient. About 0.27 lbs. of K_2O are removed by each bushel of corn grain. The amount of K_2O removed with each ton of silage averages about 7.3 lbs/ton, and the K_2O removed when harvesting the amount of stover that produced 1 bushel of grain is about 1.1 lbs of K_2O per bushel of grain.

Example 23.2 Calculating the P_2O_5 recommendation if the corn yield goal is 220 bu/acre, the soil contains 7 ppm Olsen-P, and 6 tons of solid beef manure are applied. In this equation, FPR is the fertilizer P recommendation in pounds of P_2O_5/acre, STP is the soil test P value, and RYG is realistic yield goal. The manure credit is estimated from data in Table 23.6.

FPR = (0.7 – 0.044 × STP) × RYG
FPR = (0.7-0.044 × 7) × 220 = 86.2 lbs P_2O_5/acre

Manure credit
6 tons/acre × 3 lbs P_2O_5/ton × 0.9 lbs available P/lbs of applied P = 16.2 lbs P_2O_5 /acre

Recommendation = 86.2 – 16.2 = 70 lbs P_2O_5/acre
FPR = fertilizer P_2O_5/acre recommended
RYG = realistic yield goal (bu/acre)
STP = the soil test Olsen P result (ppm)

This calculation assumes that 90% of the manure P is available to the plant.

Table 23.6 Estimated phosphorus content of manure. ***(Modified from Lorimor and Powers, 2004)*** **If an analysis of the manure is available, assume 90% of total P is available.**

Type of Livestock	P_2O_5	
	Liquid (Lbs/1,000 gal.)	Solid (Lbs/ton)
Swine		
Farrowing	12	6
Nursery	19	8
Grow-Finish(deep pit or solid)	42	9
Grow-Finish(wet/dry feeder)	44	-
Grow-Finish(earthen pit)	22	-
Breeding-Gestation	25	7
Farrow-Finish	24	8
Farrow-Feeder	18	7
Dairy		
Dairy Cow	15	3
Heifer	14	3
Calf	14	3
Veal calf	22	3
Herd	15	4
Beef		
Beef cows	16	4
Feeder calves	18	4
Finishing cattle	18	7
Poultry		
Broilers	40	53
Pullets	35	35
Layers	52	51
Tom turkeys	40	50
Hen turkeys	38	50
Ducks	15	21

These values vary depending on feeding and manure storage and handling practices and are not likely representative of actual manure nutrient content. Use only for planning purposes. These values should not be used in place of a regular manure analysis.

The amount of K in stover is approximately four times greater than that observed in grain. Precipitation leaches K out of the stover left in the field. By removing the whole corn plant as silage or by baling corn stover after grain harvest, there is potential for most of the stalk K to be removed from the field before it has the opportunity to leach out of the stover. Based on these estimates, the grain from a 150 bu/acre corn crop contains 40.5 lbs of K_2O, whereas the stover contains 165 lbs of K_2O. These values suggest that stalk harvesting has the potential to reduce plant available K. The K contained in the stalks, at \$0.50/lb of K_2O, has a value of approximately \$20 per ton of stalks.

Figure 23.7 Potassium-deficiency symptoms appear as burning of leaf edges in corn. (Photo courtesy of University of Georgia–Athens)

Using stalks for one's own livestock (feed or bedding) results in most of the stalk K being returned to the field as manure. Most agricultural soils in South Dakota have relatively high K levels. However, positive yield responses to K fertilizer applied as starter or broadcast have been observed. In South Dakota, K fertilizer recommendations are based on yield goals and the amount of K extracted from a 0- to 6-inch soil test value using the equations in Table 23.7. If manure is applied, K fertilizer may not be needed as manure usually has high amounts of K. Due to the risk of corn seed germination, and the low probability of K responses in high K soils, application of K as a pop-up fertilizer should be considered risky.

Table 23.7 Calculating a K recommendation.

Corn for Grain
FKR = (1.1660 - 0.0073 x STK) x RYG

Corn for Silage
FKR= (9.50 - 0.06 x STK) x RYG

Where:
FKR = Fertilizer K Rate (lbs K2O/A)
STK = Soil Test K Value (ppm)
RYG = Realistic Yield Goal (Bu/A)

Zinc and Iron Fertilizer Recommendations

Micronutrient deficiencies usually result from environmental conditions and may be temporary. If micronutrient deficiencies are suspected, soil testing is recommended. Table 23.8 can be used to determine the Zn and Fe recommendations. In most situations, secondary (Ca, Mg, S) and micronutrients (B, Zn, Fe, Cu Mo, Mn) have a limited impact on South Dakota corn yields. However, Zinc (Zn) deficiencies can be observed in coarse-textured soils, eroded soils, organic soils, or soils with high levels of P. Seasonal climate conditions may also affect Zn availability because Zn-deficiency symptoms, feathering and striping on the youngest leaves, are often observed in cool, wet soils. Zinc recommendations are in Table 23.8. As of 2015, the zinc recommendations are under revision. Initial analysis suggests that 2.5 lbs Zn/acre should be applied to soils in the high range.

Iron (Fe) deficiencies may be observed in leveled or eroded soil where the calcareous subsoils have been exposed. Iron-deficiency symptoms in corn are observed as yellowing with interveinal striping of younger leaves. Correcting for Fe deficiency can be difficult, and an effective approach to minimize yield losses is to

Table 23.8 Corn zinc and iron recommendations. (Modified from Gerwing and Gelderman, 2005)

Zinc soil test interpretation (ppm)	Zinc recommendations (lbs/acre)	Fe soil test (ppm)	Fe recommendation (lbs/acre)
0 -.25 Very low	10	0-2.5 low	0.15
.26 - .50 Low	10	2.6-4.5	0.15
.51 - .75 Medium	5	>4.5	0
.76 - 1.00 High	2.5		
1.01 + Very high	0		

[1]Based on inorganic products as source of zinc such as zinc sulfate

apply manure or biosolids.

Considerations for No-tillage

No-tillage can result in slower early season growth. Use of residue managers to darken the soil at planting can help, but not completely overcome the slower start. Use of strip-tillage, with the strip-tillage conducted in the fall has resulted in similar corn growth patterns to conventional-till in several studies. Starter fertilizer applied with or near the seed can be used to enhance early season growth. If N or K is applied with the seed, the total amount added should not exceed 10 lbs of N + K_2O. If possible, N fertilizer should be subsurface band-applied. In no-tillage systems, it is recommended that the N rate be increased 30 lbs/acre if the field has been in continuous no-till for less than 5 years. Nitrogen is best applied in no-till/strip-till beneath the residue using a coulter or coulter-led shank. If N must be applied to the soil surface, banded urea ammonium nitrate (UAN) or broadcast urea with either NBPT (Agrotain) or Limus (NBPT+ NPPT) are better options than broadcast UAN. Use of urease inhibitors generally prevent ammonia volatilization from urea for about 10 days. Broadcasting urea onto residue-covered fields in the fall can result in a substantial amount of N loss and is not recommended. Winter application of urea to frozen soils is not recommended.

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