Colorado State University
Extension

Fertilizing Corn

Fact Sheet No. **0.538** Crop Series | **Soil**

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Adequate soil fertility is one of the requirements for profitable corn production. Nitrogen (N) is the most yield-limiting nutrient, unless previous manure applications or excessive N fertilizer rates leave high residual NO_3-N levels in the soil. Phosphorus (P) is the next most limiting nutrient, while zinc (Zn), iron (Fe), and potassium (K) also may be limiting in some Colorado soils.

Basis of Fertilizer Suggestions

Base fertilizer rates on realistic expected yields and crop needs adjusted for residual available nutrients in the soil as well as NO_3-N in irrigation water. These rates also assume proper management practices, including weed and insect control.

Expected corn yields for individual fields are best determined by adding 5 percent to the most recent five-year average yield of corn, excluding the years when yields are reduced by hail, early frost, etc. Expected yields can be increased by using higher yielding varieties, higher plant populations, or improved irrigation, weed, or tillage management. However, expected yields should rarely change more than 20 bushels per acre in any year.

Manure is a common source of nutrients and is especially beneficial when applied to recently leveled land where top soil is removed. Manure helps improve the soil physical condition and supply N, P, K, and micronutrients to the crop. Hazards from excessive manure applications include potential weed problems, soluble salt buildup, excessive nutrient levels, potential nitrate leaching to ground water, and erosion of soils high in P. Application rates should be governed by nutrient needs of the crop.

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Soil Sampling

The value of a soil test in predicting nutrient availability during the growing season is directly related to how well the sample collected represents the area sampled. Take surface samples from the 1-foot soil depth. Subsoil samples should also be taken to 2 feet deep to determine available NO_3-N.

Sample 4 to 6 feet if a more accurate N rate is desired, especially with corn. If the field has been in no-till, reduce the sample depth of the tillage layer. A good sample is a composite of 15 to 20 soil cores taken from an area uniform in soil type. Areas with major differences in soil properties or management practices should be sampled separately.

Thoroughly air dry all soil samples within 12 hours after sampling by spreading the soil on any clean surface where the soil will not be contaminated. **Do not oven-dry the soil** because this can change the soil test results. Place the air-dried soil in a clean sample container for shipment to the soil test laboratory.

Submit a carefully completed information form with the soil sample. This form provides information so fertilizer application suggestions can be tailored to your specific situation. Take soil samples for NO_3-N analysis every year for optimum N fertilization of crops. Soil analyses for availability of the other nutrients, pH and organic matter content every three to four years may be sufficient.

Soil tests should include the determination of NO_3-N, extractable P, K, Zn, and Fe, as well as soil pH, soil organic matter, and soluble salts. The results of these soil tests should be correlated and calibrated for Colorado soils. Fertilizer programs for corn are based on such studies.

Quick Facts

- Nitrogen is the most limiting nutrient for corn production.
- Apply nitrogen fertilizers at rates based on expected crop yields minus credits for residual soil nitrates, estimated nitrogen mineralized from soil organic matter, previous legume crop residues and manure or other organic wastes, and nitrogen present in irrigation water.
- Apply phosphate and zinc fertilizers at rates based on soil test results.
- Most Colorado soils contain sufficient available potassium and sulfur for corn production.

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Nitrogen Suggestions

Base nitrogen (N) rates for corn on the expected yield for each field. Nearly all corn crops will require some N fertilizer, unless there is a substantial N carryover. High N rates in excess of crop needs can result in potential groundwater contamination by NO_3-N under irrigated conditions.

Credit should be given for the level of NO_3-N in the soil. Other credits for N include the amounts expected to be available during the season from mineralization of soil organic matter, manure, and previous legume crop residues, as well as NO_3-N in irrigation water. These credits are subtracted from the total crop needs to determine the suggested N fertilizer rate for the expected yield.

Soil nitrate-N credit. Residual NO_3-N in the soil is immediately available to plants; therefore, decrease the fertilizer rate to give credit for the amount of NO_3-N in the rooting zone. The suggested N rate is reduced 8 lb/A for each ppm of NO_3-N (average concentration in the soil sample depth) in the soil for a 2-foot sampling depth. The method to calculate a depth-weighted NO_3-N concentration in the root zone where surface and subsoil samples have been taken is as follows:

Table 1: Nitrogen credits for previous crops and manure applications.

Crop		**lb N/A credit***
Alfalfa	> 80% stand	100 - 140
	60 - 80% stand	60 - 100
	0 - 60% stand	0 - 60
Sweet clover and red clover		80% of credit for alfalfa
Dry beans		30
Sugar beets**		50
Manure		**lb N/ton credit*****
	dry basis	as is
Beef	10	5 (at 50% DM****)
Dairy	15	3 (at 20% DM)
Poultry	25	20 (at 75% DM)

*For the second year, use ½ of the first year N credit.
**Sugar beets are included due to the incorporation of beet tops. They are not a legume crop.
***For the second and third years, use ½ and ¼ of the first year N credits, respectively.
****Dry matter.

Table 2: Suggested nitrogen rates (lb/A) for irrigated corn, as related to NO_3-N in the soil and soil organic matter content, calculated from the algorithm.

ppm NO_3-N in soil*	**Soil organic matter, %**		
	0 - 1.0	**1.1 - 2.0**	**> 2.0**
0 - 6	210	185	165
7 - 12	160	135	115
13 - 18	110	85	65
19 - 24	60	35	15
> 24	10	0	0

*Average weighted concentration (ppm) in the tillage layer and the subsoil layer to 2 feet.
Note: Credits for N in manure, irrigation water, or previous legumes should be subtracted from the above N rates.

Soil layer sampled, inches	**Thickness, Inches**	**Measured NO_3-N, ppm**	**Calculations**
0 - 8	8	20	8 x 20=160
8 - 24	16	8	16 x 8=128
			288/24= 12ppm

Soil organic matter credit. Nitrogen in soil organic matter becomes available to plants through mineralization. Conditions that favor high yields also favor the activity of soil microorganisms that are responsible for mineralization. Therefore, estimated credits for N released from organic matter are related to expected yields. The suggested N rate is reduced by 14 lb/A for each percent organic matter for each 100 bu/A of corn. When a soil test for organic matter is not available, a level of 1.5 percent organic matter can be assumed for eastern Colorado soils.

Other N credits. Previous legume crop residues will release N to the succeeding corn crop after incorporation into the soil. Therefore, reduce fertilizer rates by a legume credit (see Table 1). Use values toward the lower end of the ranges for sandy soils, and use the upper end of the ranges for medium and fine textured soils.

The N content of manure varies considerably, depending on source, handling techniques and moisture content. Obtain a laboratory analysis for nutrient and moisture content to determine the N credit. In the absence of an analysis, the minimum N credit is 10 pounds per ton for beef feedlot manure and 15 pounds per ton for dairy manure (dry basis) for the first year after application and less for the next two years (see Table 2). For more information on the nutrient value of manure, refer to *Manure Utilization: Best Management Practices,* Bulletin 568A, from www.csuextstore.com.

Irrigation water may contain NO_3-N, which is available to plants. The amount of N contained in 1 acre-foot of irrigation water is 2.7 pounds of N for each ppm of NO_3-N.

Irrigated Corn for Grain Production

The basis for suggested N rates is an algorithm (equation), developed by the University of Nebraska. Nitrogen rate is determined as follows:

N rate (lb/A) = 35 + [1.2 x EY (bu/A)]
- [8 x average ppm NO_3-N in the soil]
- [0.14 x EY (bu/A) x % OM]
- other N credits (lb/A)

where EY = expected yield and % OM = percent organic matter.

For example, if your expected grain yield was 175 bushels per acre with the top 2 feet of soil containing an average 5 ppm NO_3-N, 1.0 percent organic matter in the tillage layer, a previous grass-legume crop (30 pounds N/A credit), and 2 acre feet of irrigation water containing 5 ppm NO_3-N to be applied during the growing season, the suggested N rate is:

N rate (lb/A) = 35 + [1.2 x 175]	= 245
- 8 x 5 ppm NO_3-N	= -40
- 0.14 x 175 x 1.0	= -25
- legume credit	= -30

- 2 acre-feet x 5 ppm x 2.7 = -27

123 lb N/A

The University of Nebraska includes an adjustment for corn and N fertilizer prices. If interested, see their factsheet at www.ianrpubs.unl.edu/epublic/live/ec117/build/ec117.pdf.

Table 2 suggests N rates for irrigated corn at an expected yield of 175 bushels per acre. Fertilizer N rates decrease with increasing levels of NO_3-N in the top 2 feet of soil and increasing soil organic matter content. Suggested nitrogen rates in this table do not account for other nitrogen credits. Subtract nitrogen credits from manure, legumes, and irrigation water from the nitrogen rates in Table 2 to determine the nitrogen rate for the field. Rates are rounded to the nearest 5 pounds of N/A. For more precise rates, calculate the nitrogen rate for your field by using the algorithm above, using the appropriate expected yield.

Irrigated Corn for Silage Production

Suggested nitrogen rates for corn grown for silage production under irrigation differ somewhat because nitrogen needs are based on corn forage (tons/A) instead of grain production (bu/A). The algorithm for corn silage production is:

N rate (lb/A) = 35 + [7.5 x EY (tons/A)]
- [8 x average ppm NO_3-N in the soil]
- [0.85 x EY (tons/A) x % OM]
- other N credits (lb N/A)

where EY = expected yield and % OM = percent organic matter.

For example, if your expected yield of corn silage is 28 tons/A, with the top 2 feet of soil containing an average 5 ppm NO_3-N, 1 percent organic matter in the tillage layer, a previous grass-legume crop (30 lb N/A credit), and 2 acre feet of irrigation water containing 5 ppm NO_3-N to be applied during the growing season, the suggested N rate is:

N rate (lb/A) = 35 + [7.5 x 28] = 245
- 8 x 5 ppm NO_3-N = -40
- 0.85 x 28 x 1.0 = -24
- legume credit = -30
- 2 acre-feet x 5 ppm x 2.7 = -27

124 lb N/A

Dryland Corn

Suggested N rates for dryland corn are calculated by the same algorithm as irrigated corn. However, expected yields are lower for dryland corn. Table 3 suggests N rates for dryland corn at an expected yield of 80 bushels per acre. Fertilizer N rates decrease with increasing levels of NO_3-N in the top 2 feet of soil and increasing soil organic matter content.

Suggested N rates in this table do not account for other N credits; subtract these credits from the N rates in Table 3 to determine the N rate for the field. Rates have been rounded to the nearest 5 pounds of nitrogen per acre. For more precise rates, calculate the N rate for your field by the algorithm given for irrigated corn, using the appropriate expected yield.

Methods and Timing of N Applications

Nitrogen may be applied to soil by various methods. The most efficient use is by applying N just prior to the rapid growth period 30 to 40 days after planting, when plants have about six leaves. However, apply all of the fertilizer before tasseling stage to maximize N use efficiency. Fall application of N is not recommended for most soils. Some N may be band applied in combination with starter fertilizers, but the rate should be less than 20 pounds of nitrogen per acre. Use of planter attachments with the standard 2-inch by 2-inch placement (2 inches below and beside the seed row) is preferred for starter fertilizers. Use caution with popup placement (directly with the seed) of fertilizers, including those with K and S, because seedling emergence may be decreased in dry soil, especially at rates supplying more than 10 pounds of nitrogen per acre. All sources of N fertilizers are equally effective per unit of N if properly applied. Base your choice of N fertilizer on availability, equipment available, and cost per unit of N.

Corn roots quickly grow into the soil between the rows. Sidedress N fertilizers early in the growing season to avoid root pruning. Apply nitrogen fertilizer during early cultivation.

Application of N fertilizers with irrigation water is a convenient method and allows split applications to improve N use efficiency. Use in-season soil or plant analysis to determine the nutrient status of the growing crop. If the N status of the crop is low or growing conditions appear to be above average, apply additional N with the next irrigation.

Nitrogen fertilizers may be applied through sprinkler irrigation systems. Equip all closed-irrigation systems with backflow prevention valves if N fertilizers or other agrichemicals are applied through the system. Urea-ammonium nitrate (UAN) solution is the most efficient N fertilizer to apply through sprinkler systems.

Table 3: Suggested nitrogen rates (lb/A) for dryland corn, as related to NO_3-N in the soil and soil organic matter content, calculated from the algorithm.

ppm NO_3-N in soil*	Soil organic matter, %		
	0 - 1.0	1.1 - 2.0	> 2.0
	– Fertilizer rate, lb N/A –		
0 - 6	100	90	80
7 - 12	50	40	30
> 12	0	0	0

*Average weighted concentration (ppm) in the tillage layer and the subsoil layer to 2 feet.
NOTE: Credits for N in manure or previous legumes should be subtracted from the above N rates.

Table 4: Suggested phosphorus rates for band and broadcast applications to irrigated and dryland corn calculated from the algorithm.

ppm P in soil		Relative level	Fertilizer rate, lb P_2O_5/A	
AB-DTPA	$NaHCO_3$		Banded	Broadcast
0 - 3	0 - 6	low	40	80
4 - 7	7 - 14	medium	20	40
8 - 11	15 - 22	high	0	0
> 11	> 22	very high	0	0

For more precise rates, use the algorithm in the text relating to the soil test method.

Anhydrous ammonia is not recommended for application in sprinkler systems because of N losses as ammonia and problems due to formation of solids in the water.

Apply nitrogen fertilizers in furrow irrigation systems only in fields where a tailwater recovery and reuse system is in place. For high-efficiency surge-flow irrigation systems, addition of the N fertilizer during the next to last cutback cycle improves the uniformity of application. Bubbling anhydrous ammonia into head ditches may result in N losses as ammonia. Foliar spray applications of N are not practical since only relatively small amounts of N can be absorbed through the leaves. Also, substantial leaf burn may result if the N concentration in the foliar spray is too high or if sprays are applied during hot, dry weather.

Phosphorus Suggestions

Crop responses to applied phosphorus (P) are most likely on soils with low or medium levels of extractable P. Suggested P fertilizer rates (Table 4) are determined from an algorithm related to the soil test extraction used (AB-DTPA or $NaHCO_3$) and the method of fertilizer application. The algorithm for determining the suggested P rate for banded fertilizer applications based on each soil test method is:

P rate (banded, lb P_2O_5/A) =
48 - 5x (AB-DTPA-P)
P rate (banded, lb P_2O_5/A) =
48 - 2.5x ($NaHCO_3$-P)
where x = ppm available P in soil.

The main soil tests for extractable P in Colorado soils are the AB-DTPA and sodium bicarbonate ($NaHCO_3$) tests. Values for both tests are given in Table 4. When using the above algorithms to calculate the suggested P rate, a negative P rate means the probability of response is lower at higher soil test levels and application of fertilizer P is not suggested.

Placement of P fertilizers in the root zone is important because P is not mobile in the soil. Incorporate broadcast applications of P fertilizers into the soil prior to planting. Band application at planting (starter fertilizer) is the most efficient placement method for P, and suggested rates for band application are about half those for broadcast application.

Table 5: Suggested potassium rates for irrigated and dryland corn.

ppm K in soil AB-DTPA or NH_4OAc	Relative level	Fertilizer rate, lb K_2O/A
0 - 60	low	60
60 - 120	medium	30
> 120	high	0

Subsurface placement of P may be especially important for reduced tillage cropping systems. Use caution with popup fertilizer placement (directly with the seed) because seedling emergence may be decreased in dry soil, especially at rates supplying more than 10 pounds of nitrogen per acre. Monoammonium phosphate (MAP, 11-52-0), diammonium phosphate (DAP, 18-46-0), and ammonium polyphosphate (10-34-0) are equally effective per unit of P if properly applied. Base your choice of fertilizer on availability, equipment available and cost per unit of P.

Soils that have had manure applications will require less P fertilizer because much of the P in animal manure is available to the crop in the first year after application. Poultry litter contains more P than beef or swine manure. Do not apply manure to high-P soils because of lower probability of crop response to P and also potential surface water contamination with P due to runoff and soil erosion.

Potassium Suggestions

Most Colorado soils are relatively high in extractable potassium (K) and few crop responses to K fertilizers have been reported. Suggested K rates related to soil test values (AB-DTPA or NH_4OAc) are given in Table 5. Low levels of extractable K can cause lodging of corn, but this problem more often is caused by stalk rot than by shortages of extractable K in the soil. Potassium removal from soil is much greater with production of corn silage than grain, but soil minerals generally will release K to replace that which was removed by crops. Use soil tests to monitor extractable K levels in fields mainly cropped for corn silage. The main K fertilizer is KCl (potash), and broadcast application incorporated into the soil prior to planting is the usual method.

The N content of manure varies considerably, depending on source, handling techniques and moisture content. Obtain a laboratory analysis for nutrient and moisture content to determine the N credit.

Zinc Suggestions

Zinc (Zn) availability decreases with increasing soil pH, and most Zn deficiencies are reported on soils with pH levels higher than 7.0. Zinc deficiencies of corn have been widely reported in eastern Colorado soils. They also are found on soils leveled for irrigation where subsoil is exposed, or on soils with high levels of free lime. Incorporation of manure or treated sewage sludge (biosolids) in these exposed subsoils may correct Zn deficiencies, as well as improve soil structure.

Suggested Zn rates in Table 6 for banded and broadcast applications are based on use of $ZnSO_4$. Apply effective Zn chelates at about one-third of the rate of Zn as $ZnSO_4$. Band application is more effective than broadcast application; thus, suggested rates are lower for band application. Soil test values within the response range for extractable Zn by the DTPA soil test are similar to those by the AB-DTPA soil test shown in Table 6. Several Zn sources (both solid and liquid) are sold and their relative effectiveness and cost per unit of Zn vary considerably.

Table 6: Suggested zinc rates for band and broadcast applications to irrigated and dryland corn.

ppm Zn in soil AB-DTPA	Relative level	Fertilizer rate, lb Zn/A* Banded	Broadcast
0.1 - 0.9	low	2	10
1.0 - 1.5	marginal	1	5
> 1.5	adequate	0	0
*Rates are based on zinc sulfate applications.			

Table 7: Suggested sulfur fertilizer rates for sandy soils only.

Soil Test ppm SO_4-S[1]	Amount S to Apply (lb/A)		
	Soil Organic Matter<1%		Soil Organic Matter>1%
	Broadcast	Row[2]	Row[2]
	Irrigation water with <6 ppm SO_4-S		
<6	20	10	5
6-8	10	5	0
>8	0	0	0
	Irrigation water with >6 ppm SO_4-S		
>6	10	5	0
6-8	10	5	0
>8	0	0	0

[1]Use $Ca(H_2PO4)_2$ extract for SO_4-S analysis.
[2]Applied in a band next to row but not with seed.

Zinc deficiencies also may be corrected by foliar sprays of a 0.5 percent $ZnSO_4$ solution applied at a rate of about 20 to 30 gallons per acre, but several applications may be necessary. However, it is difficult to prepare this solution in the field so ZnEDTA or other soluble Zn sources can be used. A surfactant (wetting agent) increases plant absorption of the applied Zn.

Zinc fertilizers have measurable residual effects, and repeated annual applications will result in a buildup of extractable Zn in the soil. Because of these residual effects, periodic soil tests are suggested to assess extractable Zn levels in soil. As soil test Zn increases to higher levels in soil, decrease Zn rates according to soil test results.

Sulfur Suggestions

Most Colorado soils contain adequate levels of available sulfur (S), and soil tests for available S are not routinely performed. However, some sandy soils with low organic matter may require S applications (Table 7). Gypsiferous soils contain adequate S. Elemental S is not water soluble nor immediately available to plants. First, it must be oxidized to the plant-available sulfate (SO_4) form by soil microorganisms. Irrigation water from most surface waters and some wells often contains appreciable SO_4-S, so irrigated soils usually are adequately supplied with S. However, some deep well waters are low in S, so water samples should be analyzed for SO_4-S if soils are low in organic matter and S deficiency is suspected. Be sure to consider the SO_4-S content of your irrigation water when deciding whether to apply S fertilizer (Table 7).

Iron Suggestions

Availability of iron (Fe) decreases with increasing soil pH, but most soils are adequately supplied with available Fe for corn production. Iron deficiencies are most likely to occur on highly calcareous soils (pH higher than 7.8) or on soils leveled for irrigation where the subsoil has been exposed. Visual symptoms of Fe chlorosis are yellow striping of younger leaves. Select corn hybrids that have tolerance to chlorosis as this may be adequate for overcoming iron problems.

If chlorosis persists, iron fertilizers may need to be applied. Recent research by University of Nebraska scientists shows the most effective treatment for correcting high pH chlorosis in corn requires an at-planting seed-row application of 50 to 100 pounds of ferrous sulfate heptahydrate ($FeSO_4 \cdot 7H_20$) per acre. This treatment costs $18-35 per acre (2009 prices) depending on product cost and requires dry fertilizer application equipment on the planter. Foliar spray applications of a 1 percent $FeSO_4$ solution at 20 to 30 gallons per acre are not always completely effective in correcting chlorosis, and several applications may be necessary. $FeSO_4$ solutions are difficult to prepare in the field and other Fe sources may be used. In addition, soil application of manure, compost or treated sewage biosolids can often help to correct Fe deficiencies of crops. Sewage biosolids also may contain some heavy metals; heavy metal loading limits to soil are controlled by Colorado Department of Public Health and Environment regulations.

Other Nutrients

There have been no confirmed deficiencies of boron (B), copper (Cu), manganese (Mn), and molybdenum (Mo) in corn in Colorado.