Fertilizer Recommendations for Corn in Tennessee

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"Fertilizer application, particularly nitrogen (N), phosphorus (P), potassium (K), sulfur (S) and zinc (Zn) are vital for optimal corn yields. It is important to apply the recommended amount of nutrients to prevent unnecessary expenses and decrease nutrient losses to the environment. This publication provides information on soil testing; preplant, starter, sidedress and foliar fertilizer recommendations; and sufficiency ranges of plant and tissue analysis for N, P, K, S and Zn".

I. NITROGEN

Of all the nutrients, Nitrogen (N) is required in the largest amount by corn plants. The N content of a healthy corn plant ranges from 2.5-5.0 percent of the dry weight depending on the growth stage and plant part. Nitrogen is necessary for chlorophyll synthesis, an essential requirement for the process of photosynthesis. Nitrogen is also required in amino acid synthesis which is an integral constituent of proteins. Generally, the leaves of N deficient plants are chlorotic due to reduced chlorophyll production, and ears may be smaller with lower protein content.

Soil Test for Nitrogen

Plants use N in the nitrate (NO_3^-) and ammonium (NH_4^+) forms. Ammonium levels are generally very low in upland soils, so soil nitrate tests are used to measure available soil nitrate to adjust N fertilizer applications for corn. There are two soil nitrate tests used in the United States, the Pre-Plant Nitrate Test (PPNT) and Pre-Sidedress Nitrate Test (PSNT). Soil samples for PPNT are collected prior to preplant N application while PSNT samples are collected prior to pre-sidedress application. PPNT test is not recommended for corn producers in Tennessee.

In Tennessee, only the PSNT is calibrated for corn production and is recommended only for producers using animal manure, poultry litter or biosolids. Detailed information on sample collection and processing procedure are described in the UT publication, "The Pre-Sidedress Nitrate-N Soil Test (PSNT) For Nitrogen Management in Corn Production Systems of Tennessee." Interpretation of the PSNT in Tennessee is made based on yield potential of the field, soil test level and field history.

Current N application rates for corn production should be based on realistic yield goals. Adjustments can be made based on past production records and PSNT results if applicable. Another tool available for estimating corn N rate is the Nitrogen Rate Calculator at www.utcrops.com which estimates economical N rate rather than highest yielding N rate and is useful in years where fertilizer prices are very high or corn prices are very low.

Preplant Nitrogen Fertilizer Application

Preplant N application in corn is not recommended because of the length of time from application to when the corn plant will begin significant N uptake. One exception is the application of anhydrous ammonia with properly calibrated equipment. Corn plants take up little N (less than 12 percent of N uptake during the growing season) until V6 growth stage, with the most active period of N uptake occurring between V8 to V14 (Figure 1).

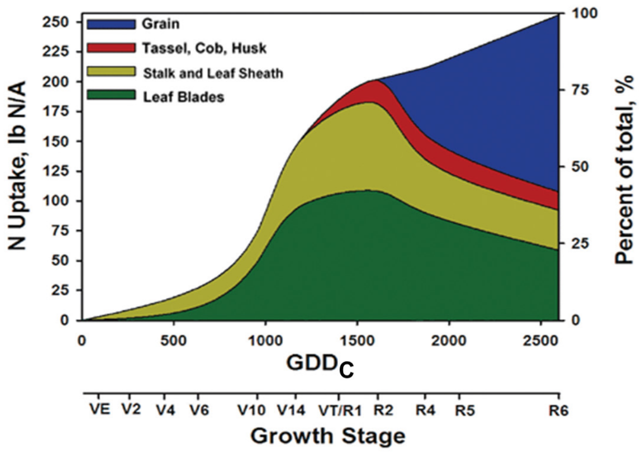

FIGURE 1. *Cumulative nitrogen (N) uptake by corn on a pound-per-acre basis and percentage from emergence (VE) to physiological maturity (R6). GDD_C or growing degree days is the measure of heat accumulation and is used to estimate the growth and development of some agronomic crops (Source: Bender et al., 2013).*

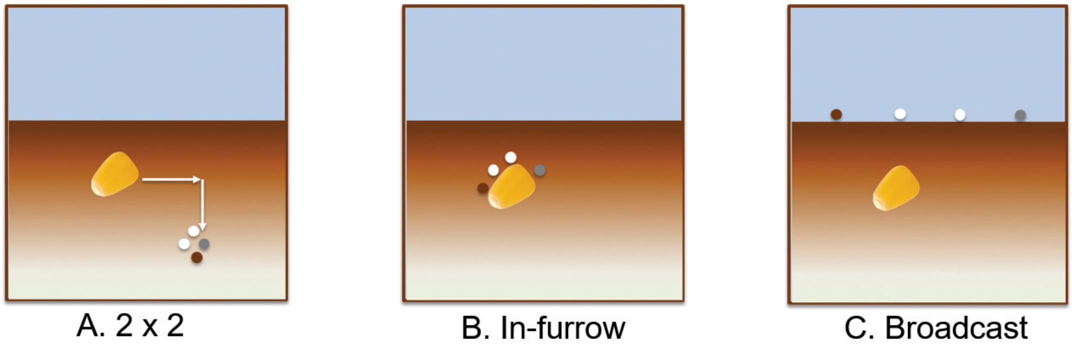

FIGURE 2. *A 2 x 2, B. in-furrow and C. broadcast starter fertilizer placement methods (diagram by Nutifafa Adotey).*

Considering there is limited N uptake prior to V8, there is a greater risk for N loss from preplant N depending on management practice, soil properties and environmental conditions. Detailed information on common N loss pathways and a reliable strategy to reduce N loss are described in the UT Extension publication "***Enhanced Efficiency Fertilizers as a Tool to Control Nitrogen Loss in Row Crops Production PB 1888***." Nitrate leaching and ammonia volatilization are common N loss pathways. In West Tennessee, historically peak rainfall occurs between April and May (2010-2020) when corn is newly planted or younger than V8 stage. The potential for leaching of nitrate is highest during the period of peak rainfall which occurs before the rapid uptake of N by the crop. Surface applied urea-based fertilizers have the potential to be converted to ammonia gas which escapes to the atmosphere (additional information on potential loss is reported under Side-dress nitrogen fertilizer applications).

Starter Nitrogen Fertilizer Application – Source, Placement and Rate

Starter fertilizer for corn is usually a combination of nitrogen and phosphorus but may contain potassium or micronutrients. The additive effect of starter fertilizers on corn yield is inconsistent. Generally, yield response to starter fertilizer application is more often observed when corn is planted earlier (prior to mid-April) than the recommended planting date, under poor growing conditions such as low temperature and excessive rainfall, or when these conditions are combined with low phosphorus soils.

Source: Research has shown that a combination of ammonium-N and phosphate is required for optimum starter fertilizer effectiveness, except for soils with high soil test P. Placement methods of starter fertilizer can influence the choice of starter materials. Urea, UAN (urea ammonium nitrate), or DAP (diammonium phosphate) are not recommended for in-furrow or 2 x 2 because of possible injury to germinating seeds and root inhibition. Ammonium polyphosphate (10-34-0) and monoammonium phosphate (11-52-0) materials are excellent for in-furrow or 2 x 2 starter fertilizers.

Placement: Currently, 2 x 2 is the most common starter placement method, where fertilizer is placed 2 inches to the side of and 2 inches below the corn kernel at planting (Figure 2A). An alternate placement method that has gained traction among corn producers is in-furrow or pop up, where fertilizer is applied in furrow or placed in contact with the seed (Figure 2B). Other starter placement options that can provide excellent results depending on soil type and environmental conditions include surface dribble or broadcast (Figure 2C).

Rate: Depending on material used and placement method, the recommended N rate for starter fertilizer ranges between 10 to 60 lbs. of N per acre. The rate for in-furrow must be below 10 lbs. of N. In-furrow fertilizer must not contain diammonium phosphate or urea because of possible injury to germinating seeds or root inhibition. For 2 x 2 placement method, the rate should not exceed 60 lbs. of N.

At-planting and Sidedress Nitrogen Fertilizer Applications – Source, Placement and Rate

Application of some N at or soon following planting lessens the number of days from application time to crop utilization and provides N to the crop in situations when a sidedress application is not timely, or impractical. Sidedress application can be done any time after planting through tasseling. However, in Tennessee, unless fertigation is an option, sidedress application for corn is recommended between V4 to V6. Sidedressing N behind starter N or at-planting N, commonly referred to as a split application, is a more efficient practice compared to a single preplant or at-planting applications. Split applications of N may be beneficial when N rates are greater than 120 lbs. per acre. A typical split management practice is to apply a third of the total intended N per acre at planting and sidedress the remaining N fertilizer between V4 to V6. Split application provides flexibility to adjusting N rate during growing season as compared to just a single application at planting.

Source: When properly managed, nitrogen fertilizer sources are equal in their ability to supply N. The International Plant and Nutrition Institute (IPNI) developed a series of one-page fact sheets on the various N fertilizer sources and gave a review on their use. Urea-based N fertilizers are more susceptible to ammonia loss when compared to other N sources. Recent UT research showed that ammonia loss from surface applied urea N fertilizers at side-dress (120 lbs. N per acre) can be more than 20 percent of the total N applied, which was equivalent to more than 24 lbs. of N acre (Figure 3).

Treating or adding an N stabilizer to urea-based N fertilizers is recommended if at least 1/4 inch of rainfall is not forecasted within two days after N application. Nitrogen stabilizers can reduce ammonia volatilization by at least 65 percent, particularly under conditions favorable for ammonia loss (Figure 4). Urea fertilizers treated with urease inhibitors containing NBPT increased grain yield compared to the untreated urea (Figure 5).

Placement: Broadcasting, injection, dribble between rows, and banding (surface or subsurface) are the common N placement methods for applying N fertilizers in Tennessee. Surface applied

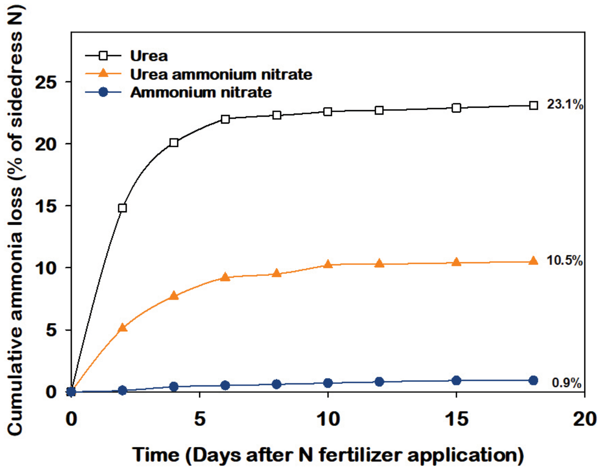

FIGURE 3. *Cumulative ammonia loss from surface applied urea, urea ammonium nitrate and ammonium nitrate over an 18-day period (Adotey et al., 2020, Unpublished).*

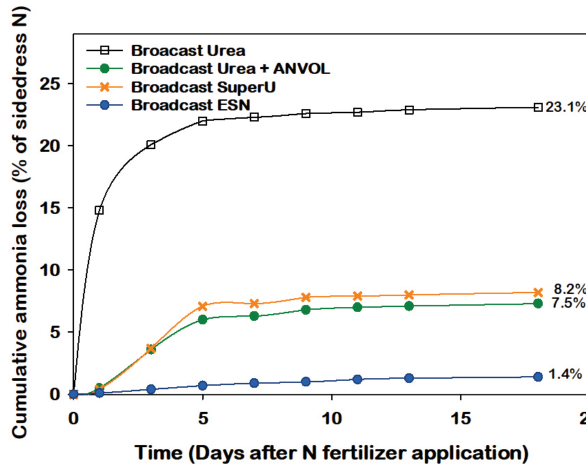

FIGURE 4. *Cumulative ammonia loss from surface applied untreated urea, urea treated with N stabilizer (ANVOL), and a slow-release fertilizer (Environmentally Smart Nitrogen, ESN) over an 18-day period (Adotey et al., 2020, unpublished).*

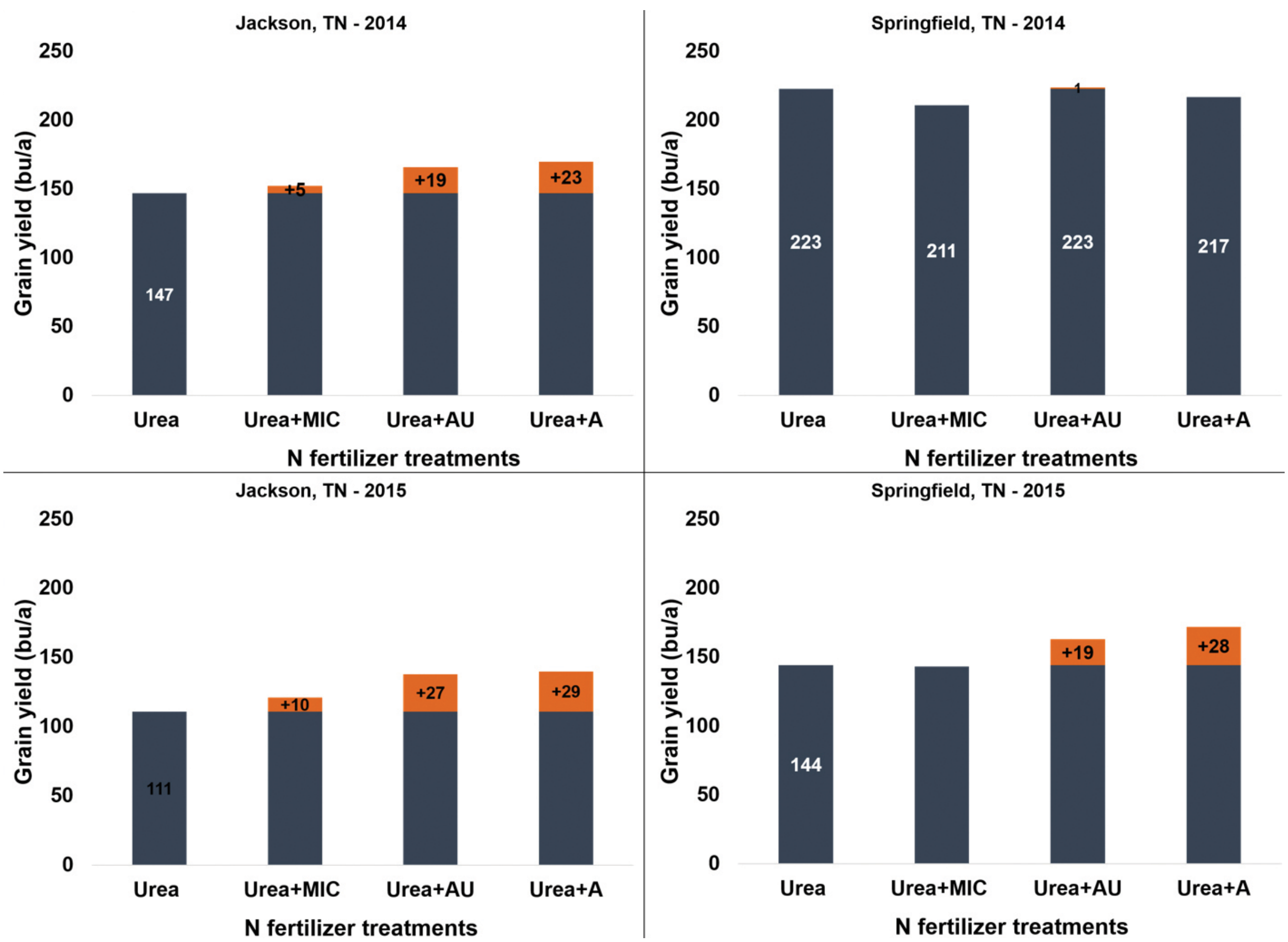

FIGURE 5. *Corn grain yield of surface applied urea treated with urease inhibitor products at Jackson and Springfield, Tennessee (Savoy et al., 2016). MIC – maleic-itaconic copolymer; AU – Agrotain® Ultra, A – Agrotain.*

placement methods such as broadcasting and dribble tends to be more susceptible to ammonia volatilization loss compared to subsurface placement.

Rate: Recommended N for the growing season is based on realistic yield goals and rates can be modified based on field production history and seasonal N loss concerns (Table 1). Split applications of N may be beneficial when N rates are greater than 120 lbs. per acre.

Plant/Tissue Analysis for Nitrogen

Plant tissue analysis is a tool to monitor N status as well as diagnose deficiency. Corn tissue sufficiency ranges differ depending on the growth stage sampled and type of tissue collected. For seedling plants (less than 4 inches in height), sampling the whole plant about 1 inch above the soil surface is recommended. For corn at vegetative growth stage (more than 4 inches in height to tasseling), the most recently matured leaf (with visible collar) from the tops of 15-20 plants is recommended. For corn plants at tasseling, the earleaf (leaf adjacent to the uppermost developing ear) of 15-20 plants is recommended. Nitrogen sufficiency ranges for sampled parts at different growth stages are shown in Table 2.

FIGURE 6. *Corn plants with N deficient leaves. Nitrogen deficient leaves exhibiting inverted V-shaped yellowing starting from the tip and progressing down the midrib towards the base of the leaf will appear first on older (lower) leaves. Photo from University of Minnesota Extension.*

TABLE 1. *Nitrogen recommendations for corn production in Tennessee. N recommendation for irrigated corn with yield potential up to 265 can be estimated using the N rate calculator.*

Yield potential (bu. per acre)	Total Nitrogen (lbs. per acre)
100 – 125	120
126 – 150	150
151 – 175	180
176 – 200	210
201 – 225	240

N recommendation for irrigated corn with yield potential up to 265 can be estimated using the N rate calculator

Visual Deficiency Symptoms at Vegetative Stage

Plant: Stunted yellowish-green plants with spindly stems.

Leaf: Symptoms appear first on older (lower) leaves with a V-shaped yellowing starting from the tip and progressing down the midrib towards the base of the leaf.

II. PHOSPHORUS

Phosphorus (P) is a macronutrient involved in photosynthesis, respiration, energy storage and cell division. It promotes early root growth and is vital to seed formation and hence important to ear development. Plants use most of their P in the orthophosphate ($H_2PO_4^-$) form. Smaller amounts of PO_4^{3-} and HPO_4^{2-} are also taken up. Historically phosphorus fertilizer sales are reported as P2O5 equivalence, or 2.29 times the elemental P value.

Soil Test for Phosphorus

UT Extension publication "***Best Management Practices for Phosphorus in the Environment PB 1645***" provides an excellent review on managing phosphorus to minimize environmental impacts. Phosphorus fertilizer application rate should be based on a soil test. In Tennessee, P fertilizer recommendations are based on the Mehlich I or double acid extraction procedur. Detailed information on how UT recommendation were developed is addressed in UT Extension publication "***University of Tennessee Fertilizer Recommendation Development W 795***." If you are using soil test analyses from laboratories that are using the Mehlich III extraction the conversion to Mehlich I is described in the UT Extension publication, "***UT Fertility Recommendations for Tennessee Row Crops SP 763***."

Preplant Phosphorus Fertilizer Application

Phosphorus is generally applied preplant in corn, either in the fall or in the spring prior to planting. Phosphorus loss can occur via soil erosion, leaching in deep sandy soils, or P may be highly retained or even fixed in certain soil types.

Source: Phosphorus fertilizer sources are equal in their ability to supply P if correctly applied, even though studies have found polyphosphate promotes more root growth than orthophosphate. The International Plant and Nutrition Institute (IPNI) developed one-page fact sheets on the various granular and liquid P fertilizer sources and gave a review on their use.

TABLE 2. *Nitrogen sufficiency ranges for sampled parts at different growth stages. When N concentration in the sampled plant parts is below the sufficiency ranges, yield may decrease even in the absence of visual nutrient deficiency symptoms. Sufficiency ranges are adapted from Campbell et al. (2013).*

Growth Stage	Sampled plant part	Sufficiency ranges
Seedling (less than 4 inches in height)	whole plant	4.0–5.0%
Vegetative growth (more than 4 inches in height to tasseling)	most recent matured leaf	3.0–4.0%
Tasseling	earleaf	2.8–4.0%

When N concentration in the sampled plant parts is below the sufficiency ranges, yield may decrease even in the absence of visual nutrient deficiency symptoms. Sufficiency ranges are adapted from Campbell et al., (2013).

TABLE 3. *Soil test phosphate interpretation and recommendation for corn production in Tennessee.*

Yield potential (bu. per acre)	**Soil test phosphorus index†** (lbs. per acre)			
	Low (0 – 18)	**Medium** (19 – 30)	**High** (31 – 119)	**Very High** (more than 120)
	P_2O_5 equivalent recommendation (lbs. per acre)			
100 – 125	100	50	0	0
126 – 150	120	60	0	0
151 – 175	140	70	0	0
176 – 200	160	80	0	0
201 – 225	180	90	0	0

†The ranges are based on Mehlich I.

TABLE 4. *Phosphorus sufficiency ranges for sampled parts at different growth stages.*

Growth Stage	Sampled plant part	Sufficiency ranges
Seedling (less than 4 inches in height)	whole plant	0.40–0.60%
Vegetative growth (more than 4 inches in height to tasseling)	most recent matured leaf	0.30–0.50%
Tasseling	earleaf	0.25–0.50%

When P concentration in the sampled plant part is below the sufficiency range, yield may decrease even in the absence of visual nutrient deficiency symptoms. Sufficiency ranges are adapted from Campbell et al., (2013).

Placement: For soils testing medium or higher, either banding or broadcasting is an effective method of application. However, banding phosphate over the row has been found to be more effective than broadcasting on soils testing low in phosphorus.

Rate: Application rates should be based on soil test and can be modified based on crop production history. Soil test phosphorus interpretation and recommendation for corn production in Tennessee is summarized in Table 3. Application of P is not recommended on high or very high test soils.

Visual Deficiency Symptoms at Vegetative Stage

Plant: Stunted, dark green to bluish-green plants, particularly early season.

Leaf: Symptoms appear first on older (lower) leaves with reddish-purplish leaf tips and margins.

FIGURE 7. *Corn plants with P deficient leaves. Phosphorus deficient leaves with purplish leaf tips and margins. Visual deficiency symptoms appear first on older (lower) leaves. Photo from Moe's Diagnostic Centre.*

III. POTASSIUM

Potassium or K (also called potash) is a macronutrient that plays an important role in protein and starch formation in the grain, transport of water, nutrients and carbohydrate within the plant, cell wall strength, stomata closure, and stalk strength. Thus, corn plants with inadequate K are susceptible to drought stress, diseases and have weaker stalks with greater risk of lodging after maturity. Additionally, K-deficient corn plants may have shorter ear length and narrower ear diameter. Plants use K in the potassium ion (K^+) form. Historically potassium fertilizer sales are reported as K_2O equivalence, or 1.2 times the elemental K value.

Soil Test for Potassium

Potassium fertilizer application rate should be based on soil test. Potassium fertilizer recommendations are based on Mehlich I extraction procedure because it correlates well with the soils in Tennessee. Detailed information on how UT recommendations were developed is addressed in UT Extension publication "University of Tennessee Fertilizer Recommendation Development W 795." Recently, a calibration for Mehlich III was established for West Tennessee soils and ranges of sufficiency for soil K using Mehlich III testing are described in the UT Extension publication, "***UT Fertility Recommendations for Tennessee Row Crops SP 763***."

TABLE 5. *Soil test potash interpretation and recommendation for corn production in Tennessee.*

Yield potential (bu. per acre)	**Soil test Potassium index**† (lbs. K / acre)			
	Low (0 – 90)	**Medium** (91 – 160)	**High** (161 – 319)	**Very High** (more than 320)
	K_2O equivalent recommendation (lbs. / acre)			
100 – 125	100	50	0	0
126 – 150	120	60	0	0
151 – 175	140	70	0	0
176 – 200	160	80	0	0
201 – 225	180	90	0	0

†The ranges are based on Mehlich I.

TABLE 6. *Potassium sufficiency ranges for sampled parts at different growth stages.*

Growth Stage	Sampled plant part	Sufficiency ranges
Seedling (less than 4 inches in height)	whole plant	3.0–4.0%
Vegetative growth (more than 4 inches in height to tasseling)	most recent matured leaf	2.0–3.0%
Tasseling	earleaf	1.8–3.0%

When K concentration in the sampled plant part is below the sufficiency range, yield may decrease even in the absence of visual nutrient deficiency symptoms. Sufficiency ranges are adapted from Campbell et al., (2013).

Preplant Potassium Fertilizer Applications

Potassium is generally applied preplant in corn, either in the fall or in the spring prior to planting.

Source: Potassium fertilizer sources are equal in their ability to supply K if correctly applied. The International Plant and Nutrition Institute (IPNI) developed one-page fact sheets on the various K fertilizer sources (potassium sulfate, potassium nitrate and muriate of potash) and gave a review on their use.

Placement: For soils testing medium, both banding and broadcasting are effective methods of application. However, banding potash has been found to be more effective than broadcasting on soils testing low in potassium.

Rate: Application of K is not recommended on high or very high testing soils. Application rate should be based on soil test and can be modified based on crop production history. Soil test potash interpretation and recommendation for corn production in Tennessee is presented in Table 5.

Starter Potassium Fertilizer Application

The additive effect of K starter fertilizer on corn yield is rarely observed in corn and starter K fertilizer application is not recommended in Tennessee. See starter section under N fertility.

Sidedress Potassium Fertilizer Application

Very little research has been done on the efficiency of sidedress K application on corn.

Plant/Tissue Analysis for Potassium

For **seedling plants** (less than 4 inches in height), the whole plant about 1 inch above the soil surface is recommended. For corn at **vegetative growth stage** (more than 4 inches in height to tasseling), the most recently matured leaf (with visible collar) from the tops of 15-20 plants is recommended. For corn **plants at tasseling**, the earleaf (leaf adjacent to the uppermost developing ear) of

FIGURE 8. *Potassium deficient leaves are yellowish green in color. Yellowing starts from the tip of the leaves and progresses along the edges towards the base of the lower leaves. Margins of leaf turn brown, as tissue dies (necrosis). Shorter corn ears on the left were harvested from K deficient plants. Photos courtesy of Jasper Teboh and Nutifafa Adotey.*

TABLE 7. *Selected sulfur fertilizer, sulfur composition and water solubility.*

Fertilizer	Sulfur composition	Water Solubility
Ammonium sulfate	24%	Soluble
Potassium sulfate	17-18%	Soluble
Potasium magnesium sulfate	21-22%	Soluble
Sulfur, elemental	30-99%	Non-soluble
Gypsum	18-23%	Semi-soluble
Thiosulfate	10-26%	Soluble

15-20 plants is recommended. Potassium sufficiency ranges for sampled parts at different growth stages is presented in Table 6.

Visual Deficiency Symptoms at Vegetative Stage

Plant: In severe cases, plants may lodge late in the growing season.

Leaf: Symptoms appear first on older (lower) leaves. Yellowing and then necrosis (tissue dies) of corn leaf margin in severe cases. Yellowing starts from the tip of the leaf and progresses along the edges towards the base of the leaf.

IV. SULFUR

Soil Test for Sulfur

UT Extension publication "***Sulfur and Tennessee Row Crops W 435***" provides an excellent review on sulfur as well as response of corn and other row crops to S application. Corn is the most likely crop to respond to S application when grown in S deficient soil. Current extraction methods are not reliable in predicting S yield response to S level in soil. As a result, S application is based on field conditions and past cropping history where crops have exhibited visual sulfur deficiency confirmed by tissue testing. Corn grown on soils with low organic matter and/or coarse textured soils tend to have a yield response to S application. Plants use S in the sulfate (SO_4^{2-}) form.

At-planting and Preplant Sulfur Fertilizer Application

Sulfur is typically applied near or at planting in corn in the spring because S in the sulfate form is prone to leaching.

Source: There are several different S fertilizers (Table 7). The International Plant and Nutrition Institute (IPNI) developed a one-page fact sheet on some S fertilizer sources and gives a review on their use.

Placement: Banding on row or broadcasting are both effective methods of S application in corn.

Rate: On soils having a coarse-textured subsoil, 10 pounds of S per acre as part of the fertilizer blend may benefit yield, especially where deficiency symptoms have been observed in corn in the past or where plant tissue tests have suggested sulfur deficiency.

Starter Sulfur Fertilizer Application

Very little research on the efficiency of starter S application on corn has been conducted in Tennessee.

Sidedress Sulfur Fertilizer Application

Very little unbiased research has been done on the efficiency of sidedress S application on corn. Broadcast applications of ammonium sulfate at sidedress may be beneficial to correct S deficiency. Recent University of Tennessee research demonstrated that dissolved ammonium sulfate applied in a row middle dribble as a sidedress may supply S at amounts high enough to correct visual S deficiency.

FIGURE 8. *Corn plant with S deficient leaves. Sulfur deficient leaves are pale or yellowish-green in color and appears first on younger (upper) leaves. Location of deficiency is useful in differentiating between S and N deficiency. Photo courtesy North Carolina State Extension.*

TABLE 8. *Sulfur sufficiency ranges for sampled parts at different growth stages.*

Growth Stage	Sampled plant part	Sufficiency ranges
Seedling (less than 4 inches in height)	whole plant	0.15–0.4%
Vegetative growth (more than 4 inches in height to tasseling)	most recent matured leaf	0.15–0.6%
Tasseling	earleaf	0.12–0.4%

When S concentration in the sampled plant part is below the sufficiency range, yield may decrease even in the absence of visual nutrient deficiency symptoms. Sufficiency ranges are adapted from Campbell et al., (2013).

Plant/Tissue Analysis for Sulfur

For **seedling plants** (less than 4 inches in height), sampling the whole plant about 1 inch above the soil surface is recommended. For corn at **vegetative growth stage** (more than 4 inches in height to tasseling), the most recently matured leaf (with visible collar) from the tops of 15-20 plants is recommended. For **corn plants at tasseling**, the earleaf (leaf adjacent to uppermost developing ear) of 15-20 plants is recommended. Sulfur sufficiency ranges for sampled parts at different growth stages is presented in Table 8.

Visual Deficiency Symptoms at Vegetative Stage

Plant: Stunted light green plants with spindly stems.

Leaf: Symptoms appear first on younger (upper) leaves with yellowing of leaves.

V. ZINC

Zinc (Zn) is involved in several plant enzyme reactions, carbohydrate metabolism, protein synthesis and membrane integrity. Zinc is particularly important in C4 plants such as corn because it's a component of carbonic anhydrase which catalyzed the conversion of carbon dioxide to bicarbonate during photosynthesis. Plants use Zn in the zinc ion (Zn^{2+}) form.

Soil Test for Zinc

The Zn fertilizer recommendation is based on the Mehlich I extraction procedure because it correlates well with the soils in Tennessee. Soils testing less than 2 lbs. per acre (Mehlich I) are considered deficient.

TABLE 7. *Selected zinc fertilizer, zinc composition and water solubility.*

Fertilizer	Zinc composition	Water Solubility
Zinc Sulfate	about 25–36%	100%
Zinc Lignosulfonate	about 10%	90%
Zinc EDTA	about 10%	100%
Zinc Oxysulfate	variable	variable
Zinc Oxides	about 70–80%	0%
Zinc Sucrate	about 35%	0%

Zinc fertilizer application to corn should be based on a soil test, except in the selected Middle and East Tennessee counties of Bedford, Cannon, Coffee, Cumberland, Davidson, DeKalb, Fentress, Franklin, Giles, Grundy, Jackson, Lincoln, Macon, Marshall, Maury, Moore, Morgan, Overton, Pickett, Putnam, Robertson, Smith, Sumner, Trousdale, Warren, Williamson and Wilson.

In these selected counties, Zn should be applied when any of these conditions are present: either the soil pH is above 6.0 and phosphorus is high; any time lime is applied; or where zinc deficiencies were observed the previous year.

Preplant Zinc Fertilizer Application

Zinc is usually applied preplant in corn to allow for soil incorporation and early uptake in seedling plants.

Source: Several granular and liquid Zn fertilizers are available (Table 9), and an effective granular Zn fertilizer should be 40-50 percent water soluble. In general, soil applied Zn EDTA tends to be more effective than zinc sulfate and zinc lignosulfonate. Generally, zinc oxides and zinc sucrate have low solubility and hence are not a good source of Zn.

FIGURE 10. *Corn plants with Zn deficient leaves. Zinc deficient leaves show a broad band of white or yellowish color and appears on younger (upper) leaves. Yellowing starts from the base of the leaves and progresses to the tip. Margins, midrib area and tips of leaf usually remain green. There is interveinal striping of leaves (not very visible in the photo). Photo courtesy of Jim Camberato and Stephen Maloney.*

TABLE 10. *Zinc sufficiency ranges for sampled parts at different growth stages.*

Growth Stage	Sampled plant part	Sufficiency ranges
Seedling (less than 4 inches in height)	whole plant	20–70 ppm
Vegetative growth (more than 4 inches in height to tasseling)	most recent matured leaf	20–70 ppm
Tasseling	earleaf	16–50 ppm

When Zn concentration in the sampled plant part is below the sufficiency range, yield may decrease even in the absence of visual nutrient deficiency symptoms. Sufficiency ranges are adapted from Campbell et al., (2013).

Placement: Banding or broadcasting are effective methods of application.

Rate: Zinc can be broadcast apply at a rate of 5 lbs. Zn per acre as EDTA or 15 lbs. Zn per acre as zinc sulfate just prior to planting for low testing soils or to fields in the above listed counties in Middle and East Tennessee where field conditions likely to cause deficiency are present.

Plant/Tissue Analysis for Zinc

For **seedling plants** (less than 4 inches in height), sampling the whole plant about 1 inch above the soil surface is recommended. For corn at **early growth stag**e (more than 4 inches in height to tasseling), the most recently matured leaf (with visible collar) from the tops of 15-20 plants is recommended. For corn **plants at tasseling**, the earleaf (leaf adjacent to uppermost developing ear) of 15-20 plants is recommended. Zinc sufficiency ranges for sampled parts at different growth stages is present in Table 10.

Visual Deficiency Symptoms at Vegetative Stage

Leaf: Symptoms appear first on younger (upper) leaves as interveinal striping from the base of the leaf that progresses to the tip or whitish band at the base of the leaf. Margins, midrib area and tips of leaf usually remain green.

RESOURCES

Adotey, N., M.A. McClure, and X. Yin. Enhanced Efficiency Nitrogen Fertilizer as a Tool to Control Nitrogen Loss in Row Crop Production. 2020. UT Extension publication, PB 1888. ***https://extension.tennessee.edu/publications/Documents/PB1888.pdf***

Bender, R.R, J.W. Haegele, M.L. Ruffo, and F.E. Below. 2013. Nutrient Uptake, Partitioning, and Remobilization in Modern, Transgenic Insect-Protected Maize Hybrids. Agronomy journal 105:161-170.

Campbell R.A. 2013. Reference Sufficiency Ranges for Plant Analysis in Southern Region of the United States. Southern Cooperative Series Bulletin #394. NC Dept. of Agriculture and Consumer, Raleigh, NC. ***https://soillab.tennessee.edu/wp-content/uploads/sites/129/2020/06/scsb394.pdf***

Duncan, L., H.J. Savoy, and D. Joines. 2015. UT fertility recommendations for Tennessee row crops. Extension Publication, SP763. ***https://extension.tennessee.edu/publications/Documents/SP763.pdf***

Duncan, L., H. Savoy, F. Walker, M. Essington, M. Buschermohle, S. Jagadamma, S. Hawkins, D. Tyler, R. Florence, A. McClure, G. Allen, D. Qualls, J. Wilson. University of Tennessee Fertilizer Recommendation Development. UT Publication. W795. ***https://extension.tennessee.edu/publications/Documents/W795.pdf***

Raper, T.B., A.T. McClure, F. Yin, and B. Brown. 2014. Sulfur and Tennessee Row Crops. UT Extension Publication W 435. ***https://extension.tennessee.edu/publications/Documents/W435.pdf***

Savoy, H.J., and D.K. Joines. 2014. Liming Acid Soils in Tennessee. UT Extension Publication, PB1096. ***https://trace.tennessee.edu/cgi/viewcontent.cgi?article=1048&context=utk_agexcrop***

Savoy, H.J., and D.K. Joines. 2012. Soil Testing. Extension Publication, PB 1061. ***https://extension.tennessee.edu/publications/Documents/PB1061.pdf***

Savoy, H. J. 2009. Interpreting Mehlich 1 and 3 Soil Test Extractant Results for P and K in Tennessee. UT Extension, W229. ***https://extension.tennessee.edu/publications/documents/W229.pdf***

Savoy, H.J. The Pre-Sidedress Nitrate-N Soil Test (PSNT) for Nitrogen Management in Corn Production Systems of Tennessee. UT BESS Information Sheet, 105. ***https://soillab.tennessee.edu/wp-content/uploads/sites/129/2020/07/FactsheetPSNTCinfosheet105.pdf***

Savoy, H.J. 2009. Procedures Used by State Soil Testing Laboratories in the Southern Region of the United States. Southern Cooperative Series bulletin 407, formerly listed as 190D. ***https://ag.tennessee.edu/spp/SPP%20Publications/SCSBno190.pdf***

Savoy, H., and X. Yin, and M.A. McClure. 2016. Summary of Current University of Tennessee Institute of agriculture Research Evaluating Urea-Nitrogen-Fertilizer Additives or Coatings. University of Tennessee Publication, W364. ***https://extension.tennessee.edu/publications/Documents/W364.pdf***

Verbree, D., A.T. McClure, and B. Lieb. Fertigation of Row Crops Using Overhead Irrigation. ***https://extension.tennessee.edu/publications/Documents/W303.pdf***

Walker, F. 2000. PB1645-Best Management Practices for Phosphorus in the Environment. The University of Tennessee Agricultural Extension Service, PB 1645-5M-6/00 E12-2015-00-203-00. ***https://trace.tennessee.edu/cgi/viewcontent.cgi?article=1019&context=utk_agexenvi***

Walker, F. and S. Hawkins. 2016. Guidelines for Using the Revised Tennessee Phosphorus Risk Index. UT Extension Publication W 372. ***https://extension.tennessee.edu/publications/Documents/W372.pdf***

Walker, F. PB1645-Best Management Practices for Phosphorus in the Environment. The University of Tennessee Agricultural Extension Service, PB 1645. ***https://extension.tennessee.edu/publications/Documents/PB1645.pdf***

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