Corn Nutrition 101

It is imperative to understand the principles of soil fertility to efficiently manage corn nutrients, corn production, and environmental stewardship. There are 17 chemical elements that are known to be essential for plant growth, 14 of these elements come from the soil. Each essential plant nutrient is needed in different amounts by the plant, each varies in mobility within the plant, and varies in concentration in the harvested mature corn plant components. Knowing the relative amount of each nutrient by crop and the amounts removed with harvest is useful for calculating the amount of fertility that will need to be added to the soil to maintain optimum harvest levels.

Table 1. Essential plant elements, source, roles and relative quantities in the plant.

Element	Source	Role in the Plant	Concentration
Carbon (C)	Air	Constituent of carbohydrates; necessary for photosynthesis.	45%
Oxygen (O)	Air/Water	Constituent of carbohydrates: necessary for respiration.	45%
Hydrogen (H)	Water	Maintains osmotic balance; important in many biochemical reactions, constituent of carbohydrates.	6%
Nitrogen (N)	Air/Soil	Constituent of amino acids, proteins, chlorophyll, and nucleic acids.	1-5%
Potassium (K)	Soil	Involved with photosynthesis, carbohydrates translocation, protein synthesis.	.5-1%
Phosphorous (P)	Soil	Constituent of proteins, coenzymes, nucleic acids, and metabolic substrates; important in energy transfer.	.1-.5%
Magnesium (Mg)	Soil	Enzyme activator; component of chlorophyll.	.1-.4%
Sulfur (S)	Soil	Component of certain amino acids and plant proteins.	.1-.4%
Chlorine (Cl)	Soil	Involved with oxygen production and photosynthesis.	.01-.1%
Iron (Fe)	Soil	Involved with chlorophyll synthesis and in enzymes electron transfer.	50-250ppm
Manganese (Mn)	Soil	Controls several oxidation-reduction systems and photosynthesis.	20-200ppm
Boron (B)	Soil	Important in sugar translocation and carbohydrates metabolism.	6-60ppm
Zinc (Zn)	Soil	Involved with enzymes that regulate various enzymes.	25-150ppm
Copper (Cu)	Soil	Catalyst for respiration; component of various enzymes.	5-20ppm
Molybdenum (Mo)	Soil	Involved with nitrogen fixation and transforming nitrate to ammonium.	.5-.2ppm
Nickel (Ni)	Soil	Necessary for proper functioning of urease and seed germination.	.1-1ppm

Table 1. from Overview of Soil Fertility, Plant Nutrition, and Nutrient Management, NRCS, Agustin Pagoni, John E. Sawyer, Antonia P. Mallarina Department of Agronomy, Iowa State University.

To be classified as "essential", the element needs to meet the following criteria:

- The plant cannot complete its life cycle (seed to new seed) without it.
- The elements' function cannot be replaced by another element.
- The element is directly involved in the plant's growth and reproduction.

Non-mineral nutrients:

Three elements, carbon (C), hydrogen (H), and oxygen (O), are non-mineral nutrients because they are derived from the air and water. Although they represent approximately 95% of plant biomass, they are generally given little attention in plant nutrition because they are almost always in sufficient supply. However, other factors such as soil management and the environmental conditions can influence the availability and crop growth response.

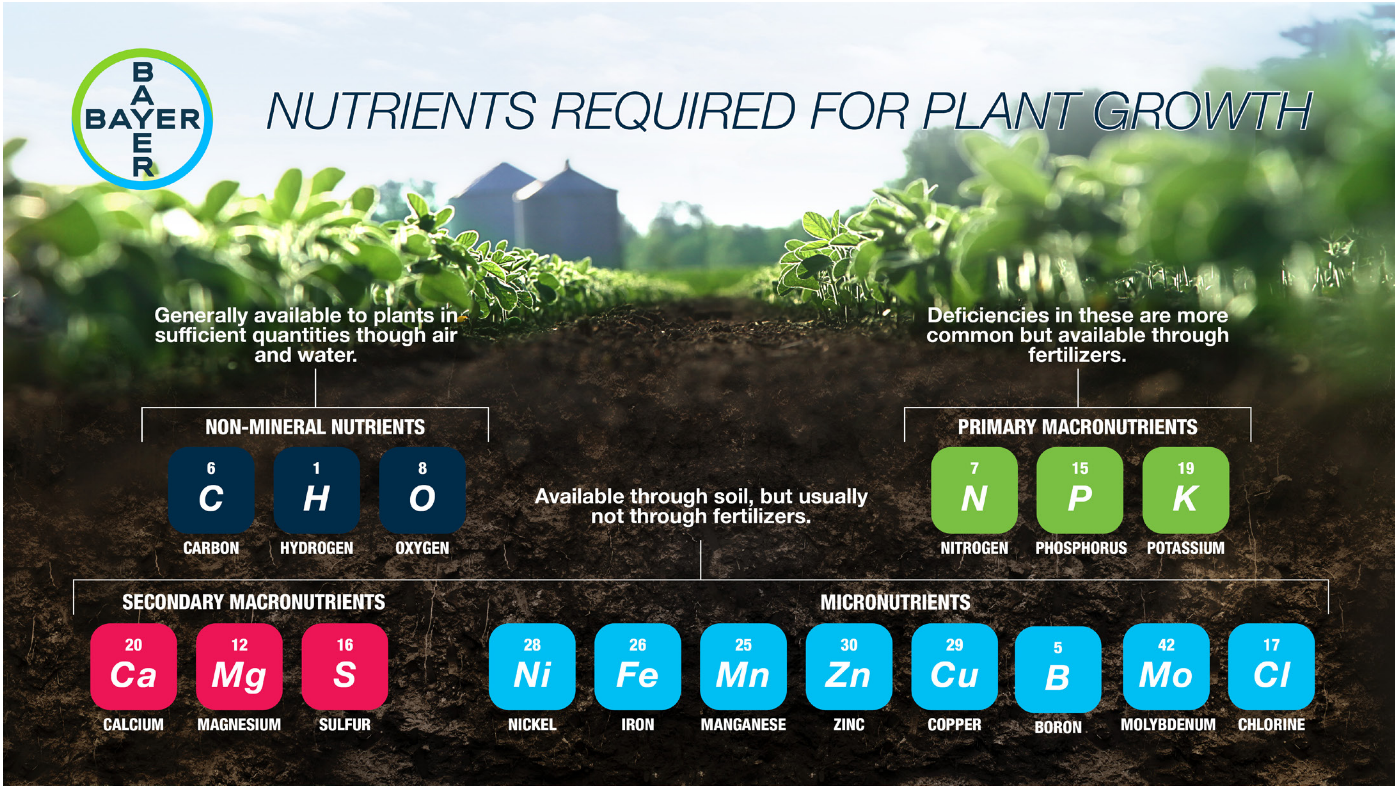

Figure 1. Mineral Nutrients Required for Plant Growth

The 14 mineral nutrients are classified as either macronutrients or micronutrients based upon plant requirements and relative fertilization need. There are 6 macronutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). The macronutrients, N, P, K, are often classified as primary macronutrients, because deficiencies of N, P, K are more common than the secondary macronutrients, Ca, Mg, and S. The micronutrients include boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn). Most of the macronutrients represent 0.1-5% or 100-5000 parts per million (ppm), of dry plant tissue, whereas the micronutrients generally comprise less than .025% or 250ppm, of dry plant tissue (Table1).

How plants uptake nutrients:

Each of the nutrients cannot be taken up by plants in its elemental form, they must instead be taken up in an 'ionic' or charged form, with the exception of boron (B) as boric acid which is uncharged (Table 2). Most fertilizers are made up of combinations of these available nutrient forms, so when fertilizer dissolves, the nutrient(s) can be immediately available for uptake. Knowing what form of a nutrient the plant absorbs helps inform what controls the cycling and movement of the nutrient in the soil. Additionally, understanding how nutrients function within the plant is useful in diagnosing nutrient deficiencies.

Table 2. Nutrient Forms Taken up by Plants.

Element	Form
Nitrogen (N)	NO_3^- (nitrate), NH_4^+ (ammonium)
Potassium (K)	K^+
Phosphorous (P)	$H_2PO_4^-$, HPO_4^{-2} (phosphate)
Calcium (Ca)	Ca^{+2}
Magnesium (Mg)	Mg^{+2}
Sulfur (S)	SO_4^{-2} (sulfate)
Chlorine (Cl)	Cl^- (chloride)
Iron (Fe)	Fe^{+2} (ferrous), Fe^{+3} (ferric)
Manganese (Mn)	Mn^{+2}
Boron (B)	H_3BO_3 (boric acide), $H_2BO_3^-$ (borate)
Zinc (Zn)	Zn^{+2}
Copper (Cu)	Cu^{+2}
Molybdenum (Mo)	MoO_4^{-2} (molybdate)
Nickel (Ni)	Ni^{+2}

Table 2. from Overview of soil fertility, plant nutrition, and nutrient management, NRCS, Agustin Pagoni, John E. Sawyer, and Antonia P. Mallarina, Department of Agronomy, Iowa State University.

Nutrient uptake by roots is dependent on the activity of the root (corn root number, root dry matter, and root length), ability to absorb nutrients, and the nutrient concentration at the surface of the root. Roots come directly in contact with some nutrients *(interception)* as they grow; however, this only accounts for a very low percentage of the total amount of nutrients taken up by plants. Therefore, other mechanisms must cause the movement of nutrients to the plant.

Water moves toward and into the root as the plant uses water or transpires. This process is referred to as '*mass flow*', accounts for a substantial amount of nutrient movement toward the plant root, especially for the mobile nutrients such as NO_{3-}. Specifically, mass flow has been found to account for about 80% of N movement into the root system of a plant, yet only 5% of the more immobile P. It has been found that *'diffusion'* accounts for the remainder of the nutrient movement.

Diffusion is the process where chemicals move from an area of high concentration to any area of low concentration. Fertilizing near the plant root, the plant is less dependent on exchange processes and diffusion to uptake nutrients, especially P. The nutrients that are most dependent diffusion to move them toward a plant root are relatively immobile, have relatively low solution concentrations, and yet are needed in large amounts by the plant, such as P and K. The secondary macronutrients (Ca, Mg, S) often do not depend of diffusion because their solution concentrations are fairly high in soil, relative to plant requirements.

How nutrients move within the plant:

All nutrients move relatively easily from the root to the growing portions of the plant. Some nutrients can also move from older tissue to newer tissue if there is a deficiency of that nutrient. Knowing which nutrients are 'mobile' is very useful in diagnosing plant nutrient deficiencies because if only the lower leaves are affected, then a mobile nutrient is most likely the cause. Conversely, if only the upper leaves show the deficiency, then the plant is likely deficient with an immobile nutrient because that nutrient cannot move from older to newer leaves. Table 3 list the six mobile and eight immobile mineral nutrients. Sulfur is one element that lies between mobile and immobile elements depending on the degree of deficiency.

Table 3. Mobile and Immobile Nutrients

Mobile Nutrients	Immobile nutrients
Nitrogen (N)	Sulfur (S)
Phosphorous (P)	Calcium (Ca)
Potassium (K)	Iron (Fe)
Chloride (Cl)	Zinc (Z)
Magnesium (Mg)	Manganese (Mn)
Molybdenum (Mo)	Boron (B)
	Copper (Cu)
	Nickel (Ni)

Table 3. from Overview of Soil fertility, Plant nutrition, and Nutrient Management, NRCS, Agustin Pagoni, John E. Sawyer, and Antonia P. Mallarina, Department of Agronomy, Iowa State University.

Nutrient Deficiencies of Corn Symptoms

The following pictures represent some of the more common nutrient deficiency symptoms in corn. When visual symptoms of nutrient deficiency particularly N and K, yield loss has occurred.

Figure 2. Nitrogen (N) Deficiency in Corn

Nitrogen (N) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, C.Witt, J.M. Pasuquin

Figure 3. Phosphorous (P) Deficiency in Corn

Phosphorous (P) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, Jason Kelly, Mozaffari

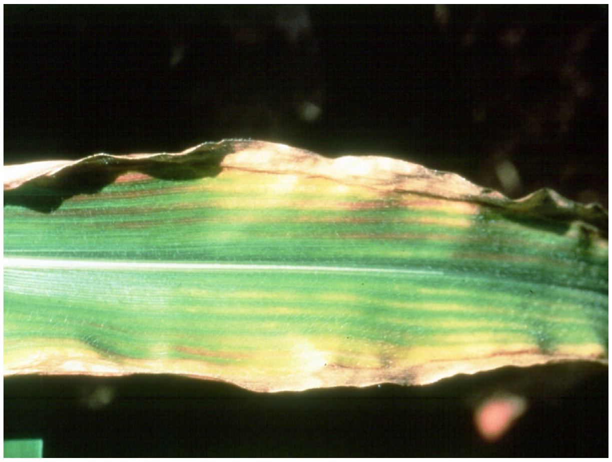

Figure 4. Potassium (K) Deficiency in Corn

Potassium (K) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, M. Hasegawa

Figure 5. Magnesium (Mg) Deficiency in Corn

Magnesium (Mg) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, P. Kumar

Figure 6. Calcium (Ca) Deficiency in Corn

Calcium (Ca) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, M.K. Sharma and P. Kumar

Figure 7. Iron (Fe) Deficiency in Corn

Iron (Fe) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, M, K. Sharma and P. Kumar

Figure 8. Zinc (Zn) Deficiency in Corn

Zinc (Zn) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, Dr. Gurupada Balol.

Figure 9. Manganese (Mn) Deficiency in Corn

Manganese (Mn) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, M, K. Sharma and P. Kumar

Figure 10. Boron (B) Deficiency in Corn

Boron (B) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, J.E. Espinoza

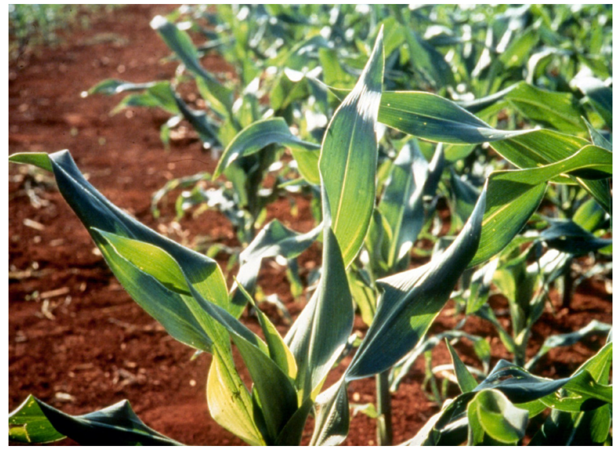

Figure 11. Copper (Cu) Deficiency in Corn

Copper (Cu) Deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, T. Yamada

Developing Fertilizer Recommendations, Understanding Nutrient Uptake and Partitioning

Biotechnology, breeding, and agronomic advancements have increased corn yields to new highs. Current fertilization practices developed decades ago, may not match the requirements of newer hybrids which are now grown at population densities higher than ever before. A re-evaluation of nutrient uptake and partitioning can provide the foundation for fine-tuning our practices as we strive to achieve corn's maximum yield potential.

When developing fertilizer recommendations, two major aspects of plant nutrition are important to understand and manage high yield corn production:

Figure 12. Sulfur (S) deficiency in Corn

Sulfur (S) deficiency in Corn. Photo is provided courtesy of the International Plant Nutrition Institute (IPNI) and its IPNI Crop Nutrient Deficiency Image Collection, Jashandeep Kaur

- Total Nutrient Uptake: The amount of a given mineral nutrient acquired during the growing season.
- Partitioning: The amount of that nutrient contained in the grain or removed with the grain.

Further improving fertility practices require matching in-season nutrient uptake with the availability of nutrients. For some nutrients (e.g., N, P, K, Mg, Mn, and Fe), as much as two-thirds of total uptake occurs during vegetative growth. Of critical importance is supplying N to meet corn's peak needs of 7.8 lb N/day from V10-V14. Uptake of N does not cease at VT/R1 since as much of 50 lb N/acre is accumulated and petitioned directly into the developing seeds during grain fill.

Contrary to nutrients like N and K, nutrient accumulation of P, S, Zn, and Cu is equally distributed between vegetative growth and during reproductive growth (ear development and grain-fill). Season-long supply of P, S, Zn, and Cu is imperative to maximize corn yields. Relative to total uptake, P is removed to a greater extent than any other nutrient. Agronomic practices which do not adequately replace removed P may eventually lead to a depletion in soil fertility levels.

Even though nutrient management is a complex process, improving understanding of uptake timing and rates, partitioning, and remobilization of nutrient by corn provides opportunities to optimize fertilizer rates and application timing.

Table 4. Corn Nutrient Removal - Grain Only (lb)

Bushels/Acre	300	280	260	240	220	200	180	160	140	120	100	80
Nitrogen (N)	201.00	187.60	174.20	160.80	147.40	134.00	120.60	107.20	93.80	80.40	67.00	53.60
Phosphate (P_2O_5)	105.00	98.00	91.00	84.00	77.00	70.00	63.00	56.00	49.00	42.00	35.00	28.00
Potassium (K_2O)	75.00	70.00	65.00	60.00	55.00	50.00	45.00	40.00	35.00	30.00	25.00	20.00
Sulfur (S)	24.00	22.40	20.80	19.20	17.60	16.00	14.40	12.80	11.20	9.60	8.00	6.40
Calcium (Ca)	4.05	3.78	3.51	3.24	2.97	2.70	2.43	2.16	1.89	1.62	1.35	1.08
Copper (Cu)	0.15	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.07	0.06	0.05	0.04
Manganese (Mn)	0.21	0.20	0.18	0.17	0.15	0.14	0.13	0.11	0.10	0.08	0.07	0.06
Zinc (Zn)	0.33	0.31	0.29	0.26	0.24	0.22	0.20	0.18	0.15	0.13	0.11	0.09
Boron (B)	0.72	0.67	0.62	0.58	0.53	0.48	0.43	0.38	0.34	0.29	0.24	0.19
Iron (Fe)	0.45	0.42	0.39	0.36	0.33	0.30	0.27	0.24	0.21	0.18	0.15	0.12

Table 5. Corn Nutrient Removal - Stover Only (lb)

Bushels/Acre	300	280	260	240	220	200	180	160	140	120	100	80
Nitrogen (N)	135.00	126.00	117.00	108.00	99.00	90.00	81.00	72.00	63.00	54.00	45.00	36.00
Phosphate (P_2O_5)	48.00	44.80	41.60	38.40	35.20	32.00	28.80	25.60	22.40	19.20	16.00	12.80
Potassium (K_2O)	330.00	308.00	286.00	264.00	242.00	220.00	198.00	176.00	154.00	132.00	110.00	88.00
Sulfur (S)	21.00	19.60	18.20	16.80	15.40	14.00	12.60	11.20	9.80	8.40	7.00	5.60
Calcium (Ca)	39.00	36.40	33.80	31.20	28.60	26.00	23.40	20.80	18.20	15.60	13.00	10.40
Copper (Cu)	60.00	56.00	52.00	48.00	44.00	40.00	36.00	32.00	28.00	24.00	20.00	16.00
Manganese (Mn)	2.25	2.10	1.95	1.80	1.65	1.50	1.35	1.20	1.05	0.90	0.75	0.60
Zinc (Zn)	0.45	0.42	0.39	0.36	0.33	0.30	0.27	0.24	0.21	0.18	0.15	0.12
Boron (B)	0.09	0.08	0.08	0.07	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.02
Iron (Fe)	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.20

Tables 4 and 5: N, P, K, and S numbers courtesy of International Plant Nutrition Institute (IPNI). These numbers are estimations. Actual nutrient removal may vary based on many factors.

Fertilization of Macronutrients in Corn Production:

Nitrogen (N) is the fertilizer element required in the largest amounts and the greatest cost. Each bushel of grain harvested will contain almost a pound of N. For silage nitrogen use is over 10 pounds for every 1,000 pounds of dry matter. Nitrogen must be provided by the soil or by fertilizer N since only one-third to two -thirds of the N added is recovered in the harvested corn. Most of the unrecovered N is irreversibly lost from the soil (leaching).

Nitrogen recovery is not only variable but also unpredictable. The unpredictability is primarily due to the effect of weather on the release of soil N on the fate of fertilizer N. This makes it impossible to predict precisely the quantity of N required for maximum yield and maximum economic return. It also makes it impossible to perform a meaningful soil test for N. Biological and chemical reactions are continuously changing soil N from one form to another, and each form behaves very differently.

Organic soil N is mostly insoluble and not directly available to plants. Virtually all soils contain a large quantity of organic N. A soil that has 3 percent organic matter contains over 3000 pounds of organic nitrogen per acre. However, only a small part of this, 1 to 5 percent each growing season, is broken down to in inorganic N forms and available to plants.

Inorganic ammonium (NH_4^+) is either released by organic matter decomposition or added as fertilizer N. Ammonium is a relatively immobile ion that behaves much like K^+. Under some conditions, it can be lost from the soil as ammonia (NH_3) gas but is not susceptible to leaching or denitrification as is nitrate (NO_3^-). Corn takes up NH_4^+ less readily than NO_3^-. In most soils that are suitable for corn production, NH_4 is rapidly converted to NO_3^- in a process called 'nitrification'. This reaction is completed within a few days to a month after fertilization, depending on soil temperatures.

Nitrate is a highly mobile ion because its solubility in water is essentially unlimited and because it does not interact significantly with the clays or organic matter of most soils. Since NO_3^- moves with soil water, it is readily available to plants but also is susceptible to leaching below the root zone. Leaching losses of fertilizer N are most significant on well-drained soils during long-lasting or very intense rainfall. Denitrification is a microbiological reaction that can proceed very rapidly when soils become water-saturated. It is important in soils with slow drainage characteristics are prevalent in the rooting zone. Some nitrate is lost almost every year in all soils, but such losses become serious when heavy rains fall within a month after fertilization. Soil drainage is the most reliable predictor of total loss so more N fertilizer is required in poorly drained soils. The tillage system also influences this process. **Denitrification, leaching, and immobilization can all be greater in no-till soils,** so N rates should general be increased slightly when using no-till.

With few exceptions, plants respond equally to all inorganic forms of N fertilizer. Ammonia forms are generally equivalent to NO_3^- forms because they are converted to NO_3^-. Urea ($NH_2^-CO^-NH_2$) can be an important exception. Urea is rapidly converted to NH_4^+ in the soil which makes the soil near the granule more alkaline. This favors the formation of NH_3 gas from NH_4. The large fraction of N sometimes can be volatilized as NH_3 if urea is broadcast on moist, warm soil. Losses can be minimized by avoiding these conditions or by incorporating the urea into the soil. In some locations, urea is available at a lower price than alternative N forms and so it may be more economical to use, despite the greater risk of loss. Urea should not be considered a slow-release fertilizer.

Organic sources of N should not be ignored when estimating N fertilizer needs. Sods, legumes cover crops and animal manure can replace a large portion or, in some cases almost all the inorganic N application.

Nitrogen applied as a liquid, ether solution or suspension, is not necessarily more effective than solid N. The choice between liquids and solids should be the case on cost, handling, and convenience.

Nitrogen application timing and effective method of increasing N recovery by corn are to delay or split the N application. This practice works because young corn plants (up to 4 to 6 weeks) require very little N and most can be supplied by the soil. Soil are the wettest and so most prone to N loses early in the season. Delayed applications are most beneficial where denitrification and leaching losses are greatest, particularly on poorly or moderately well-drained soils. A general guideline for these types of soils, if two-thirds or more of the N is applied 4 to 6 weeks after planting, the total N application can be reduced by 25 to 50 pounds per acre. Fall application of N in most corn production areas is generally not recommended. In those areas where fall anhydrous ammonia is applied, attention to soil temperature that needs to be below 50°F.

Nitrogen placement has no consistent, significant effect on the efficiency of N fertilizers containing NH_4 and NO_3^- salts. Researchers have sometimes observed benefits of banding or sub-surface application under certain conditions, but the evidence is not yet complete enough to justify the machinery alterations and extra time which will usually be required. Incorporating area immediately after application will reduce the risk of volatilization.

Nitrogen inhibitors are chemicals that act specifically to inhibit the conversion NH_4 to NO_3^- and indirectly reduce the change of early-season leaching and denitrification. These chemicals are beneficial only when such losses are potentially significant. In many areas where corn is produced, plants have responded consistently to inhibitors on less than well-drained no-till soils.

Phosphorous (P) and Potassium (K):

Both phosphorus (P) and potassium (K) are required in large quantities for good corn growth and yields. A good corn crop will take up 30 to 40 pounds of phosphate (P_2O_5) and 100 to 150 pounds of potash (K_2O) per acre. About three-fourth of the phosphate and about a third of the potash is in the grain, the remainder is being utilized in the leaves, stalk, roots, husks, and cob. In grain production systems where all crop residues are left on the field, 20 to 30 pounds of P_2O_5

and 35 to 40 pounds of K_2O are removed from the soils in the grain. In silage production, all P_2O_5 and K_2O taken up by the plant, except that in the roots and stubble, is removed from the soil.

It is important that adequate P_2O_5 and K_2O are available for plant uptake during the first half of the growing season. By the time kernels start filling rapidly (70 to 75 days after seedling emergence and 10 to 15 days after silking) the plant will have taken up about 70 percent of its P_2O_5 requirement and nearly 90 percent of its K_2O requirement.

Both P and K are considered immobile elements since they react with the soil in many ways that minimize their movement with soil water. This is particularly true of P since it forms compounds with soil calcium, iron, aluminum, manganese and zinc which are less soluble than the P compounds in fertilizer. If soil pH is in the range of 6.0 to 6.5, much of the fertilizer P will react to form monocalcium or dicalcium phosphates which are more soluble than the iron, aluminum and manganese phosphate that form at lower pH levels. Therefore, increased P availability is one benefit of good liming practices. Potassium, like NH_4, is retained on clays and organic matter by cation exchange (CEC). Except on low cation exchange capacity soil such as very sandy soils, the soil cation exchange capacity is great enough to hold an adequate reservoir of readily available K^+. Leaching of P and K is generally limited to these low CEC soils. Loss of P and K by the erosion of topsoil is a great concern in many areas of the corn belt.

P and K requirement for good corn growth are directly related to the amount of plant-available P and K already in the soil. Using a reliable soil testing lab which employs field-tested procedures is the best way to determine soil content of plant-available P and K. Recommendations made by university soil labs and many of the independent labs, based on the Mehelich III extraction (see example Table 6). The annual amount of P and K taken up by the plant form fertilizer is not likely to exceed 15 to 20 percent of P or 25 to 40 percent of K applied. **Check with your local extension service or fertilizer dealer for a specific recommendation for your area.**

Table 6. Recommended Rates of Phosphate and Potash Application (in lb/A) for Corn, as Related to Soil Test Value.

Soil Test Value	(P_2O_5)	(K_2O)
High (above 60P, 300 K)	0	0
Medium (60-30 P, 300-190 K)	0-60	0-60
Low (below 30 P, 190 K)[1]	60-120	60-120

[1] Where soil test values indicate extremely low levels of P in the soil (less than 5) and where fertilizer P must be broadcast and disked into the soil, up to 200 lb/acre may be beneficial. Developed as an example from University of Kentucky AGR-15 Fertilization and Liming for Corn.

Commercial fertilizers are the most widely used source of P and K for corn production. Sources of P most commonly used are triple superphosphate (0-46-0), diammonium phosphate (18-46-0), monoammonium phosphate (11-48-0), and a wide array of other ammoniated phosphates, both liquid and dry. The most commonly used sources of fertilizer P are considered equally effective for agronomic purposes when used at recommended rates and properly applied. Solid and fluid forms of P are also considered equally effective.

Almost all K fertilizer used for corn is murate of potash (0-0-60). Other sources are sulfate of potash (0-0-50) and sulfate of potash magnesia (0-0-18, 11S, 18Mg). All are considered equally effective.

Organic sources of P and K, such as animal manures and sewage sludge, may also be used for supplying P and K. The nutrient content of manures and sewage sludge varies, so a nutrient analysis of the manure is necessary to determine how valuable it will be as a soil amendment. Also, it is important to know the content of heavy metals (nickel, cadmium, and chromium) to prevent toxic build-up in the soil.

Placement of P and K by broadcast is the most convenient method of application, although large amounts are required at very low soil test levels. Banded applications (2 inches to the side and 2 inches below the seed) can increase agronomic efficiency of P and K, making it possible to decrease the usual rate by 1/3 to 1/2. A "starter" effect, or improved initial growth, is likely to result from a banded placement. This may appear very significant during the early growing season, but rarely does it increase yields, provided that the P and K is used at recommended rates.

Sources:

Overview of soil fertility, plant nutrition, and nutrient management. Agustin Pagani, John E. Sawyer, Antonio P. Mallarino/Department of Agronomy, Iowa State University. Developed in cooperation with Lara Moody, TFI; John David, NRCS; and Steve Phillips, IPNI.

http://www.agronext.iastate.edu/soilfertility/4r/ppt/Chapter-1%20Overview_Ver4.pdf

AGR-105 Fertilization and Liming for Corn, University of Kentucky, www2.ca.uky.edu/agcomm/pubs/agr/agr105/agr105.htm

Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat, and Alfalfa, Extension Bulletin E-2567

Sources Verified 9/14/2019

Legal Statements:

Performance may vary, from location to location and from year to year, as local growing, soil and weather conditions may vary. Growers should evaluate data from multiple locations and years whenever possible and should consider the impacts of these conditions on the grower's fields. 1011_G1