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AGRONOMY GUIDE

COOPERATIVE EXTENSION SERVICE, PURDUE UNIVERSITY, WEST LAFAYETTE, INDIANA

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Corn Fertilization in Indiana

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Knowledge of the relationship between plant growth and nutrient uptake is helpful in understanding corn fertilization. Corn grows (or accumulates dry matter) at a rather constant rate from the time it is 2 feet tall until safe from frost, or physiologically mature. However, the rate of nutrient uptake during this interval is not constant.

Research shows that, by silking time, the corn plant has already accumulated 65 percent of the nitrogen, 50 percent of the phosphorus and 75 percent of the potassium it will take up. However, only 44 percent of the total dry matter has been produced by that stage of growth.

Uptake of nutrients per foot of root length is greatest during the first month; in fact, phosphorus and zinc deficiencies are most likely to occur at this time. Nutrient uptake per plant, on the other hand, is fastest during the 2-week period before tasseling. In this time, the rate of uptake averages approximately 3.8 pounds nitrogen (N), 0.6 pound phosphorus (as P₂O₅) and 4.7 pounds of potassium (as K₂O) per acre per day.

Corn's nutrient requirements are frequently reported in relation to grain yield—e.g., 124 pounds of N per 100 bushels of grain. However, nutrient uptake is actually more closely related to total plant growth than to grain yield. Late-planted corn may use as many nutrients as early-planted corn, even though the grain yield of late-planted corn is much lower. Grain, as a percent of total plant weight, may vary from as little as 30 percent to more than 60 percent.

Removal of nutrients from the soil is much less when only the grain portion of the crop is harvested than when the entire crop is harvested as silage. Table 1 gives the approximate nutrient content in grain and stover of a 150-bushel-per-acre corn crop.

NITROGEN REQUIREMENTS AND APPLICATION METHODS

More than 200 pounds of nitrogen per acre are required for top corn yields. According to experiments in the Corn Belt, the amount of N released from decomposing organic matter in the soil is only about 40 pounds per acre under a continuous corn program. That would produce a yield of only 30-40 bushels of corn. Consequently, substantial quantities of additional N must be supplied through commercial fertilizer, animal waste or a previous legume crop.

Nitrogen fertilization rates for corn, as recommended by Purdue University's Soil Testing Laboratory, are found in Table 2.

Several factors must be considered in selecting the proper time and method of nitrogen application. Among them are: the form of N to be used; the soil's texture, organic matter content, drainage and acidity; and the tillage system used. In addition, the availability of labor and equipment or custom application should be considered.

It is essential to have adequate N in the zone where corn roots are feeding at the time of maximum uptake. However, getting the root and the nitrogen 'together' during this period is not always easy. Climatic conditions have a major effect on where the roots are at this time, as well as on the mobility and transformation of N in soils. For instance, when cold wet conditions result in shallow rooting, nitrogen may be in an unavailable form in soils that are not well drained or may be below the root zone in an excessively drained sandy soil.

Fall Application of N

Nitrogen can be fall-applied for corn on most soils if the producer: (1) uses a fertilizer that contains only ammonium-type N; (2) incor-

Table 1. Mineral Nutrient Content of the Above-Ground Plant Material in an Acre of 150-Bushel Corn.

Element	Pounds of element per acre in —			Pct. in grain
	Stover	Grain	Total	
Nitrogen (N)	55	130	185	70
Phosphorus (P ₂ O ₅)	16	64	80	80
Potassium (K ₂ O)	168	42	210	20
Calcium (Ca)	35	1	36	4
Magnesium (Mg)	29	10	39	26
Sulfur (S)	8	11	19	58
Iron (Fe)	1.80	0.10	1.90	5
Manganese (Mn)	0.25	0.05	0.30	17
Copper (Cu)	0.08	0.02	0.10	20
Zinc (Zn)	0.17	0.10	0.27	40
Boron (B)	0.12	0.04	0.16	25
Molybdenum (Mo)	0.003	0.005	0.008	63

Derived from chemical composition data on corn from the Indiana, Iowa, Michigan and Nebraska Agricultural Experiment Stations.

Table 2. Recommended Nitrogen Rates for Corn Based on Yield Goals and Previous Crop Grown.

Previous crop	N rate when bushel-per-acre yield goal is —				
	100-110	111-125	126-150	151-175	176-200
	Pounds N per acre				
Good legume (5 plants/sq. ft.) (Alfalfa, red clover, sweet clover)	40	70	100	120	150
Average legume (2-4 plants/sq. ft.) (Alfalfa, red clover, sweet clover)	60	100	140	160	180
Soybeans, legume seeding (Alfalfa, red clover, sweet clover)	100	120	160	190	220
Corn, small grain, grass crops, etc.	120	140	170	200	230

porates the fertilizer into the soil, and (3) either adds a nitrification inhibitor to the fertilizer or waits until soil temperature at the 4-inch depth remains below 50°F (normally mid-November in central Indiana).

If an inhibitor is not added, but the N is applied after soil temperatures cool to 50°F or less, it is suggested that the N rate be increased at least 5-10 percent to offset lower efficiency. Even this added amount may not completely compensate for potential denitrification or leaching losses. If a nitrification inhibitor is used, N can be applied after the soil temperatures have dropped below 55°F at the 4-inch depth. Normally, this allows for application 10 days to 2 weeks earlier in the fall with minimal loss.

Fall nitrogen applications are not recommended on soils with low cation exchange capacity (CEC < 6). Generally, these are sandy, light-colored soils where excess leaching would occur.

Improper management of fall-applied N can have an adverse effect on the environment. For instance, applying N before the soil cools to 50°F or less may result in substantial nitrification—i.e., the conversion of ammonium N to nitrate forms by soil bacteria. Nitrate N could then leach below the root zone and enter streams or ground water supplies. Thus, any practice that might lead to the leaching of nitrate beneath the root zone should be avoided.

Spring Preplant Applications of N

All but the most sandy soils are suited to spring preplant applications of nitrogen. The potential for N loss at this time is less than in the fall, and the possible problems associated with sidedressing are also avoided.

Regardless of the form of N used, spring applications should be incorporated into the soil to

avoid N loss. On sloping lands, nitrogen fertilizer left on the surface is subject to loss by surface runoff. Even on level land, incorporation is advisable to minimize volatilization losses. This is especially important if urea or solutions containing urea are applied when air temperatures are above 60°F or soil pH is above 6.5.

In no-till or reduced tillage systems where urea or solutions containing urea are applied to residues, losses from volatilization are a major problem. Thus, if at all possible, consider incorporation in reduced tillage systems, or injection of solution or ammonia in reduced or no-till systems. If urea or solutions must be surface-applied in no-till, N rates should be increased 10-20 percent to compensate for N loss.

The majority of the spring preplant N in Indiana is applied as anhydrous ammonia. Ammonia is a very toxic material, and precautions should be taken to ensure that no seedling injury occurs. Normally, corn should not be planted for at least 1 week after anhydrous ammonia application. This allows the conversion of the toxic ammonia N to non-toxic ammonium.

Under certain adverse weather conditions, however, this conversion process may take more than a week. So as an additional safeguard to minimize seedling injury, ammonia should be applied at least 7 inches deep, and the applicator should be run at an angle (35° or more) to the direction the rows will run. By applying the ammonia at an angle, any injury which might occur will be distributed uniformly across the field, thus preventing large skips or sections of rows missing where the planter drops seed directly in the ammonia band.

In addition to being capable of injuring corn seedlings, ammonia can cause serious injury to humans; so operators should always use caution when handling ammonia.

Sidedress Applications of N

Corn takes up very little nitrogen the first month of growth; but then rapid uptake occurs during the second and third months. Sidedressing the N immediately prior to this period of rapid growth not only insures its ready availability, but also eliminates the losses that might have occurred were the N applied earlier.

Historically, sidedressing gives the highest efficiency of any N management system. However, the major difficulty in sidedressing large acreages is one of timeliness. Beyond this, nitrogen application by sidedressing has both advantages and drawbacks which the producer should consider.

Advantages are: (1) more flexibility if planting dates are changed (e.g., corn can be shifted to

beans); (2) a more accurate estimate of the optimum N rate, since planting date and stand are known and yield potential is better established; and (3) less time for leaching to occur on sandy soils.

Potential hazards in sidedressing include: (1) likely damage from root pruning if sidedressing is done after corn is more than knee high, and (2) chance of prolonged wet periods preventing application until plants are too tall to use an applicator without breaking stalks. The latter is most likely to be a problem on poorly or somewhat poorly drained soils.

Application of N at sidedressing time has the greatest value on soils that are both sandy and low in organic matter—i.e., CEC of 5 or less. On these soils, preplant N may be leached below root zones by late spring and early summer rains.

For additional information on nitrogen, see Purdue Extension Publication AY-204, "Types and Uses of Nitrogen Fertilizer for Crop Production," available from your county Cooperative Extension Service office.

PHOSPHORUS REQUIREMENTS AND APPLICATION METHODS

Corn does not require as much phosphorus (P) as it does nitrogen. However, since phosphorus is relatively immobile in the soil, only 10-20 percent of that added through fertilizer will be used by the immediate crop. The major portion remains in the soil to build up the phosphorus fertility level for subsequent crops. Thus, a reliable soil test is needed to determine the most economical rates of P to apply.

A Bray P₁ test in the 'high' category (31-50 pounds P per acre) indicates adequate P for corn yields of approximately 98 percent of maximum, based on Corn Belt research results. Application of phosphorus fertilizer above that required to maintain this high level is probably not economical.

The rates of phosphorus recommended by the Purdue Soil Testing Laboratory at various yield goals and soil test levels are shown in Table 3.

P Application to 'Low' or 'Very Low' Test Soils

Phosphorus soil test levels help to determine the appropriate P fertilizer application method. When P levels are low or very low according to Table 3, a combination of broadcast-plowdown and row or starter application is needed. A general guide is to broadcast and plowdown 2/3 to 3/4 of the recommended phosphorus, then apply the remainder through a row attachment on the planter.

Table 3. Recommended Phosphorus (P₂O₅) Rates for Corn Based on Yield Goals and Soil Test Levels.

Soil test level	Bray P ₁ test	P ₂ O ₅ rate when bushel-per-acre yield goal is —				
		100-110	111-125	126-150	151-175	176-200
	lb. P/ac.	pounds P ₂ O ₅ per acre				
Very low	0-10	100	110	120	130	150
Low	11-20	70	80	90	100	120
Medium	21-30	50	60	60	70	80
High	31-50	30	30	40	50	50
Very high	Over 50	0	0	10	10	10
Maintenance recommendations		35	40	45	55	65

P Application to 'Medium', 'High' or 'Very High' Test Soils

Plants obtain a lower percentage of their nutrient requirements from applied fertilizer as fertility level in the soil increases. Research shows that, when P soil test levels are medium or above, either broadcast or row application will give equal yield response under most situations. There are, however, several potential advantages when *all* the phosphorus can be broadcast:

- No time is needed to fill fertilizer boxes or tanks during planting, an operation which might otherwise slow down and delay the planting process.

- In the case of dry bulk blends, the plant food cost is less than when a manufactured N-P-K fertilizer is used as a starter.

- Broadcast applications don't have to be made each year. Research has shown that 200 pounds of P₂O₅ per acre applied once every 4 years gave yields equal to 50 pounds of P₂O₅ applied annually. This works on most soils but is not recommended on low organic matter sandy soils, on low pH soils (under 5.5) that are high in aluminum or iron, or on alkaline soils (above pH 8.0). Plans can be devised whereby only 1/4 of the acreage receives fertilizer in a given year to avoid high fertilizer bills every fourth year. Application costs will also be reduced, since only 1/4 of the acreage is covered each year.

In some Purdue experiments, the efficiency and response of phosphorus placed in a narrow (3-inch) strip on the soil surface before moldboard plowing have been superior to both broadcast and starter placement. Soils testing low in P showed the greatest increase in efficiency.

At high soil P levels, direct response to P fertilization is less in both magnitude and frequency of occurrence, thus more difficult to measure and verify in field experiments. So are

response differences due to variations in width of fertilizer strip, distance between strips, methods of tillage after application, source of P fertilizer, or length of planting time after application.

P Application in Starter Fertilizer

Corn has a low P requirement per acre but a high rate of absorption per foot of root during the first 4 weeks of growth, when roots can take part of their phosphorus out of the starter fertilizer band. An application rate that supplies 20-40 pounds P₂O₅ per acre is adequate when placed in a band 2 inches to the side and slightly below the seed. Half this amount is sufficient if the fertilizer is placed in contact with or very close to the seed in a 'pop-up' placement. Starter or pop-up applications are suggested for early growth effort when corn is planted early—i.e., before April 1 in the southern half of the state or before May 1 in the northern half.

Use of a starter or pop-up application is also recommended in no-till or strip tillage methods of planting. Residues left on the surface with these planting methods result in lower soil temperatures early in the season. Fertilizer placed close to the seed is needed to get the seedling off to a good early start.

POTASSIUM REQUIREMENTS AND APPLICATION METHODS

Corn requires such large amounts of potassium (K) that the native supply in most Indiana soils is too low to meet the demand. Corn harvested for grain removes only 30-50 pounds of K₂O per acre for a 150-bushel yield (an equivalent of 1/4-1/3 pound per bushel). Corn harvested for silage removes 150-240 pounds per acre.

Potassium is readily fixed in a relatively unavailable form in certain soils, particularly those

high in clay and organic matter like Brookston silty clay loam. As a result, it is often difficult to increase the K soil test level of such soils.

Usually, a soil that tests at the top of the 'high' category for K (300 pounds per acre) will permit corn yields at nearly maximum levels. Most soils that have been well fertilized with K will not give increased yield responses from additional K if soil tests are above the 'medium' level (210 pounds per acre).

Purdue Soil Testing Laboratory recommendations for potassium on corn at different soil test levels and yield goals are presented in Table 4.

K Application Methods, Rate and Frequency

Potassium may be applied either by broadcasting and plowing under ahead of planting or by banding 2 inches to the side and below the seed at planting time. Normally, either method should effectively supply K to the corn plant. However, in some situations, row application has proven superior, such as (1) when soil K is very low and (2) where K is broadcast and disced in rather than broadcast and plowed under.

When placed with the seed in a pop-up situation, the rate should be determined by the amount of salt (nitrogen and potassium) in the fertilizer. The N + K₂O content should not exceed 5 pounds per acre on sands or 8 pounds on clays. Example fertilizers and their rates per acre for sands would be: 4-10-10, 35 pounds; 7-22-5, 40 pounds; or 8-32-16, 20 pounds.

Normally, a 2-year K₂O application can be made at one time for continuous corn or alternating corn and soybeans. However, on low CEC soils or on high potassium-fixing soils such as Brookston, annual application of K is recommended.

SECONDARY AND MICRONUTRIENT REQUIREMENTS AND APPLICATION METHODS

Higher corn yields mean increased need for all elements. Even though soil testing procedures for calcium and magnesium are well developed, more work is needed in correlating test values to yield responses from application of these nutrients. Further developmental and correlation work is also needed for sulfur and micronutrient tests. It is advisable to supplement soil test information with a plant analysis to determine the actual nutrient status within the corn plant before making decisions about whether to apply secondary or micronutrients.

Secondary Nutrients

Magnesium is the secondary nutrient most likely to be deficient in Indiana corn fields. This deficiency shows up throughout the state on very acid soils and on soils in the southern part which are naturally low in exchangeable magnesium. Exchangeable Mg is the soil test used as the basis for recommendations in Indiana. Soils which have more than 100 pounds per acre of exchangeable Mg are considered to have an adequate supply of this nutrient.

Mg deficiency can be corrected in low pH soils by using dolomitic limestone, which contains magnesium carbonate. Where the pH does not need to be raised, apply 50 pounds of magnesium per acre using a sulfate form.

Sulfur is part of the organic matter of soils. Therefore, its availability to plants is related to the amount of soil organic matter, rate of decomposition of that organic matter, and the amount of sulfur that comes from rain and air.

In high rainfall regions like Indiana, once sul-

Table 4. Recommended Potassium (K₂O) Rates for Corn Based on Yield Goals and Soil Test Levels.

Soil test level	Exchangeable potassium lb. K/ac.	K ₂ O rate when bushel-per-acre yield is –				
		100-110	111-125	126-150	151-175	176-200
Very low	0-80	100	120	150	180	200
Low	81-150	70	90	120	140	160
Medium	151-210	50	60	70	90	120
High	211-300	30	30	40	60	80
Very high	Over 300	0	0	0	0	0
Maintenance recommendations		25	30	35	45	55

phur is in the decomposed soluble sulfate form, it is either taken up by the growing crop or lost by leaching below root levels. While sulfur deficiency would be expected to occur on very low organic matter soil, Purdue experiments on some soils low in sulfate sulfur have failed to obtain a clearcut response on corn.

Micronutrients

Availability of micronutrients, such as zinc, manganese, copper and boron, is usually closely related to weather and climatic conditions. And there is often a narrow range between deficiency and excess of the same nutrient.

For example, in one year of a Purdue experiment, copper content in corn leaves was found to be inadequate, and a foliar application of copper produced a positive response. The next year, no copper deficiency was observed in leaves, and a foliar application actually resulted in a yield decrease. In Indiana, a copper response of corn is more likely on strongly acid peat soils than on mineral soils.

Severe micronutrient deficiencies can be identified through a combination of plant and soil analyses. Mild deficiencies are not as easy to identify; thus, correlation to response from micronutrient fertilization is difficult to obtain and verify.

Zinc is the micronutrient most likely to be lacking in corn. Although only 0.002 pound of zinc is required per bushel, even this small amount occasionally is not available. Conditions favoring zinc response are: (1) soil pH above 6.5, (2) heavy P row applications on soils already high in phosphorus, (3) cool, wet soil conditions, (4) high corn yields, and (5) less than 20 ppm zinc in corn leaves at the knee-high stage or a P to Zn ratio in the leaves greater than 150:1.

Zinc should be broadcast-applied at the rate of 2-3 pounds per acre in the organic form or 10 pounds per acre in the inorganic form. Rates for row application are 1/2-1 pound per acre with organic forms and 3 pounds with inorganic. Broadcast applications will remain effective for several years, while row applications need to be repeated annually until soil test levels are medium or higher.

Under certain conditions, corn has also shown a response to applications of *manganese* and *boron*. However, applying several micronutrients together in a 'shotgun' approach to correct deficiencies is not recommended.

For additional information on micronutrients, see Publication AY-239, "The Role of Micronutrients in Efficient Crop Production," also available at your county Extension office.

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