Circular 608

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NITROGEN in KENTUCKY SOILS

sources * reactions * fertilization

UNIVERSITY OF KENTUCKY COOPERATIVE EXTENSION SERVICE AGRICULTURE AND HOME ECONOMICS

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This publication replaces Kentucky Cooperative Extension Service Leaflet 186, "Nitrogen Fertilizers."

Nitrogen in Kentucky Soils
Sources, Reactions, and Fertilization

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Nitrogen is one of the major nutrients essential to plant growth. An inadequate supply of available nitrogen limits crop production on thousands of acres of non-leguminous cropland in Kentucky each year.

An ample supply of nitrogen promotes rapid vegetative growth and increased yields, produces succulent crops, crisp tender leaves of vegetables, increases the protein content of grains and foliage, promotes flowering and the development of extensive root systems.

Plants growing under conditions of low available nitrogen supply have a pale green or yellow color, grow very slowly, become dwarfed in total growth, and "fire up" as is often seen in corn.

If the available nitrogen is high or if the available phosphorus and potassium are inadequate, plants are more susceptible to some diseases and mature slowly. The stems may be weak and fall down; they may fail to set fruit or the fruit may be watery and of poor quality.

SOURCES OF NITROGEN

Nitrogen in the elemental form is a colorless, odorless, inert gas. The air over each acre of land contains approximately 35,000 tons of nitrogen. Atmospheric nitrogen is not available to plants until it has undergone a change.

Bacterial fixation. Special groups of micro-organisms can take this inert gaseous nitrogen from the air and convert it to forms that plants can use. One group of such micro-organisms, called symbiotic nitrogen fixers, is found in the nodules on roots of leguminous plants—clover, alfalfa, lespedeza, soybeans and peas—when they are properly inoculated. Legumes grown in association with grasses will supply some available nitrogen to the grass in addition to that required by the legume crop. Another group of soil micro-organisms, called non-symbiotic nitrogen fixers, incorporate some atmospheric nitrogen into their cells which is later released for plant growth.

Organic Matter. Considerable nitrogen is released when soil organic matter is decomposed. The decomposition is carried on by many different kinds of soil organisms. A number of factors influence the rate of breakdown of organic matter as well as the amount of nitrogen released. The process proceeds more rapidly in a well aerated (well drained) soil than in a poorly aerated (poorly drained) soil. Generally, the rate of decomposition is more rapid as the temperature increases. Assuming adequate moisture, considerably more nitrogen is released for crop growth during warm weather as compared to cool weather.

Crop residues are important sources of nitrogen for succeeding crops when it is returned to the soil and properly managed. However, decomposition of some residues such as straw, corn stalks, and sawdust, which contain very little nitrogen relative to their carbon content, may reduce the amount of nitrogen available to the crop during the initial stages of decomposition. Since these residues are high in carbonaceous material, the microbial population of the soil increases rapidly during the early stages of decomposition and will compete with the growing crop for nitrogen. More nitrogen in fertilizers is needed when large quantities of these high-carbon crop residues are added to the soil. This competition for available nitrogen is not a factor when crop residues having a narrow carbon–nitrogen ratio such as leguminous leaves or material from young plants are returned to the soil. In fact, these residues supply nitrogen for crops even in the early stages of decomposition. For this reason the kind of crop residue influences the amount of fertilizer nitrogen required.

More than 16 million tons of farm manures are produced annually in Kentucky. Assuming 10 pounds of nitrogen per ton, manure supplies 80 thousand tons of nitrogen annually which exceeds the total amount purchased in fertilizers in 1964. Manure properly handled is a good source of nitrogen (see Kentucky Cooperative Extension Service Circular 593, *Farm Manures*).

Commercial Nitrogen Fertilizers. While considerable nitrogen is made available to crops from organic matter, farm manure, crop residues, and legumes crops, additional nitrogen is needed for tobacco, corn, small grain, and grass sods having little or no leumes. This additional nitrogen must be purchased in commercial fertilizers.

Commercial nitrogen fixation processes developed by the fertilizer industry take nitrogen from the air and convert it into various nitrogen compounds for use as nitrogen fertilizers.

In Kentucky the use of commercial nitrogen increased 27½ times from 1940 to 1964. Kentucky farmers used 2,458 tons of actual nitrogen in 1940 and 67,711 tons in 1964. Still much more nitrogen could be used profitably on certain crops.

In 1964 about one-half of the total nitrogen purchased in Kentucky was in mixed fertilizers. The amount of nitrogen in mixed fertilizers varies considerably depending on the grade purchased. The first figure in the guaranteed analysis refers to the pounds of nitrogen in each 100 pounds of fertilizer. A 5-10-15 contains 5 pounds of nitrogen in each 100 pounds, while a 10-10-10 contains 10 pounds of nitrogen in each 100 pounds. The 0-20-20 contains no nitrogen. Much of the nitrogen in mixed fertilizer is in the ammonium form.

Kentucky farmers purchased 34,606 tons of elemental nitrogen as straight nitrogen materials in 1964. These nitrogen materials are available in three physical forms: solid, gaseous, and liquid.

NITROGEN FERTILIZERS

Solid nitrogen. The more common solid forms of nitrogen fertilizers are ammonium nitrate, urea, and nitrate of soda. One or more of these materials is always available at your fertilizer dealer, and no special equipment is needed to handle them. All of these nitrogen sources produce good crop yields. Research shows that these sources of nitrogen are equally effective in increasing most crops yields if: (1) rates are used to supply the same amounts of nitrogen and (2) little volatilization loss occurs.

Gaseous form. Anhydrous ammonia is being widely used in certain areas of Kentucky. At atmospheric pressure and ordinary temperature ammonia is a gas. Under pressure ammonia gas is condensed to a liquid and designated as anhydrous ammonia. Anhydrous ammonia must be handled under high pressure until it is applied 4 - 6 inches into the soil where the water, clay, and humus particles will hold it. Special equipment is needed for handling and applying this product. The nitrogen in anhydrous ammonia is the cheapest nitrogen source, but the equipment for handling and applying it is relatively expensive. Precautions must be taken to prevent the loss of ammonia to the atmosphere during storage and application.

Nitrogen solutions. Most nitrogen solutions are mixtures of ammonium nitrate and urea in liquid form. The behavior of these solutions in plant nutrition is the same as their solid counterparts. Nitrogen solutions sprayed on foliage may cause some burning. Except at high rates of application this burning is not serious since the plants will quickly recover.

As with anhydrous ammonia, nitrogen solutions save some labor in handling. However, some special equipment is needed for handling and applying them. If this equipment is not available on the farm, it can be supplied by custom operators.

The nitrogen fertilizers most commonly used in Kentucky react with the soil to make it more acid. With increased nitrogen fertilization, an adequate and more frequent liming program is essential. Research shows that an application of 300 pounds of actual nitrogen per acre reduced the soil pH from 5.5 to 5.0. Heavy nitorgen applications are a contributing factor to manganese toxicity, a common disease in tobacco grown on acid soils. This disease has also appeared in corn in Kentucky.

This is not to imply that acid-forming nitrogen fertilizer should not be used. Generally, the cost of lime to neutralize the acidity caused by the acid-forming fertilizers will be much less than the additional cost of nitrogen in those fertilizers that are not acid forming.

Some of the characteristics of the more common nitrogen materials are summarized in Table 1.

Table. 1.— Characteristics of Common Nitrogen Fertilizers

Material	Percent Total Nitrogen	*Form of Nitrogen*		Acid Forming or Basic	Accompanying Element
		Ammonium	Nitrate		
Ammonium Nitrate	33.5	16.75	16.75	**	
Urea	45.0	45.0*		**	
Nitrate of Soda	16.0		16.0	Basic	Sodium
Nitrate of Potash	13.0		13.0	Neutral	Potassium
Anhydrous Ammonia	82.0	82.0		**	
Solutions	21.0-41.0	†		**	

* Forms ammonium in the soil.

** It requires approximately 2 pounds of agricultural limestone to neutralize the acid-forming effect of each pound of nitrogen applied in these materials. A sound liming program is essential to insure good crop yields.

† Nitrogen from the solutions will be largely in the ammonium form but may contain a small amount of nitrate nitrogen depending on the basic ingredients.

NITROGEN REACTION IN THE SOIL

Some crops use ammonium nitrogen to some extent, but most crops use the nitrate form much more readily. Nitrogen in the form of ammonium reacts with the clay and humus in the soil and is held. The soil microbes, however, change the ammonium to the nitrate form. This change is rapid in warm weather when conditions are favorable for microbial activity, slower in cool weather, and practically ceases in cold weather as the soil microbes became inactive.

Nitrogen in the nitrate form is not held by the soil particles. It dissolves in the soil solution and is free to move with the water through the soil.

Most commercial fertilizers contain nitrogen in the form of ammonium, nitrate, or a combination of the two. While there are fundamental differences between these two forms of nitrogen, research generally shows no significant differences in crop response between the two forms if they are retained in the soil. When nitrogen is needed in early spring before the soil is warm enough for the soil microbes to be active in converting the ammonium to nitrate nitrogen, a fertilizer containing some nitrate nitrogen may be desireable.

LOSS OF NITROGEN

An understanding of the reactions of nitrogen fertilizers in the soil is essential to the proper application and efficient use of these materials. Nitrogen can be lost or made unavailable to the growing crop in several ways. Nitrogen can be lost by volatilization, denitrification, leaching, and erosion. It may be tied-up temporarily by the soil microbes.

Volatilization. Ammonia is a gas which will escape to the atmosphere. For this reason certain precautions must be taken when applying nitrogen fertilizer in the ammonia form or those that are converted to ammonia.

Anhydrous ammonia is handled as a liquid under pressure. When the pressure is released ammonia gas is formed. To prevent the loss of ammonia (82 percent nitrogen) to the atmosphere it must be released at a depth of 4 inches or more in the soil and preferably in a well prepared seedbed. Wheels may be attached behind the applicator knives to close the furrows left by the knives. This helps seal the ammonia in the soil. When applied in this manner the ammonia quickly reacts with water to form ammonium nitrogen which is held by the soil colloids. The higher the sand content of the soil, the deeper the ammonia must be applied.

When urea is applied to the soil, it quickly converts to ammonia. Recent research at Kentucky and other experiment stations shows that considerable amounts of nitrogen may be lost by volatilization of ammonia when urea or solutions containing urea are applied as a topdressing. The rate of volatilization loss increases with high temperature, high pH, and high moisture. The loss is avoided if the urea or solution containing urea is mixed with the soil either by plowing or disking within a day or two after it is applied.

Apparently there is less loss when these materials are applied as a top dressing on cultivated or bare soil than when topdressings are made on fields having a vegetative cover. This is caused, no doubt, by more of the material being in contact with soil particles on cultivated soils; therefore, as ammonia is formed more of it reacts with the soil colloids, reducing the volatilization loss.

Where herbicides or insecticides are applied in nitrogen solution, the savings in labor over applying dry materials probably would more than offset the nitrogen loss due to volatilization.

Very little volatilization loss of nitrogen as ammonia from dry materials is reported except when urea is applied as a topdressing on very high pH soils.

Denitrification. Under conditions of poor aeration or a low supply of free oxygen, adequate energy material such as soil organic matter, and a supply of nitrates, anaerobic bacteria will reduce nitrates to nitrous oxide or elemental nitrogen. These nitrogen gases will escape to the atmosphere and be lost to crops. In low wet areas of a field or during periods of heavy rainfall where the soil stays saturated for few days considerable loss may occur by this process. Where nitrogen deficiency symptoms results from such conditions, sidedressing with a nitrogen fertilizer will be profitable.

Leaching. Leaching probably accounts for the greatest nitrogen loss under Kentucky climatic conditions. Any nitrogen in the nitrate form goes into the soil solution and moves with the water in the soil. In the winter and early spring as the water moves through the soil profile, nitrate nitrogen will be carried out in the drainage water and lost. The ammonium forms of nitrogen are held by the soil colloids and not subject to leaching loss. However, the ammonium is converted to the nitrate form of nitrogen by soil micro-organisms when the soil temperature is above 32 degrees. At temperatures of 32-50 degrees the rate of change is slow, but when the soil temperature is above 60 degrees the change takes place rapidly.

During the late spring, summer and fall months rapid transpiration of moisture by the growing crop and evaporation from the soil surface removes soil moisture rapidly. Since water is being removed rapidly during this period, there is seldom sufficient precipitation for water to move through the soil profile except in sandy soils. For this reason the leaching loss of nitrogen during this period is negligible on silt loam and heavier soils.

With the variable winter temperatures existing in the state there is evidence that some nitrogen will be lost by leaching even where the ammonia forms of nitrogen are applied in the fall. For this reason maximum crop response is not obtained in Kentucky when nitrogen fertilizers are applied in the fall for next year's crops.

Erosion. Considerable nitrogen is lost each year by erosion. Most of the organic matter in the upland soils is in the surface, 6-8 inches. With poor conservation practices, erosion removes the organic matter with the nitrogen as well as the other plant nutrients it contains.

EFFICIENT USE OF NITROGEN

Nitrogen is not a substitute for other elements essential to plant growth. To obtain the maxium response from nitrogen applications, a proper balance of those elements needed by the plant must be available in the soil.

Since nitrogen is lost from the soil more readily than the other plant nutrients, particularly through leaching, it should be applied at rates to meet the needs of the crop each growing season. Other soil amendments, such as agricultural limestone, phosphate and potash fertilizers can be applied at heavier rates to meet the cropping needs for several years since leaching losses of these nutrients are minimal in the silt loams and heavier soils. On sandy soils smaller and more frequent applications of all fertilizers should be made.

Fertilizer placement is not usually so important with nitrogen as with other plant nutrients since nitrogen in the nitrate form moves with the soil moisture and will be carried to the plant roots during periods of adequate rainfall. Topdressings of nitrogen feritlizers are usually effective. However, where extended dry periods follow a topdressing, the nitrogen may not be carried into the root-feeding zone. When nitrogen fertilizer can be worked into the soil without additional cost, it is a good practice to do so.

Based on available research little evidence exists that one source of commercial nitrogen is preferable to another. The *cost of actual nitrogen applied to the land* should determine which material is the best buy when proper precautions are taken against volatilization loss. Costs of nitrogen materials varies from one area to another and from one season to the next. Table 2 shows the amount of the different materials required to supply different rates of nitrogen per acre. Low nitrogen rates are shown in the table, but by doubling or combining these rates the amount of material required for heavier rates can easily be calculated.

Table 2.— Amount of Material Required to Supply the Desired Rate of Nitrogen

Material	Percent Nitrogen	Pounds of nitrogen per acre			
		20	30	40	50
Ammonium nitrate	33.5	60	90	119	149
Urea	45.0	45	67	89	111
Nitrate of Soda	16.0	125	188	250	313
Nitrate of Potash	13.0	154	231	308	385
Anhydrous ammonia	82.0	24	37	49	61
Solutions*	30.0	67	100	133	167

* Nitrogen content of solutions may vary widely. The guaranteed analysis shows the pounds of nitrogen in each 100 pounds of solution. The rates shown in the table are the pounds of a 30-percent solution required.

AMOUNTS OF NITROGEN FERTILIZER TO USE

The amount of nitrogen fertilizer required per acre depends on the kind of crop grown, residues and manure, soil fertility, soil aeration, expected yield, available moisture, and other factors. General nitrogen fertilizer recommendations for various crops grown in different cropping systems are shown in Table 3.

Table 3.— General Nitrogen Recommendations*

Crop	Preceding crop	At planting	Supplemental**	Remarks
Corn	Good grass legume sod	10-20	40-50	Apply before or shortly after planting except on sandy soils. Sidedress with part of N on sandy soils.
	Poor grass legume sod	10-20	80-90	
	Corn	10-20	100-110	
Small Grain	Other than tobacco	20-30	20-30	Apply in early March.
	Tobacco	None	None	
Burley	Grass sod or cover crop	None	125-150	Plow down after April 1. If plowed early, broadcast and disk in before setting.
	Grass legume sod or legume	None	75-100	
Dark Tobacco	Grass sod	None	125-150	Same as for burley tobacco.
	Grass legume sod	None	75-100	
Soybean		None	None	Inoculate seed.
Establishing Legume and pasture		20-30	None	Inoculate legumes.
Topdressing Legumes & grass legume mixtures			None	
Annual topdressing Mainly grass			60	30 lb in spring. 30 lb in August.

* Pounds of actual N
** See remarks for time of application

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