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NITROGEN

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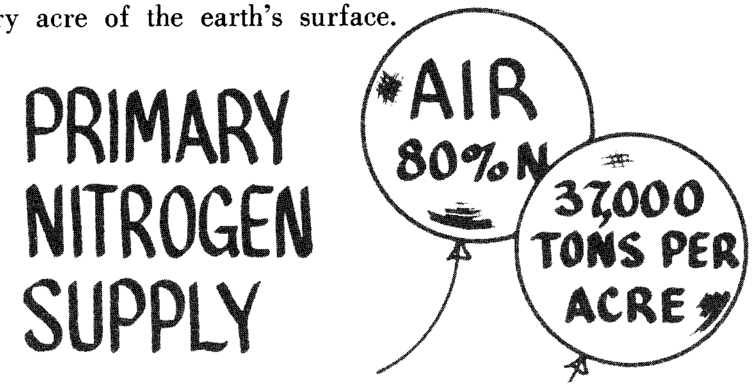
NATURAL SOURCES

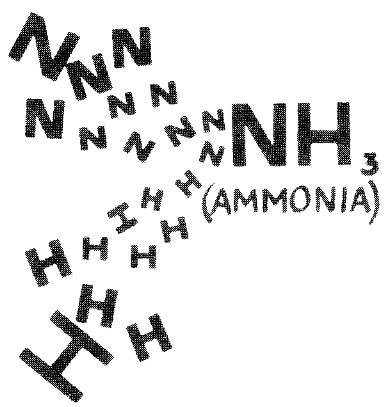
The Atmosphere

Nitrogen is the most abundant element in the earth's atmosphere, accounting for about 80 percent of its volume. In fact, it is estimated that there are more than 37,000 tons of nitrogen over every acre of the earth's surface.



For many years very little of this nitrogen was used in plant growth, except for that fixed by legume plants. Atmospheric nitrogen is an inert gas (N_2). It is unavailable to plants unless converted to such available forms as ammonium (NH_4) or nitrate (NO_3).

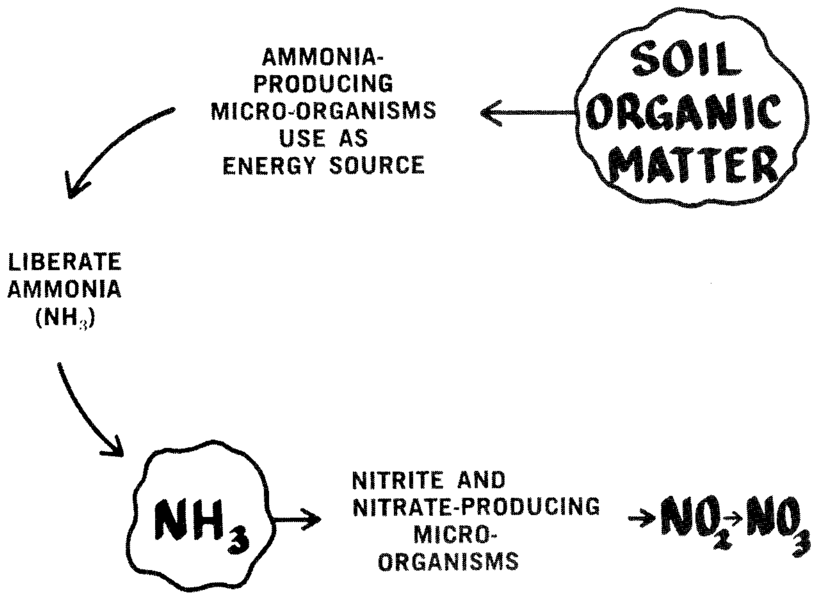
The nitrogen industry was revolutionized at the turn of the 20th Century when scientists discovered a way to convert atmospheric nitrogen to ammonia. This discovery made a relatively cheap form of nitrogen available. Farmers had earlier depended on low analysis organic materials and natural deposits of nitrate of soda for their commercial nitrogen.



Organic Matter

Organic matter is the soil's storehouse of reserve nitrogen. Organic matter or humus is formed from crop litter, such as corn, cotton and peanut stalks and leaves, and manures.

The nitrogen in organic matter is not immediately available to plants. Microorganisms decompose the material, converting the organic nitrogen to *ammonia* and then to *nitrates*.



This decomposition is a slow process. Soil organic matter contains an average of about five percent nitrogen. However, only a small portion of this becomes available during the year. For most Georgia soils, only 15 to 30 pounds per acre of organic nitrogen becomes available during one growing season.

Legumes

Properly inoculated legumes, such as alfalfa, clover, peanuts and soybeans, can fix considerable amounts of atmospheric nitrogen. The inoculant bacteria multiply in the soil, attach themselves to plant roots and form nodules.

The plant furnishes the bacteria with food and energy; the bacteria fix and convert atmospheric nitrogen to a form available to the plant.

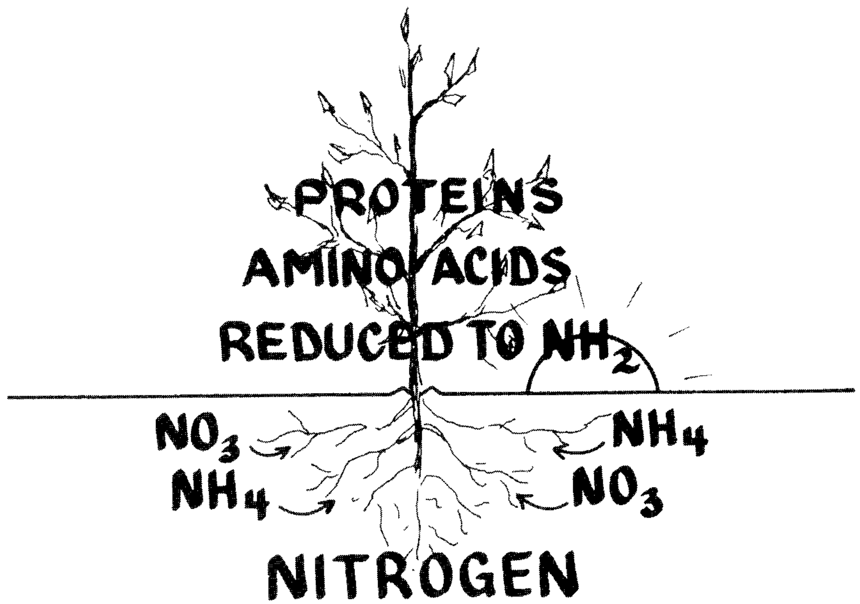
WELL NODULATED SOYBEAN ROOTS

TABLE 1. LEGUME NITROGEN FIXATION

Legume	Lbs. Nitrogen Fixed/A
Alfalfa	194
Ladino Clover	179
Soybeans	160
Peanuts	150
Lespedeza (Annual)	85

FUNCTION OF NITROGEN

Plants absorb nitrogen primarily in the inorganic form, either as *ammonium* (NH_4) or *nitrate* (NO_3). Once absorbed, the nitrogen is rapidly reduced to the *amine form* (NH_2) and used to produce *amino acids*. These are combined to form plant *protein*. Proteins are used by plants in forming *protoplasm*—essential for cell division and, consequently, plant growth.



So, nitrogen is closely associated with vegetative growth. This is evident by the rapid growth response of forage crops, such as Coastal bermudagrass, to an application of nitrogen.

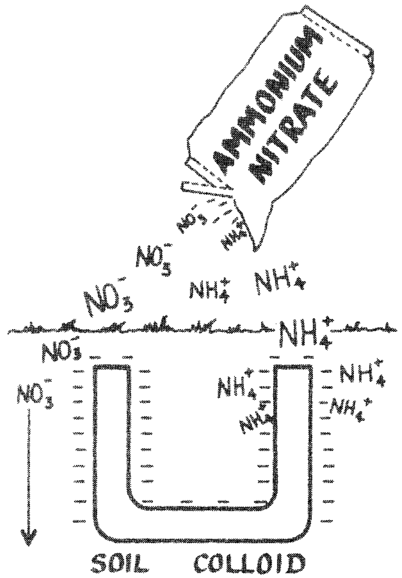
Nitrogen is also essential in chlorophyll formation. A deficiency results in *chlorosis* (yellowing) of plant leaves, beginning on the lower leaves.

HOW NITROGEN IS LOST FROM THE SOIL

Leaching

Most commercial nitrogen is in water-soluble, inorganic forms. These forms are mobile, moving up and down the soil profile, depending on the soil's moisture condition. They move downward when the soil is wet and upward as the soil dries out.

Although it is water-soluble, the ammonium form is positively charged (NH_4^+). Therefore, it is held by negatively charged soil colloids (clay and organic soil particles) against leaching loss. Ammonium *ions* are held on soil colloids by electrical attraction. This is similar to the way a nail is held by a magnet.



Nitrate nitrogen (NO_3^-), being negatively charged, is not held by similarly charged soil particles. So it is subject to leaching loss. Urea nitrogen contains no charge, and is also subject to leaching loss until converted to the ammonium form.

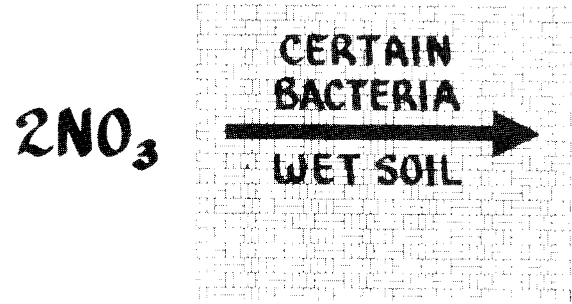
The amount of nitrogen leached beyond plant roots depends on the amount of rainfall, texture of the soil and the type of plant involved. Sandy-textured soils have less water-holding capacity than do clay soils. Consequently, nitrate nitrogen will move farther down the soil profile in sandy type soils than in clay soils.

Deep-rooted plants, such as Coastal bermudagrass, are able to extract nitrogen from deeper soil depths. However, shallow-rooted plants, such as onions and irish potatoes, must draw their nitrogen from shallow depths.

Denitrification

Air is displaced when the soil pores become temporarily filled with water. Under these *anerobic* (absence of oxygen) conditions, nitrate nitrogen can be reduced by soil organisms to the gaseous form (N_2) and lost to the atmosphere. A considerable amount of soil nitrogen can be lost in this way when the soil becomes temporarily water logged from heavy rains. Nitrogen can be lost even though ammonium or urea forms of nitrogen are applied. These forms are rapidly converted to nitrate nitrogen in warm, moist soils.

DENITRIFICATION



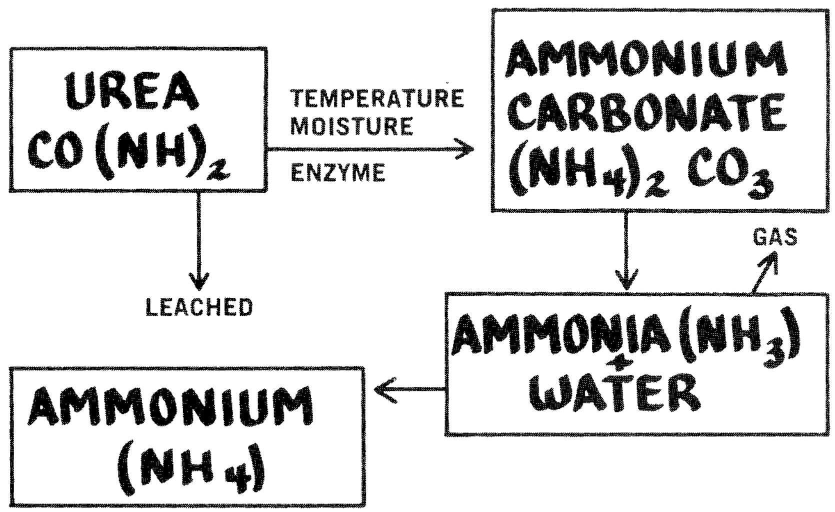
In one experiment, losses from denitrification ranged 25 to 50 percent of the nitrogen applied. The highest losses were on heavy soils containing large amounts of clay.

Ammonia - Volatilization

Volatilization loss from the soil refers to the conversion of stable forms of nitrogen to the gaseous form, either chemically or biologically.

This type of loss is confined primarily to ammonium and urea forms. When urea is surface applied to warm-season forage grasses, a considerable amount of the nitrogen may be lost. Under adequate moisture and temperature conditions and in the presence of the enzyme *urease*, urea nitrogen is rapidly converted to *ammonium carbonate*. This is an unstable compound which breaks down to ammonia, carbon dioxide and water. The ammonia released can then be lost to the atmosphere unless the conversion takes place in the soil.

UREA NITROGEN

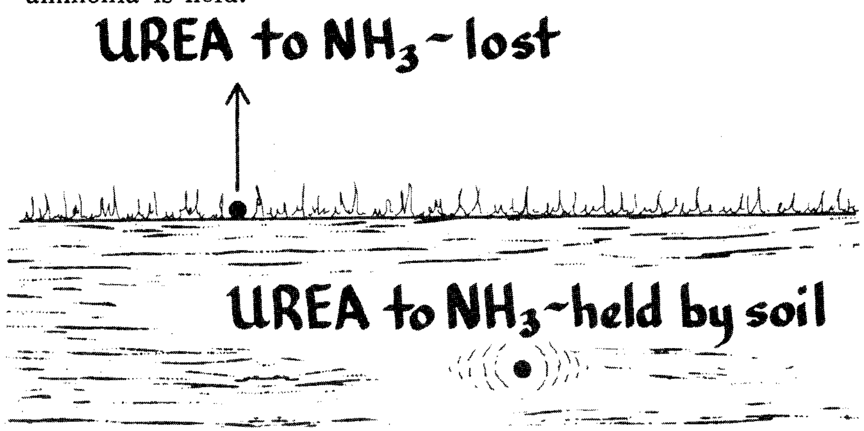


Research at the Coastal Plains Experiment Station showed that solid urea nitrogen was 15 percent less effective than other nitrogen sources when surface applied to Coastal bermudagrass. Nitrogen solutions containing urea were eight percent less effective.

TABLE 2. SOURCES OF NITROGEN - COASTAL BERMUDAGRASS

N Source	Relative Yield
Ammonium Nitrate	102
Sodium Nitrate	100
Urea - Solid	77
Urea - Amm. Nit. Sol.	92

The amount of nitrogen lost from surface-applied urea sources may vary considerably, depending on the weather. If it rains soon after the urea is surface applied, very little will be lost. Urea nitrogen, being water-soluble, moves downward in the soil. When it is converted to ammonia, it will be held by soil particles (*colloids*) much in the same manner that anhydrous ammonia is held.



Volatilization loss of surface-applied nitrogen can also occur when ammonium forms of nitrogen (ammonium nitrate, ammonium sulfate or nitrogen solutions containing ammonium nitrate) are applied to alkaline soils. The ammonium nitrogen may chemically react with *calcium carbonate,* resulting in the conversion of the *ammonium* form (NH_4) to the gaseous *ammonia* (NH_3) form.

The same reaction and resulting loss can occur when ammonium forms are surface applied to recently limed soils. So lime and ammonium forms of nitrogen should not be surface

applied near the same time. If the nitrogen or the lime is turned into the soil or if it rains soon after the ammonium nitrogen is surface applied, the danger of volatilization loss is reduced.

Volatilization loss can also occur when anhydrous ammonia is improperly applied to the soil. Things that can result in volatilization loss of anhydrous ammonia are:

1. Shallow depth of soil incorporation. Anhydrous ammonia should be applied to a depth of four to eight inches. The sandier the soil, the deeper the placement.

TABLE 3. ANHYDROUS AMMONIA DEPTH OF PLACEMENT AND SOIL TYPE[1]

Soil Type	Depth of Placement	% Ammonia Loss
Sand	3″	14
Sand	6″	13
Sand	9″	11
Clay	3″	2
Clay	6″	0.5
Clay	9″	0

[1]Air dry soil, 100 lbs. N/Acre - 40″ spacing - Tisdale & Nelson.

2. Soil moisture. Anhydrous ammonia applied to extremely wet or dry soils can also result in some volatilization loss. As far as soil moisture is concerned, the best time to apply anhydrous ammonia is when it is just right for plowing.

3. Knife spacing of anhydrous ammonia applicators. In one experiment, knife spacings of 40 inches resulted in a five-percent loss of nitrogen. Only two percent was lost when the knife spacings were 16 inches. The higher the rate of nitrogen applied and the sandier the soil, the more likely it is that nitrogen will be lost at wide knife spacings.

TABLE 4. ANHYDROUS AMMONIA KNIFE SPACING[1]

Knife Spacing	Depth of Placement	% Ammonia Loss
16″	6″	2%
40″	6″	5%
16″	3″	4%
40″	3″	12%

[1]2% Soil Moisture - Tisdale & Nelson

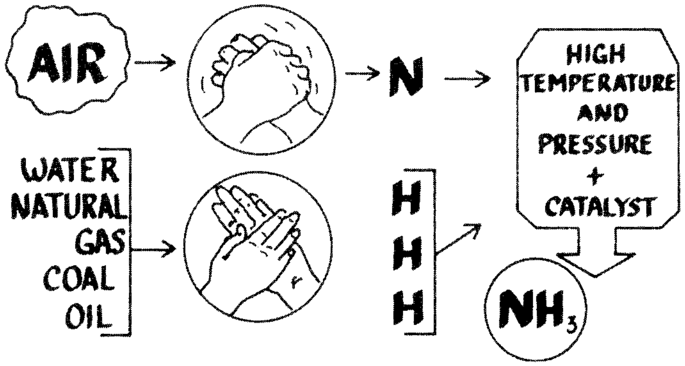
FORMS OF COMMERCIAL NITROGEN

The three basic types of inorganic nitrogen carriers are: (1) *urea,* (2) *ammonia* (NH_3) or *ammonium* (NH_4) and (3) *nitrates* (NO_3). They account for most of the commercial nitrogen sold.

Anhydrous Ammonia

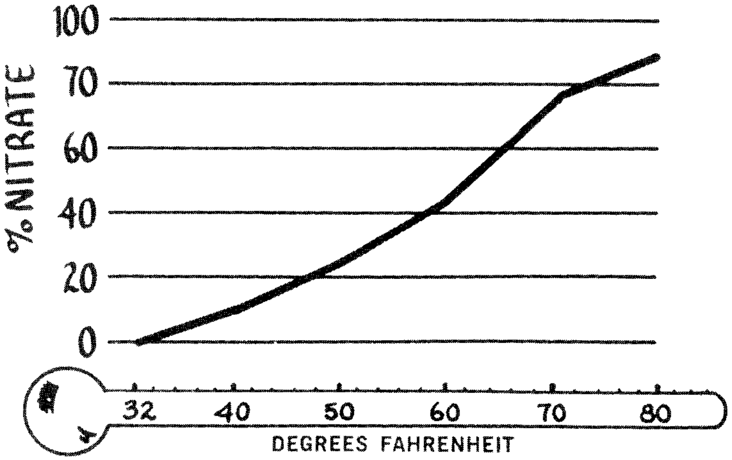
Anhydrous ammonia is the first material produced in synthetic nitrogen manufacturing. It is made by combining atmospheric nitrogen with a source of hydrogen under high temperatures and pressure and in the presence of a *catalyst* (an element which promotes the reaction). Anhydrous ammonia is a lighter-than-air, colorless gas containing 82 percent nitrogen. It can be used for direct soil applications or in making other nitrogen products. It is usually converted to a liquid for shipping. This is done either by pressure or refrigeration. Because of its high nitrogen content and the fact that it does not have to be processed further, it is generally the cheapest source of nitrogen.

NITROGEN FIXATION — AMMONIA



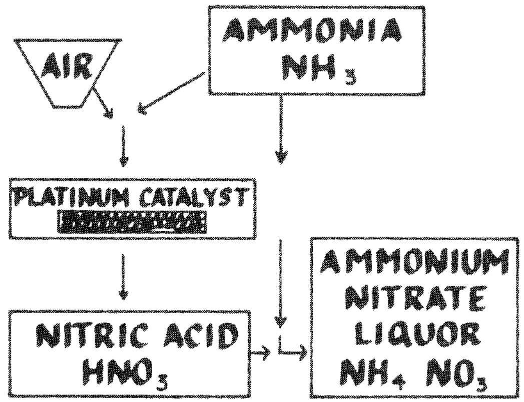
Anhydrous ammonia contains all of its nitrogen in the ammonia form. Therefore, when it is applied to soils it is not as subject to leaching loss as is the nitrate form. However, in warm, well-aerated soils, ammonia and ammonium forms are rapidly oxidized to the nitrate form by soil organisms.

INFLUENCE OF TEMPERATURE ON NITRIFICATION OF AMMONIUM NITROGEN



The main thing governing nitrification of ammonium nitrogen is soil temperature. The process speeds up as soil temperatures rise above 50°F., slows down considerably below 50°F., and stops at freezing (32°F.).

Extremely low soil pH (below 5.0) can also prevent conversion of ammonium nitrogen to nitrates. Extremely acid soils reduce the soil bacteria responsible for this conversion.



Most of the anhydrous ammonia produced is used in manufacturing other nitrogen products. Ammonium nitrate is produced by combining anhydrous ammonia with air in the presence of a *platinum catalyst* to produce *nitric acid.* The nitric acid is combined with additional anhydrous ammonia to produce *ammonium nitrate liquor.*

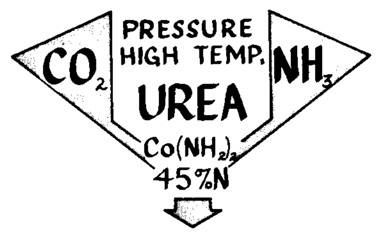
Solid ammonium nitrate is produced by first removing most of the moisture from this liquor. The concentrated solution is then put through a prilling process to produce solid ammonium nitrate.

Nitrogen solutions can also be made from the ammonium nitrate liquor. If ammonium nitrate liquid solutions are made, water is added to keep the ammonium nitrate particles from forming crystals as the solution cools. The solution produced contains 19 to 22 percent nitrogen as ammonium nitrate.

Ammonium nitrate-urea solutions can be made by adding urea and water to the ammonium nitrate liquor. The addition of urea increases the nitrogen content to 30-32 percent. About half the nitrogen is in the ammonium nitrate form and half in the urea form.

Urea Nitrogen

Urea nitrogen is produced by combining carbon dioxide, a by-product of anhydrous ammonia production, with ammonia under pressure and high temperatures. Urea nitrogen is a water-soluble material containing 45 percent



nitrogen which converts to ammonium nitrogen when applied to the soil. Therefore, its action in the soil is very similar to ammonium forms. The major difference is that it is more slowly available to plants since it must first convert to the ammonium form. This conversion takes place rapidly in well-aerated, warm soils.

Nitrate Nitrogen

All forms of nitrogen eventually convert to the nitrate form in most soils. Urea nitrogen converts to ammonia, which is oxidized by soil organisms to the nitrate form. Organic nitrogen is converted to ammonia by one group of soil organisms, then oxidized to nitrate nitrogen by a different group. Therefore, most soil nitrogen, whether applied in commercial forms or derived from soil organic matter, is converted to the nitrate form. In this form it is readily available for plant uptake. However, it is subject to leaching and denitrification loss, as previously explained.

Some commercial forms of nitrate nitrogen are *ammonium nitrate, calcium nitrate, potassium nitrate* and *sodium nitrate.*

SLOW RELEASE NITROGEN MATERIALS

Urea-Formaldehyde

Urea formaldehyde is a slowly soluble nitrogen material made by combining urea and formaldehyde in fixed proportions. It contains about 38 percent nitrogen. About two-thirds of the nitrogen is not water soluble. Its main advantages are: (1) Uniform release over the growing season. This results in more uniform plant growth and less leaching loss. (2) Non-burning action of foliage.

Its main disadvantages are: (1) Relatively high cost per pound of nitrogen. (2) Not all of the nitrogen in the material is released during the growing season. Its primary use is in lawn and specialty fertilizers.

Coated Nitrogen Materials

There are certain advantages to coating ammonium and urea nitrogen with materials that slowly dissolve when they are applied to the soil. The slowly soluble coating slows the conversion of urea to ammonium or ammonium to nitrate. This provides a more uniform release of nitrogen and decreases the possibility of volatilization and leaching loss. The possibility of foliar burn is also reduced.

The Tennessee Valley Authority has tried various coating materials, but sulfur appears to be the most promising. Field

research has shown that sulfur-coated urea and ammonium nitrate are more slowly available and provide a more uniform nitrogen release than do uncoated materials. *Cost* is the primary disadvantage of the coated materials. Further research is needed before they can be generally recommended.

Nitrifying Inhibitors

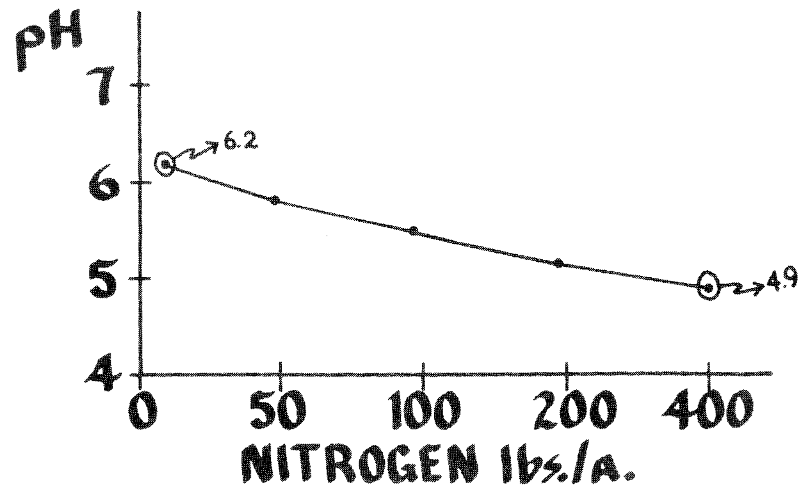
A chemical has been developed that, when added in small amounts either to the soil or mixed with the nitrogen source, slows the conversion of ammonium nitrogen to nitrate. The chemical temporarily deactivates the nitrifying soil bacteria. While these chemicals show promise, further research is needed before they can be generally recommended.

ACIDIFYING EFFECT OF AMMONIUM FORMS

Ammonium forms of nitrogen, such as ammonium nitrate, anhydrous ammonia, nitrogen solutions and urea (which converts to ammonia), are excellent and economical sources. However, they also make the soil acid. This is no problem if you follow good liming practices. But it can reduce crop yields if you don't use enough lime, particularly if you apply high rates of nitrogen.

AMMONIUM NITROGEN EFFECT ON SOIL pH

COASTAL BERMUDAGRASS



Theoretically, 1.8 pounds of calcium carbonate is required to neutralize the acid formed by each pound of ammonium nitrogen. *Ammonium sulfate requires 5.4 pounds.* Under field conditions, however, about five pounds of agricultural lime will effectively neutralize the acid formed by each pound of ammonium nitrogen.

Ammonium sulfate requires a proportionally higher amount of lime. For instance, if you apply 200 pounds of actual nitrogen per acre as anhydrous ammonia, urea or ammonium nitrate, you would need about 1,000 pounds of lime to neutralize the acid formed. If you use high rates of ammonium forms, make a soil test each year to determine lime requirements.

TIME OF NITROGEN APPLICATION

Nitrogen is more subject to loss from the soil than is any of the other major fertilizer elements. Consequently, the most efficient time to apply it is as near as possible to the time of maximum plant uptake. This means sidedressing or topdressing after the crop is planted. However, this time is not always best from your standpoint. Bad weather may delay application when nitrogen is needed, and split applications mean additional labor and time.

Because of these factors, many farmers prefer to preplant their nitrogen. Research indicates that applying all of the nitrogen in late January does not reduce corn yields significantly when compared with conventional spring-applied nitrogen. Except for deep sandy soils, applying nitrogen to most Georgia soils in late January appears to be about as efficient as split applications, provided recommended rates are used.

Extremely heavy rains between the time of application and planting may cause loss by leaching and denitrification.

Fall application for spring-planted crops is not recommended. Research shows that this method has resulted in much lower yields than if the same amount of nitrogen were applied in the spring.

TABLE 5. FALL-APPLIED NITROGEN - CORN

Soil Series	Percent Efficiency[1]
Greenville	69
Cecil	48
Ruston	45
Tifton	13

[1]Per acre yields compared with nitrogen applied in spring.

Two split applications are recommended for pastures and small grain. For pastures, the first application should be made when growth first starts; the second in the middle of the growing season.

For small grain, the first application should be made before or soon after planting; the second in early or mid-February. Applications for hay crops, such as Coastal bermudagrass, should be made after each cutting.

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