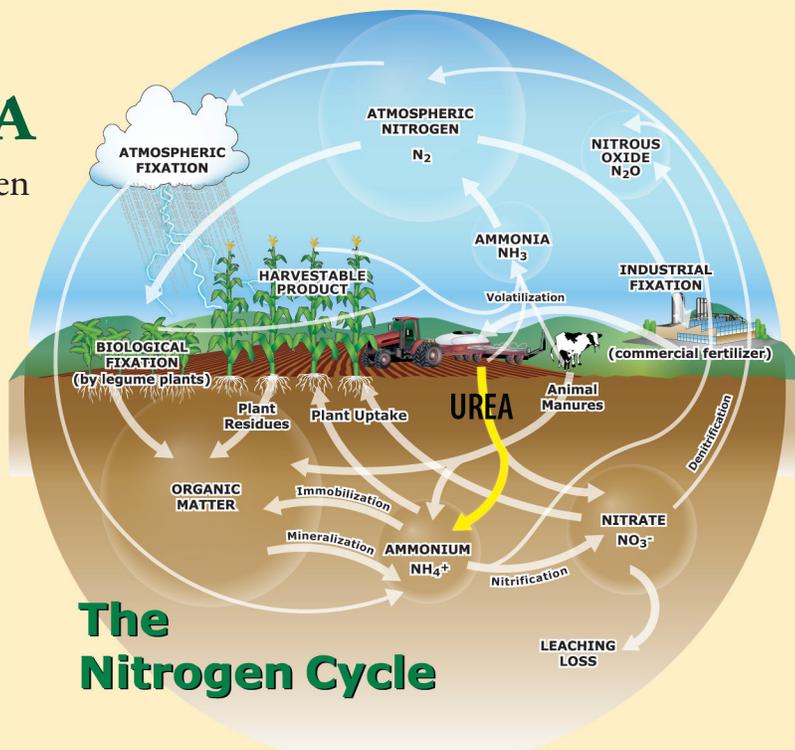


MANAGING UREA

Urea is the most widely used solid nitrogen (N) fertilizer in the world. Urea is also commonly found in nature since it is excreted in the urine of mammals. The high N content of urea (46% N) makes it efficient to transport to farms and apply to fields. Understanding its behavior is important for getting the maximum benefit from this important plant nutrient.



Urea is used in several ways to provide N nutrition for plants. It is most frequently broadcast and incorporated (mixed) with soil, or broadcast applied to the soil surface in a solid form. Due to its high water solubility (1,080 g/L at 20° C or 9 lbs/gal), urea can also be dissolved in water and applied to soil as a fluid, added to irrigation water, or sprayed onto plant foliage. It is commonly combined with a solution of ammonium nitrate to form UAN (urea ammonium nitrate), where urea accounts for half of the N content.

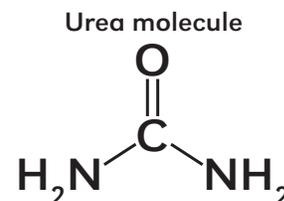
Despite its widespread use, there are fundamental properties of urea that necessitate careful management in order to recover its full nutritional value.

Urea in Plants

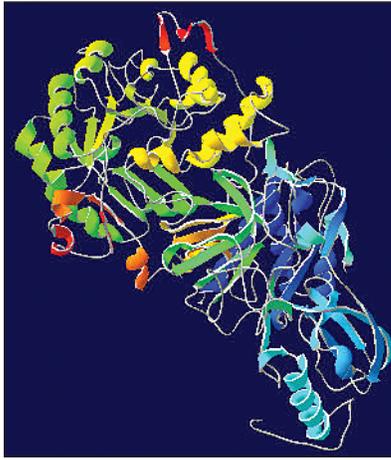
Urea can be a valuable source of plant nutrition while still in the urea form; however, most N uptake from urea occurs after it is converted to ammonium and nitrate in the soil. Plants

are capable of directly absorbing urea, but it is not actively involved in plant nutrition until it is hydrolyzed to ammonium by urease, a plant-produced enzyme (**Figure 1**). Once the urea is converted to ammonium it is further incorporated to glutamate and various organic compounds within the plant.

Urea can also be synthesized within plants where it serves as an important metabolite for N movement and translocation. Redistribution of organic N compounds within plants begins with hydrolysis and release of urea. The urea is subsequently mobilized throughout the plant until it is converted back into various amino acids. These complex processes have been studied in great detail, but are not reported here.



Nitrogen Notes is a series of bulletins written by scientific staff of the International Plant Nutrition Institute (IPNI). This series was supported by a grant from the California Department of Food & Agriculture and through a partnership with the Western Plant Health Association. This series is available as PDF files at www.ipni.net/publications.



<http://en.wikipedia.org/wiki/File:Urease-1E9Z.jpg>

Urea in Soil

Urea Movement

As an uncharged molecule, urea is relatively mobile and moves freely with water in the soil. However, once the urea is converted to ammonium, it is largely retained on the soil cation exchange sites and is no longer easily leached. Therefore the extent of urea movement depends largely on the moisture conditions prior to hydrolysis and the length of time before hydrolysis occurs.

Figure 1. Diagram of urease enzyme.

A study was conducted where the downward movement of nitrate, ammonium, and urea was compared through representative California soils. It was found that nitrate moved the furthest from the point of application, followed by urea, and then by ammonium (**Figure 2**). It is noteworthy that urea was less mobile than nitrate in all the soils.

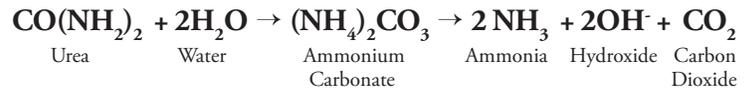
In a follow-up study, 5.7 in. of water was required to leach nitrate to a soil depth of 9 in., but 7.1 in. of water was needed

to move urea to this same depth (Salinas clay). In a Hanford sandy loam soil, it required 5.9 in. of water to move nitrate to a depth of 9 in. and 6.5 in. for urea. This demonstrates that urea is highly mobile in soil, but not as much as nitrate.

Urea Hydrolysis

After urea comes in contact with soil or plants in the presence of moisture, the commonly occurring urease enzyme quickly begins to split urea, creating ammonium bicarbonate in the process of hydrolysis. Hydrolysis refers to the cleavage of chemical bonds by the addition of water.

This instantly forms a high pH environment in the vicinity of the urea as hydroxide ions (OH⁻) are released. The speed of hydrolysis will depend on the concentration of these three components and the environmental factors affecting urease activity.



Urea hydrolysis is generally a rapid process, typically occurring within several days after application. A study done in four California soils showed that a fertilizer application of 200 lb urea-N/A was completely hydrolyzed to ammonium within two days in three soils (Salinas clay, Yolo loam, and Sacramento clay). In a less-buffered Hanford sandy loam, the urea was hydrolyzed within three days (Broadbent, 1958). Therefore,

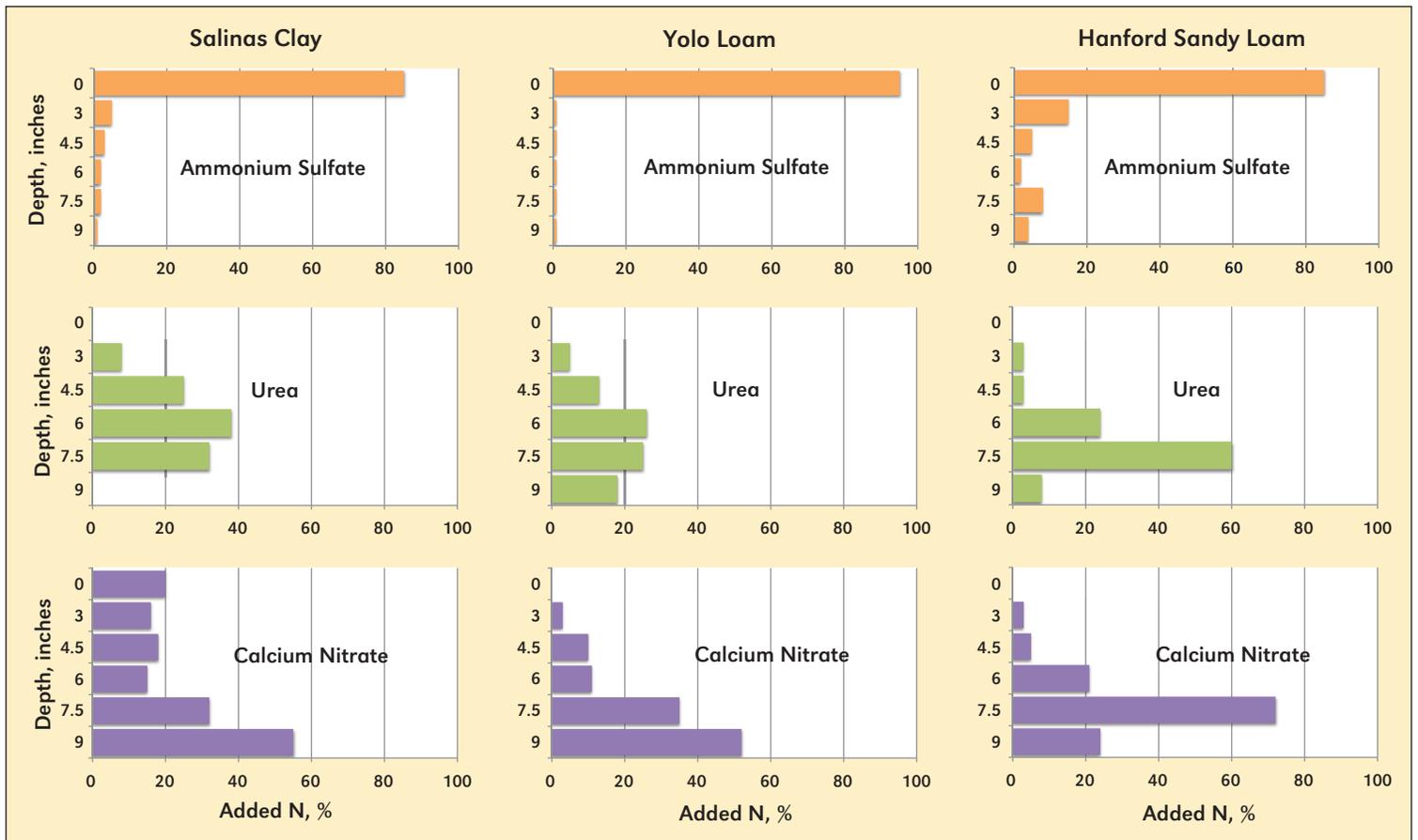


Figure 2. The movement of ammonium, urea, or nitrate in the surface 9 in. of three soils. The urea and calcium nitrate were applied to the soil surface and irrigated with a uniform amount of water. The ammonium sulfate was added as a solution. The soils were sampled 90 minutes after fertilizer and water application. (Broadbent et al., 1958).

Nitrogen NOTES

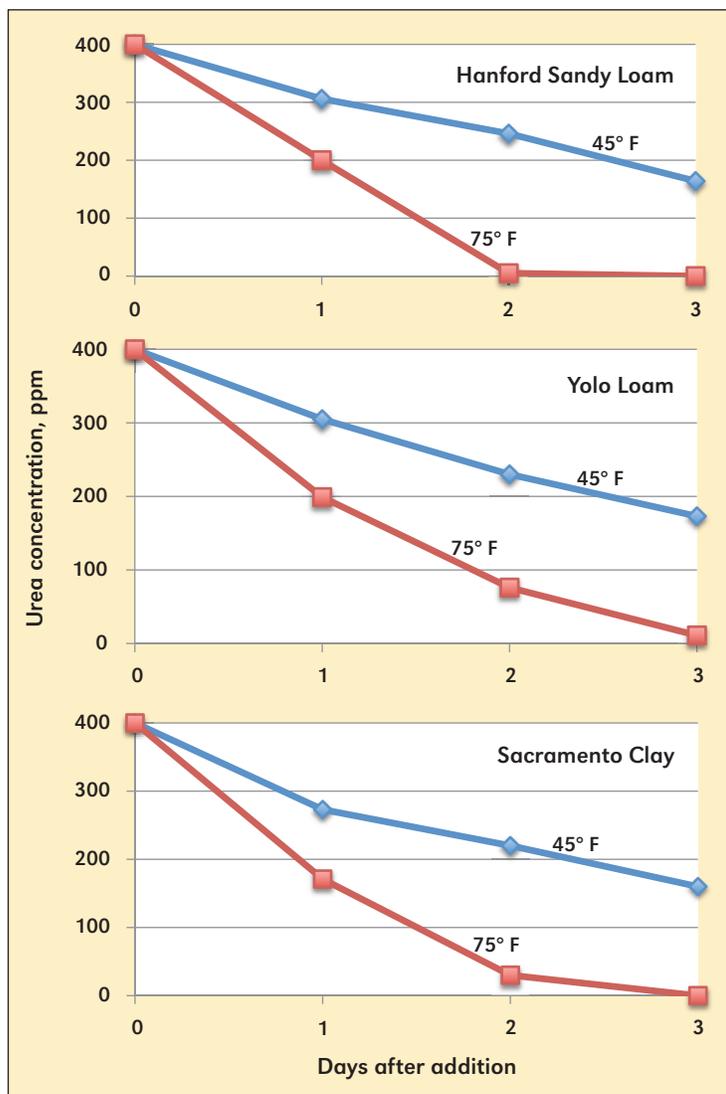


Figure 3. The rate of urea hydrolysis in three soils incubated at 45° F or 75° F after receiving an application of 200 lb urea-N/A (Broadbent et al., 1958).

urea is susceptible to movement with soil water for only a day or two (or even hours) before it is converted to ammonium.

While urea is undergoing hydrolysis to ammonium, production of nitrate (nitrification) is simultaneously occurring. Therefore, fertilization with urea initially results in roots being simultaneously exposed to urea, ammonium, and nitrate.

Nickel was added to the list of essential plant nutrients in the 1980s when this trace element metal was found to be required for the synthesis of the urease enzyme. In carefully controlled conditions, the absence of nickel results in accumulation of toxic urea concentrations in plant tissue. Since this time, other essential functions of nickel for plants have been proposed.

Factors Affecting the Rate of Urea Hydrolysis

Urease

The urease enzyme must be present for hydrolysis to occur, but this is seldom a limiting factor in agricultural soils. Since

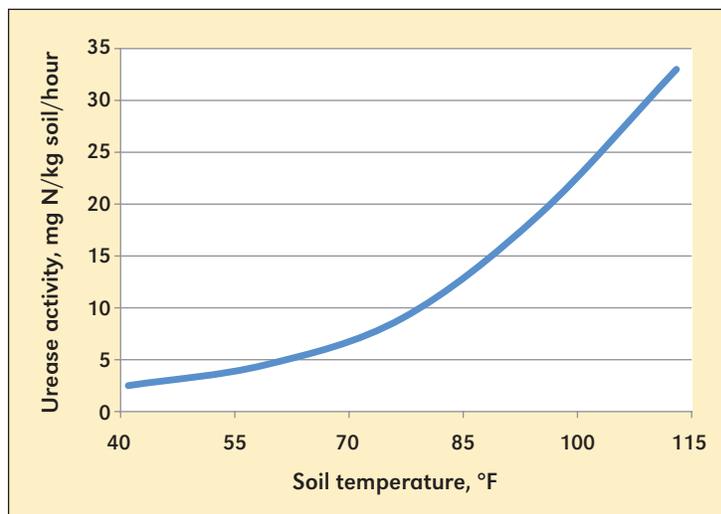


Figure 4. The effect of temperature on soil urease activity (Kansas). Adapted from Moyo et al., 1989.

both soil microbes and plants produce urease, the enzyme activity is greatest near the soil surface. Although differences in urease numbers can be measured between soils, it is not a significant factor for fertilizer management.

Soil pH

The rate of urea hydrolysis typically increases as the soil pH increases from 5 to 9, but pH does not limit the process in most agricultural soils.

The initial reaction of urea hydrolysis increases the alkalinity of the soil solution to pH >9 due to the formation of ammonium carbonate. However, the subsequent conversion of ammonium to nitrate is an acid-forming process, offsetting the initial and temporary pH spike. The ultimate soil pH effect of adding urea is acidification.

Farmers are advised not to apply urea on the soil surface without incorporating or irrigating it into the soil soon after application, and not to place urea in a band with or near the seed. This is due to the temporary pH increase, which makes ammonia gas more abundant and susceptible to volatilization loss.

Soil Temperature

Urea hydrolysis is slower at 45° F than 75° F, but even in the cooler soil (similar to California winter conditions) hydrolysis is generally complete within a week (**Figure 3**).

In another study, raising the soil temperature from 41° F to 113° F resulted in a steady increase in urease activity (**Figure 4**), corresponding to a “ Q_{10} ” of 2 within this temperature range (indicating a doubling of the reaction rate for each 10° C [18° F] rise).

Soil Water

Urea hydrolysis comes to a stop as the soil becomes very dry. However, in the range of soil conditions where crops grow, moisture is not a limiting factor for urea hydrolysis. Hydrolysis occurs rapidly in flooded soils, such as where rice is grown. The increase in soil salinity (EC) that occurs during soil drying has also been shown to decrease the rate of both urea hydrolysis and the subsequent nitrification.

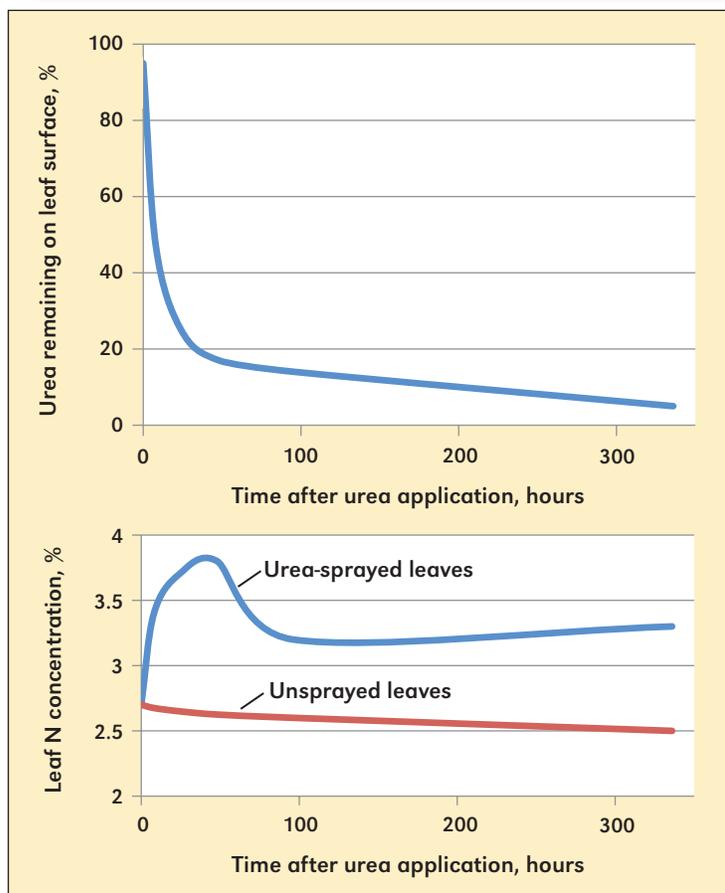


Figure 5. The disappearance of urea from nectarine leaves (top), and the incorporation of urea into nectarines leaves (bottom). Adapted from Rosecrance et al., 1998.

Foliar Application of Urea

Foliar sprays of urea are common, and considerable research has been done to demonstrate its potential benefit for plant nutrition. Foliar application of urea is usually done as a supplement to the soil N supply during key growth periods. For many crops, targeted foliar application of urea can have significant benefits to yield and/or quality. However, the economics of this practice also need to be carefully considered.

One foliar application study found that 80% of the applied urea was gone from the surface of nectarine leaves within 48 hours of application, with most of it absorbed by the leaves and a small amount unaccounted for (**Figure 5**).

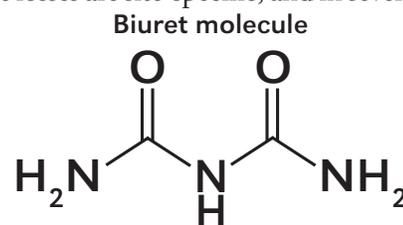
Spray application of urea to foliage needs to be done with careful attention to the requirements of each specific crop. Over application of urea can result in leaf-tip necrosis or even whole-plant scorching. These symptoms of damage are attributed to ammonia released following urea hydrolysis within the plant, although some have speculated that it may be related to

internal urea accumulation.

Another precaution to be taken with foliar urea sprays is the possible contamination of the fertilizer with biuret. During the urea manufacturing process excessively high temperatures can cause two urea molecules to link, resulting in biuret formation. Most urea manufacturers carefully control this process and maintain the biuret concentration below 0.3%. However some plant species may be especially sensitive, and the use of low-biuret urea is recommended for these situations. Biuret breaks down to urea and ammonium after a few weeks in the soil.

Urease Inhibitor

Although urea is the most widely used N fertilizer in the world, it has a disadvantage in that it is susceptible to ammonia loss after application. These losses are site-specific, and in severe cases can exceed 25% of the applied N if the fertilizer remains on the soil surface for a prolonged period. Considerable efforts have been made to slow the conversion of urea to ammonia and reduce the magnitude of volatilization losses to the atmosphere.



Most enzymes, including urease, can be disrupted by specific chemical additives. Thousands of compounds have been screened to find a chemical that specifically inhibits urease, is safe to handle, compatible with urea fertilizer, and not overly persistent in the environment.

Commercially available urease inhibitors are best suited for application with urea or solutions of UAN that will be applied directly on the soil surface or to grassland. Under these conditions, the inhibitor delays conversion to ammonia and provides additional management flexibility to allow irrigation, rainfall, or tillage to move the urea into the soil. Once below the soil surface the potential for ammonia loss is greatly reduced. Urease inhibitors have also been shown effective at decreasing the toxicity of urea placed near germinating seeds.

Urea is a very common fertilizer material for agricultural crops. When managed properly, it can provide an excellent source of N nutrition. However, it requires knowledge of its behavior to keep it in the root zone so it can be used to its full potential. ❖

References

- Broadbent, F.E., G.N. Hill, and K.B. Tyler. 1958. Proc. Soil Sci. Soc. Amer. 22: 303-307.
 Moyo, C.C., D.E. Kissel, and M.L. Cabrera. 1989. Soil Bio. Biochem. 21: 935-938.
 Rosecrance, R.C., R.S. Johnson, and S.A. Weinbaum. 1998. HortSci. 33: 158.