4-1968

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CROPS
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UNIVERSITY of KENTUCKY • COLLEGE of AGRICULTURE

AGRONOMY NOTES

DEPARTMENT of AGRONOMY Lexington 40506

Vol. 1, No. 11 April 1968

WHAT HAPPENS TO FERTILIZER NITROGEN IN THE SOIL?

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What happens to the nitrogen a farmer applies as fertilizer each spring?

First, let us consider the forms of nitrogen normally applied, and then attempt to trace what happens to the nitrogen once it is added to the soil. The average complete fertilizer contains approximately 70 percent of its nitrogen in the ammonium nitrogen form (NH_4), about 10 percent in the urea form (this is quickly converted to ammonium nitrogen), and the remaining 20 percent in the nitrate nitrogen form (NO_3).

All of the nitrogen, whether ammonium or nitrate, quickly dissolves when it is added to a moist soil. Once dissolved, the nitrate nitrogen is free to move in the soil wherever there is water. Certain physical forces cause the dissolved nitrate to work toward becoming equally distributed throughout the soil layer in which it was mixed. Following this, as water from rainfall or irrigation moves down in the soil, the nitrate moves with it. Similarly, when the soil dries out, water moves up through the soil to replace water evaporating at the soil surface; simultaneously, nitrate moves upward in the water.

After dissolution, the ammonium nitrogen from the fertilizer is attached to soil particles instead of remaining free to move about in the soil as was the case for the nitrate nitrogen. The ammonium is attracted to the soil particles because the two have opposite electrical charges. Urea nitrogen is quickly transformed to the ammonium form when it is added to soil, so that for all practical purposes, whether the fertilizer nitrogen is from an ammonium source or urea, you end up soon after application with the ammonium nitrogen form in the soil. The ammonium does not stay on the soil particle; it is just a temporary home. During warm weather most of the ammonium will be converted to nitrate within a few weeks.

Before describing the conversion of ammonium nitrogen to nitrate nitrogen, let me point out one other source of ammonium nitrogen. This is ammonium nitrogen released from soil organic matter. Certain kinds of soil microorganisms break down soil organic matter. The ammonium so released mixes with the fertilizer ammonium nitrogen, and the two are then indistinguishable.

Agricultural and Home Economics Extension Service of the University of Kentucky, the United States Department of Agriculture cooperating. W. A. Seay, Director. Issued in furtherance of the Acts of May 8 and June 30, 1914.

What happens to the ammonium nitrogen in soil is the same, whether it came from the fertilizer ammonium, the added urea, or from that released by soil organic matter. Ammonium nitrogen is attacked by certain groups of micro-organisms (nitrosomonas) and converted to nitrite (NO_2). Fortunately, this is not the end of the process, because nitrite-nitrogen is toxic to plants. Almost at the same time the nitrite is formed, a second group of micro-organisms (nitrobacter) converts the nitrite to nitrate (NO_3). The nitrate thus formed is free to move in the soil in the same way as the nitrate from the added fertilizer.

The above processes of nitrification (changes from ammonium to nitrate) proceed best in moist but not wet soil and are greatly affected by the temperature of the soil. At temperatures below 50°F, the conversion proceeds slowly. In contrast, the conversion is rapid at temperatures above 75°F. Thus, conversion may be very slow during the late fall, winter and early spring months, but may occur rapidly during the remainder of the year.

Nitrogen Levels

A week by week picture of the nitrate nitrogen levels in one soil is given in Figure 1 (see page 3). On April 13, the Maury silt loam soil contained approximately 4 pounds of nitrate nitrogen per acre.

In soil receiving no fertilizer nitrogen, the nitrate nitrogen content increased from 4 to 41 pounds per acre during the period April 13 to May 18. Decomposition of organic matter thus provided 37 pounds of nitrate nitrogen per acre during that period.

In soil receiving 100 pounds nitrogen per acre from ammonium nitrate (1/2 ammonium, 1/2 nitrate) on April 30, the soil nitrate nitrogen content was 86 pounds per acre on May 18. The difference between 86 pounds of nitrate nitrogen in the fertilized soil and 41 pounds in the unfertilized soil accounts for most of the nitrate added as fertilizer.

Rapid accumulation of nitrate nitrogen in the soil continued until June 16. By this time, most of the ammonium nitrogen in the fertilizer had been oxidized. Tobacco plants, which had been transplanted to the field on May 19, also began rapid growth, utilizing nitrogen at a high rate. When the tobacco plants were harvested on August 26, soil nitrate nitrogen was very low.

A by-product of the conversion of ammonium nitrogen to nitrate nitrogen is the concurrent production of hydrogen ions. Two of the 4 hydrogens contained in an ammonium ion (NH_4^+) are released by the soil micro-organisms as an acid by-product during the formation of nitrate nitrogen. The other two hydrogens go into the formation of water. The acid-forming process lowers the soil pH, as is shown in the lower half of Figure 1. With few exceptions, as the soil nitrate nitrogen content increased, the soil pH decreased. After the nitrification of ammonium from fertilizer and organic matter was almost completed and plant uptake of nitrate and accompanying ions was proceeding rapidly, the soil pH increased. This increase was due either to uptake of hydrogen by the plant, excretion of hydroxyl ions by the plant, or both.

In summary, the behavior of fertilizer nitrogen in soils is generally as follows: the added ammonium nitrogen is converted to nitrate nitrogen and in turn is mixed with other nitrate nitrogen which comes from fertilizer or from soil organic matter, first through the ammonium nitrogen form and finally to the nitrate nitrogen form. Nitrate nitrogen continues to build up in aerated soils until plant removal or leaching exceeds the rate of the nitrate formation. At this time, the overall level of nitrogen in the soil starts to decrease. The conversion of ammonium nitrogen (either from fertilizer or soil organic matter) to nitrate nitrogen gives an acid by-product which lowers the soil pH. If the pH is quite low at the beginning, this acidity may result in manganese toxicity and other harmful effects to the crop.

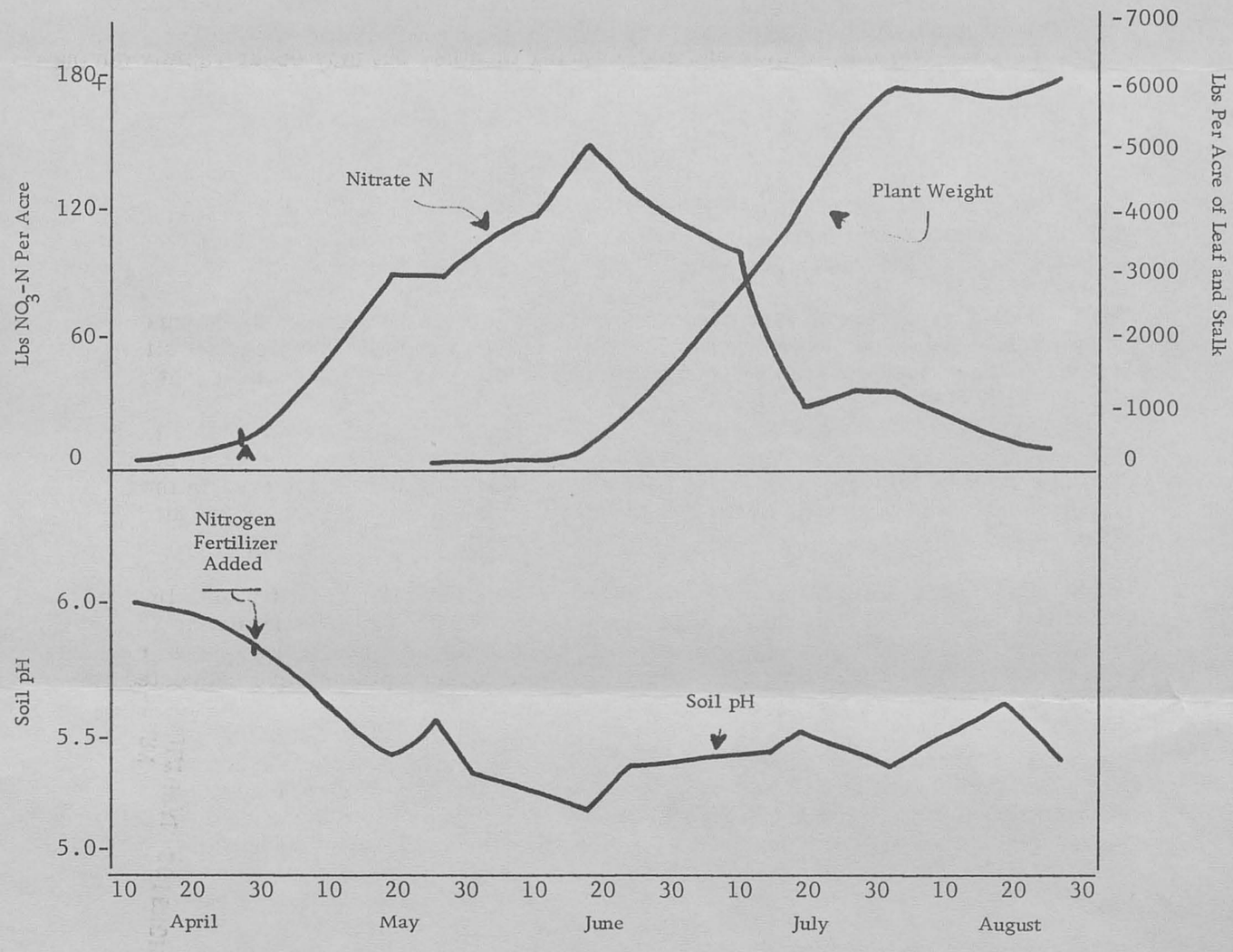

Fig. 1. - Changes in soil nitrate nitrogen content, soil pH and tobacco plant weights during the 1965 growing season. One hundred pounds of nitrogen was added as ammonium nitrate on April 30.