Historical Highlights in Indiana Soil Science

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Abstract

Within just a few years of de Saussure's identification of aluminum in plants in 1905, S. D. Conner and Associates were studying aluminum toxicity in Indiana soils. Their publication in 1913 is recognized as the first identification of aluminum toxicity in soils in the United States. These studies led into the work of G. N. Hoffer on heavy metal accumulation in corn stalks which in turn became the basis for the Hoffer Corn Stalk Test as a diagnostic aid. Continued developmental work culminated in the introduction of the Purdue Soil and Plant Tissue Test Kits in the early thirties.

T. M. Bushnell introduced the use of aerial photography into soil survey in the early twenties. His development of the catena concept was a major step forward in soil survey. George D. Scarseth's revolutionary research on nitrogen nutrition of corn and other crops initiated a whole new era of increased productivity for soils around the world.

Introduction

It is a general human trait to take the present situation as something obvious and normal and to overlook completely how this situation has come about. In the words of Isaac Newton on his deathbed: "If I have seen farther than others, it is by standing on the shoulders of giants." Actually we stand on the shoulders of those that have gone before us and who have contributed to the development of the physical, social, emotional, and the scientific environment in which we live and operate. This is good, so we should not be burdened with gratitude or disgust for those that have preceded us in our brief sojourn on earth. Nevertheless, it seems appropriate at times to recall the development in the main field of our interest and endeavors. This will show us at what spot we ourselves entered the scene and to give us perspective in planning for our future activity.

This is the reason that we are presenting some of the historical highlights in Indiana soil science.

Potassium

Some of the black soils of the swampy region of Northern Indiana proved to be unproductive, even after they were properly drained. Some of these soils were mucks and peats, others were sandy with enough admixture of humus to make them dark.

In 1892 Henry A. Huston (9) started to investigate the reasons for the infertility of this so-called "bogus" soil and how it might be made productive. His chemical analyses convinced him that the soils were well endowed with nutrients, even though they were not available to the plants. He conducted field experiments on drained "bogus" land, applying potassum fertilizer, lime and straw. The rates per acre were approximately 5 tons of lime, 250 lbs of K_2O and enough straw to contain around 150 lbs K_2O. He found that the application of both the potassium salts and of the straw resulted in large yield increases, actually changing the useless soil into a very productive one. Huston also recognized that drainage was an important aspect of the infertility of this soil, for he states: "The use of straw or Kainit has proved very profitable as a means of *temporary* improvement of such lands. The *permanent* improvement of such lands must be effected by *efficient* drainage."

To make more certain about these findings, Conner and Abbott (7) conducted extensive fertilizer experiments with corn and onions in ten counties from 1904 to 1911.

It turned out that in most cases, potassium fertilization resulted in the greatest increases in yield. Phosphate application was a distant second. Evidently it was not assumed that nitrogen fertilizer was important on these black soils. Only in a few cases was nitrate of soda used in the experiments. Manure and dried blood were other sources of nitrogen. The result of this work was that the once useless black soils of northern Indiana became highly productive and gained greatly in land value, mainly through generous application of potassium fertilizer.

Aluminum

One of the early achievements in soil investigation was the discovery of toxicity of soluble aluminum compounds in the soil and of the methods of control within a few years after de Saussure identified aluminum in plants. Abbott, Conner, and Smalley reported in 1913 on some unproductive soils in the Kankakee marsh region (1). They found fairly large amounts of aluminum nitrate in these soils. While earlier investigators had noted that aluminum salts in water cultures were toxic to plants, the work by the Indiana scientists was the first that showed that this situation occurs also in the field (12). The soils were very acid, but as the studies were made before the introduction of the "pH" concept in chemistry, we do not have a quantitative report on the intensity of the acidity of the soils in question. The reclamation of these soils was accomplished by a combination of drainage and the application of lime and fertilizer. The calcium and magnesium of the lime, by neutralization of the acids, precipitated the aluminum in the soil solution and decreased the activity of the exchangeable aluminum.

Plant Tissue Tests

Interest in determining plant nutrients in soils and plants dates from 1903 when Jones and Huston (10) conducted an experiment with corn to determine the composition of its various parts throughout the growing season. This gave information not only on the amounts of nutrients needed by the plants but also the rate at which these nutrients have to be available to enter the plants. These investigators stressed "the importance of a continuous and abundant supply of plant food from the time of planting to the time of harvesting the maize plant."

The next logical step was taken by Hoffer (8). He developed a number of chemical corn stalk tests for nitrate and for potassium in the plant and described nutrient deficiency symptoms. The interpretation of the tests and the appearance of the corn plants gave an indication of the nutrient status of the plant and the need for fertilization of the soil. For the nitrate test he used diphenylamine dissolved in 75 percent sulfuric acid. This reagent is still employed today for this purpose. Hoffer found that "when corn plants grow in soils without adequate available potassium, iron compounds accumulate in the joint tissues." For this reason he used a test for ferric iron in the nodes of the corn plants to determine whether there was a deficiency of potassium in the plant.

Later on Thornton, Conner, and Frazer (15) developed direct tests for potassium and also for phosphorus in plant tissues. The reagents were the same as those used to test soils for these elements. A soil and plant tissue test kit was developed in 1934 that has been used and still is being used without any essential modification. More than 10,000 such kits have been sold all over the world and have helped in the advance of fertilization methods in many countries.

Phosphate Fertilizer

Early in this century the problem of the most economical phosphate fertilizer had not been settled by the agronomists. In 1904 Wiancko and Conner (16) set out to determine whether raw rock phosphate or acid phosphate (superphosphate) would give better results. Extensive field experiments with corn were conducted during several years. The investigations found that "the per acre net profit has been seven times as great from acid phosphate as from rock phosphate. The value of the crop increase per pound of phosphorus applied has been 28.3 cents for acid phosphate and 3.5 cents for the rock phosphate." These results should have settled this problem once and for all. But in our neighboring state of Illinois Cyril Hopkins maintained that rock phosphate was economically superior to acid phosphate. Because of his reputation as an outstanding leader in soil fertility investigations, the controversy raged another 40 years until it was finally laid to rest during the 1950's.

Fertilization Rates that Meet Crop Needs

While experiments with commercial fertilizers were conducted in Indiana during the last quarter of the nineteenth century, their use in general agriculture in Indiana before 1900 was minimal. Discussing the cultivation of sugar beets in 1894, Henry Huston, soil chemist at the Purdue University Agricultural Experiment Station, comments: "Little has been done in America in experimenting with commercial fertilizers on beets. Such experimental facts as have come under my observations seem to indicate that the results obtained did not justiy the cost involved." Phosphate fertilization in Indiana became general at the beginning of the current century. Potash and nitrogen followed around 1915. But the rates used were very small. During the Great Depression of the thirties fertilizer use was all but abandoned (11). Even in the more prosperous years that followed, fertilizer rates for corn were in the order of 125 lbs. of 2-12-6 per acre. In the early forties during July and August most corn in Indiana showed severe nitrogen deficiency symptoms. Scarseth reasoned that the lack of success of earlier nitrogen fertilization experiments was due to several causes. In some cases the amount of nitrogen used in the experiments was so small that it only stimulated vegetative growth and was used up before the ears were formed. In those years fertilizer was usually applied with the corn planter in the row. Substantial rates of fertilizer near the seed create a high osmotic tension and reduce its viability. On the other hand nitrate nitrogen is readily leached beyond the reach of the roots, especially in a wet year, and therefore is lost to the plant. Because of the erratic responses of these early nitrogen experiments, nitrogen fertilization was not recommended in amounts that would meet the crop's requirement.

In this environment Scarseth reasoned that if ammonia types of nitrogen were placed deep in the soil (5 to 9 inches) the nitrogen would remain absorbed on the clay and be taken up by the corn in late July and August. Experiments in '39 with ammonium sulfate broadcast and plowed under confirmed his hypothesis. In many experiments corn yields were increased from less than 30 bushels per acre to over 90 bushels per acre—an unbelievable increase in yield (14)!! These results stimulated the great transformations in crop production systems and fertilization. Fortunately, simultaneously, World War II ended. Consequently low-cost nitrogen became available at the same time the knowledge on how to use it came into existence. Formerly corn was dependent on manure and legumes in the rotation for nitrogen. Now continuous cropping of corn was not only possible but rapidly became an acceptable practice when used with minimum tillage. The rationale for plowing under of nitrogen also was applicable where large amounts of the other nutrients needed to be applied. It was only logical then to plow under large quantities of P and K on infertile soils. Such plowed-under fertilizer was supplemented with row fertilizers for starter effects. This pioneering work in Indiana had not only national but international impact on the food, feed, and fiber production in the world. Indiana was the first state where farmers generally adopted copious fertilization. Up into the fifties, Indiana used more fertilizer than any of the other states. But soon the evidence of the soundness of this technique became so obvious that it spread to the other states of the cornbelt and eventually to the rest of the country and the world. The yields of our main crops that had shown only very modest increases up to the late thirties have more than doubled in the following quarter century.

Catena Concept

The word catena (Latin for chain) was originally introduced into soil mapping by Milne, working in Africa (13). He used this term with two meanings. In one case it designated a pattern of soils that repeated itself many times and was too intricate to allow for separation of the different soils on a map of broad scale. An example of this is the alternate occurrence of soils on mountain ridges and soils in the intervening valleys. He also used the word catena to describe a group of soils of the same parent material but of differing physiographic location. Bushnell (4) adopted the latter meaning and crystallized the concept of catena. He recognized the effects that waterlevel and degree of slope have on the development of soil profiles derived from similar parent material. He classified all of the soil series of Indiana according to parent material and drainage profile in the so-called "Key to Indiana Soil" that is a classic of organization (5) and has proven very useful in Indiana and stimulated similar use of the catena concept elsewhere.

Aerial Photographs

Thomas M. Bushnell had done soil work for six years before the First World War. In 1918 he joined the Aviation Section of the U.S. Signal Corps and was trained as an observer. He took many oblique shots of the land with a camera from the plane and recognized the value aerial photographs might have for soil survey. After becoming head of the Indiana Soil Survey, he investigated the possibility of using aerial photographs (3). In 1925 commercial companies quoted $23 per square mile for the photographs. At that time the rather generalized field work of soil survey cost around $5 per square mile. For that reason administrators considered aerial photographs too expensive. In 1925 Bushnell together with another surveyor, Mark Baldwin contacted Capt. Goddard at Chanute Field in Illinois and received aerial photographs covering several square miles in the Lafayette vicinity. These were used for experimental soil survey mapping.

Also the National Guard took aerial photographs but most of them were taken at a distinct angle instead of vertically. They therefore distorted the dimensions. An engineer, Coblentz (6), working with Bushnell rigged up a large camera to retake these photographs in order to rectify the scale and to get a planimetrically true picture of the ground. A field party used these maps in 1930 in Martin county. Private companies objected to the competition by government agencies and Bushnell ordered an entire set of aerial photographs of Jennings county in 1929. This was the first soil survey of an entire county that was done on aerial photographs anywhere.

The value of aerial photographs for easy and accurate location has become obvious. Interpretation of aerial photographs with or without detailed ground control has become a valuable aid in soil survey. Soon after the introduction of the use of aerial photographs by Bushnell, civil engineers at Purdue University have made use of them for the study of engineering features of soil (2).

Conclusion

Indiana has been responsible for a good share of the progress in soil science. Only the most obvious highlights of the history of Indiana soil science have been presented here. It is difficult to select those items that are truly highlights as compared to other developments in soil science that may be equally important, depending upon the viewpoint.

Literature Cited

1. ABBOTT, J. B., S. D. CONNER, and H. R. SMALLEY. 1913. The reclamation of an unproductive soil of the Kankakee marsh region. Purdue Univ. Agric. Exp. Sta. Bul. **70**:17.

2. BELCHER, J. D., L. E. GREGG, and K. B. WOODS. 1943. The formation, distribution, and engineering characteristics of soils. Purdue Univ. Engineering Bulletin, Research Series **87**:27.

3. BUSHNELL, T. M. 1927. Aerial photography for Indiana. Proc. Ind. Acad. Sci. **37**:63-72.

4. BUSHNELL, T.M. 1942. Some aspects of the soil catena concept. Soil Sci. Soc. America Proc. **7**:466-476.

5. BUSHNELL, T. M. 1944. The story of Indiana soils. Purdue Univ. Agr. Exp. Sta. Spec. Circular 1, p. 52

6. COBLENTZ, C. S. 1939. Restitution of aerial enlargements for area determination. Photogrammetric Engineering. **5**:138.

7. CONNER, S. D. and J. B. ABBOTT. 1912. Purdue Univ. Agr. Exp. Sta. Bul. **157**:233-264

8. HOFFER, G. N. 1926. Testing corn stalks chemically to aid in determining their plant food needs. Purdue Univ. Agr. Exp. Sta. Bul. 298, p. 31.

9. HUSTON, *H. A.* 1895. The improvement of unproductive black soils. Purdue Univ. Agr. Exp. Sta. Bul. **57**:81-100.

10. JONES, W. J. and H. A. HUSTON. 1914. Composition of maize at various stages of its growth. Purdue Univ. Agr. Exp. Sta. Bul. **175**:599-628.

11. KOHNKE, H. and L. S. ROBERTSON. 1966. Changing patterns of Agriculture. Natural Features of Indiana, Ind. Acad. of Sci. A. A. Lindsey, Ed. 519-531.

12. MCGEORGE, W. T. 1925. The influence of aluminum, manganese and iron salts upon the growth of sugar cane, and their relation to the infertility of acid island soils. Hawaiian Sugar Planters' Ass'n. Agric. and Chem. Series Bul. 49, p. 95.

13. MILNE, G. 1935. Composite units for the mapping of complex soil associations. Trans. Third Int. Cong. Soil Sci. Vol. **1**:345-347.

14. SCARSETH, G. D., H. L. COOK, B. A. KRANTZ, A. J. OHLROGGE. 1944. How to fertilize corn effectively in Indiana. Purdue Univ. Agr. Exp. Sta. Bul. 482, p. 41.

15. THORNTON, S. F., S. D. CONNER and R. R. FRAZER. 1934. The use of rapid chemical tests on soils and plants as aids in determining fertilizer needs. Purdue Univ. Agr. Exp. Sta. Circular 204, p. 16.

16. WIANCKO, A. T., and S. D. CONNER. 1916. Raw rock phosphate as fertilizer. Purdue Univ. Exp. Sta. Bul. **187**:1053-1083