Guides to the Management of Illinois Soils

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"THE wealth of Illinois is in her soil, and her strength lies in its intelligent development." This statement, which appears on the frieze of Davenport Hall on the University of Illinois campus, was made half a century ago by President Draper. It is as true today as it was 50 years ago.

One of the major functions of the University's Agronomy Department has been and continues to be to assist in the intelligent development of the soils of Illinois. It is our firm conviction that sound soil management is the foundation on which an efficient, productive, and progressive agriculture must be built. Not only for this reason, but because of the wide range of soil conditions found in Illinois and because of the steadily growing reservoir of knowledge concerning soil and crop behavior, a review of the basic concepts of soil management is appropriate. We are keenly aware of our opportunities and responsibilities in working with all the technical agricultural personnel in the State in assisting farmers in the selection of soil management practices. Therefore, the Agronomy Department accepts as one of its major functions the collection, summarization, and dissemination of basic information concerning soils and their behavior under use, so that farmers will have at their disposal the necessary facts on which to make intelligent soil management decisions.

Basic Principles

The soil management problems encountered on individual farms involve specific combinations of many factors. This fact, together with the large amount of experimental data on the effects of particular practices under specific conditions, makes it necessary to establish certain guideposts to assist in evaluating practices for individual farms. The following basic precepts should be kept constantly in mind when advising farmers on the selection of soil management practices.

1. The relation of practices to the attainment of the over-all soil management objectives of the farmer should be emphasized. These objectives, irrespective of type of farming enterprise, should be, in our opinion, (a) to supply the amounts and forms of plant nutrients necessary for efficient levels of crop production, (b) to provide a satisfactory state of tilth for normal root development and favorable soil-air, -water, and -temperature conditions, and (c) to minimize the loss of productive capacity arising from erosion.

2. There can be a range of alternative practices that merit serious consideration in answering the above objectives. These can be expected to vary with the soil and economic conditions prevailing on the farm, the abilities and desires of the operator, and the risks he is willing to assume. Therefore, it becomes the responsibility of those who advise farmers on soil management problems to acquaint them with the alternative practices available and to inform them, to the extent possible, of the consequences arising from the choice of any one of the alternatives. The particular set of practices

which most efficiently meets the objectives on one particular farm at one particular time may be quite different from those best suited for that farm at some later time or for a neighboring farm.

3. Specific practices must be considered in relation to other soil management practices and to other aspects of the entire farm enterprise from the standpoint of how they are complementary, competitive, and supplementary with respect to the employment of land, labor, machinery, capital, etc.

4. For soils having multiple nutrient deficiencies, proper amounts of each of the nutrients must be supplied if efficient use is to be obtained from any one of them.

Facts Needed on Individual Farms

Specific information on the following points is necessary to select properly the soil management practices for a particular farm or field.

1. The objective and goals of the farmer—An understanding of these is fundamental to the adoption of practices.

2. Soil type—The physical nature of the profile, particularly its moisture and air relations, is of considerable importance in any consideration of soil management practices.

3. Production limitations imposed by soil resources—The existence of erosion hazards, susceptibility to flooding, lack of adequate drainage, or the existence of insufficient storage capacity for soil moisture often imposes rather severe limitations on the choice of soil management practices and also on the economic returns.

4. Nutrient status—Full use should be made of soil test data, information on previous fertilization and cropping practices, current yield levels, and yield potentials in the development of a set of soil fertilization practices.

Although it is impossible to list all of the combinations of specific practices that should be considered on one or more of the farms of Illinois, certain generalizations that serve as a basis for making decisions concerning soil management can be made. These principles are well established and are supported by many direct and indirect research data; they provide the building blocks from which acceptable, sound soil management systems are constructed.

Soil Reaction

Most but not all Illinois soils are naturally acid. The degree of acidity is a function of the relative amounts of exchangeable hydrogen and exchangeable cations, such as calcium and magnesium, on the colloidal surfaces of the soil. The proportion of exchangeable hydrogen, and hence the acidity of an acid soil, can be reduced by the addition of such basic compounds as $CaCO_3$, $Ca(OH)_2$, CaO, $MgCO_3$, etc. The rate at which the neutralization occurs is determined by the rapidity with which the added material goes into solution in the soil. This is influenced by the chemical nature and fineness of the liming material, the rate of application, and thoroughness of mixing with the soil.

Soil reaction affects crop growth indirectly through its influence on the chemical forms and availability of the nutrient ions as well as the solubility of certain essential and nonessential elements, such as Al, Mn, etc., which are harmful in high concentrations. Soil reaction also influences microbial activity in the soil.

For cropping systems which include legumes, the soil should be maintained at pH 6.0 to 7.0 and should not be lower than pH 5.5 for most of the commonly grown field crops. The priority to be given lime, particularly where limited capital is available, should be based on the expected responsiveness of the crops grown to lime and to other nutrients which might be deficient. For example, soil tests might indicate a pH of 5.5 and severe phosphate or potash deficiencies.

This degree of acidity is relatively more serious for the legume than for the other crops. The severe potash or phosphate deficiency, on the other hand, will seriously limit the yields of all crops. In this case top priority would be assigned to phosphorus or potash for all crops, with lime also applied ahead of the legume. Below pH 5.5 there is little basis for choice, and lime as well as phosphorus and potash, if deficient, should be applied for all common crops. This illustrates that no set sequence of soil treatment can be recommended for all conditions.

If proper proportions of high calcium and dolomitic limestones are added in amounts necessary to correct soil acidity, then the calcium and magnesium nutrient requirements for plants will be met.

Phosphorus

It has long been recognized that many Illinois soils contain insufficient phosphorus for efficient levels of crop production. Those constituents which contribute to phosphate fertility in soils reside in organic forms and in two principal inorganic forms, adsorbed and acid-soluble. The relative proportion of the latter forms is largely determined by the pH of the soil. The phosphorus taken up by plant roots is derived from the adsorbed and acid-soluble inorganic soil forms, both of which can be measured by soil tests. Phosphates added to a soil are ultimately converted into the native soil forms mentioned above. The rate of conversion of inorganic carriers is determined primarily by the solubility of the added phosphorus. This, in turn, is determined by the chemical form of the added phosphorus, the acidity of the soil, and the thoroughness of mixing.

With respect to phosphate fertilizers, the following points merit emphasis:

1. There is no one best carrier for correcting the phosphorus deficiencies of all Illinois soils.

2. Soluble phosphatic fertilizers can be used effectively to meet the crop needs irrespective of the crop or the pH of the soil.

3. Soil acidity affects the solubility of rock phosphate. In very sweet soils (pH 6.5 to 7.0), and especially in alkaline soils (pH above 7.0), rock phosphate dissolves so slowly that it does not supply sufficient available phosphorus for maximum yields. On these soils the phosphate needs of crops should be supplied largely through soluble phosphates.

4. In soils limed according to test which have reached a pH range of 6.0 to 6.5, plant roots can feed on rock phosphate, and it is therefore classed as available, although for many plants its availability is limited. Rock phosphate should be broadcast and mixed with the soil. Its effectiveness on soils in this pH range appears to be increased by duration of soil contact. Even so, supplementary soluble phosphorus would appear to be necessary for maximum yields of some crops, notably wheat.

5. For starter fertilizer, for direct application to wheat, for corn subject to injury by grape colaspis or other root insects, or for crops with restricted root systems, only soluble phosphates are recommended.

Potassium

Although Illinois soils contain a large amount of total potassium, the amount of this element in the exchangeable or "plant-available" form is too low in many soils for efficient levels of crop production. It is established that potassium exists in several forms in Illinois soils and that the amounts found in each of these forms are in dynamic equilibrium with each other. This important concept constitutes the logical basis for potassium fertilization practice.

The rate at which potassium is released from the reserve soil forms in southern Illinois and sandy soils is much lower than that of most northern Illinois soils. For this reason maintenance as well as build-up requirements for potassium in soils of these areas are quite different. On soils testing low in potassium, the required potash should be added in two or more applications per rotation to avoid excessive conversion to the "storehouse" forms. Because of its highly soluble nature, potash applied with or near the seed at planting time may cause injury to seedlings. Since many crops have the capacity for luxury consumption of potassium when large amounts of this nutrient are present, it is not a good practice to apply surplus amounts of potash immediately ahead of a forage crop from which hay is to be removed.

Build-up and Maintenance

One of the basic concepts concerning soil fertility management is that of raising the nutrient level of the soil to that required for efficient crop production and then maintaining it at or near that level by regular fertilization as determined by the nutrient losses from crop removal, leaching, and erosion and by periodic soil tests. This concept applies primarily to such immobile nutrient elements as phosphorus and potassium. In economic terms, the fertility build-up might be considered as a capital investment and the maintenance application as an operating cost.

It is possible, depending on the nutrient in question and its level of availability, to operate on a strictly maintenance basis, on a partial build-up and maintenance basis, or on a complete build-up and maintenance basis. On soils that are highly deficient in potassium, the build-up of potassium should be achieved on a gradual basis which permits maximum yields without excessive conversion of the applied potash into "storehouse" forms. Except for calcareous soils, a phosphorus build-up can be achieved either as a single full application or on a gradual basis. The choice among the several alternative routes will be determined usually by the magnitude of the build-up requirement, by the financial status of the farmer, and by the manner in which the alternative systems fit into the farmer's system of operations.

The concept of build-up and maintenance involves no explicit requirements as to the forms used to meet the fertility needs. It is usually true, however, that the large amounts of nutrients, required for full build-up can be most economically supplied in the form of straight fertilizer materials rather than in mixed fertilizers. The same may also apply for rotational maintenance applications following complete build-up. If the maintenance needs are met wholly or in part through the use of fertilizers on the individual crops, a higher-unit-cost mixed fertilizer of suitable grade may be preferred if it reduces the number of applications that have to be made. Thus starter fertilizers can be used to meet fertility maintenance requirements and at the same time provide a supply of available nutrients for seedling establishment and vigorous early growth.

Nitrogen

Of the essential plant nutrients that are supplied from the soil, nitrogen is the element that is required in the greatest quantities. This fact, coupled with the knowledge of the mobile nature of the nitrogen forms absorbed by crop plants, makes it essential that continuing attention be given to the nitrogen supply for each crop. All the possible sources of nitrogen should be considered in meeting crop demands for nitrogen. These sources include soil organic matter, crop residues, legumes, manure, and nitrogenous fertilizers.

In evaluating legumes as a source of nitrogen for subsequent crops, adequate attention must be given to the manner in which they are utilized, amounts of nitrogen added, the fixed charges involved in their production, and the hazards arising from stand failures. When needed, nitrogen fertilizers can be effectively used to supplement legume nitrogen.

The proportion of nitrogen secured from the air by nodulated legumes decreases as the supply of available nitrogen in the soil increases. Therefore, legumes will be most effective as suppliers of nitrogen to the cropping system when grown on soils that are low in available nitrogen and at the position in the rotation where the available nitrogen supply is at its lowest level.

In the presence of organic material that is low in nitrogen and under favorable environmental conditions, soil microorganisms compete with the growing crop for nitrogen. Sufficient nitrogen must be supplied to meet the needs of the crop and the microorganisms if satisfactory yields are to be obtained. The amount of nitrogen required for the microorganisms will depend upon the kind and amount of residue returned to the soil.

Organic Matter

Organic matter is an important soil constituent. It serves as a reservoir of nutrients, particularly nitrogen, and it alters the physical properties of the soil. The effects of organic matter on soil aggregation and tilth are determined primarily by the unstable intermediate compounds formed during decomposition. It is important that a steady supply of actively decomposing organic matter be present in the soil if it is to be kept well aggregated. All sources of organic matter should be utilized as effectively as possible. Legumes, nonlegumes, manure, cover crops, and crop residues are all good sources of organic matter. Except for manure the quantities of these materials available for incorporation into the soil will be highest on soils in a high state of fertility.

Organic matter, either incorporated in the soil or used as a mulch, aids in water infiltration. Except on very sandy soils it probably does not significantly increase the water-supplying power of the soil.

Soil Tilth

To function normally, plant roots require water and oxygen as well as nutrients. The amounts and rates of supply of both air and water are strongly affected by the physical condition of the soil. Highly compact soils, or soil horizons, may seriously impede the movement of air and water through the soil and may prevent full exploitation of the soil volume by roots. When rooting volume is restricted, plants are less efficient in their utilization of the total available water and nutrient supplies of the soil.

Soils in a good state of tilth are well aggregated, have a low bulk density, and exhibit a considerable amount of resistance to compaction. Such soils have moderate to high infiltration rates, good internal drainage, and enough large pores to permit adequate aeration. Management systems that favor the creation of good tilth are those which regularly supply large amounts of readily decomposable organic matter to the soil, those which maintain a vegetative cover on the soil for a maximum portion of the time, and those in which tillage operations, particularly during times of high soil moisture, are minimized.

The effects of soil tilth on crop yields on soils of high fertility are not sufficiently well established to permit, at this time, a quantitative evaluation of tilth as a factor in crop production. In many instances yield effects which in the the past have been attributed to poor physical conditions have in recent years been found to be associated with insufficient nutrient levels, particularly nitrogen. This is especially true on the medium-textured soils. However, on very fine-textured soils the effect of tilth upon yield is more clear-cut.

Erosion Control

One of the principal objectives of any sound system of soil management is to minimize the loss of productive capacity arising from erosion. The relative position of erosion control as a major consideration affecting the selection of management practices varies widely and is determined by the slope and soil profile characteristics. Since, under Illinois conditions, erosion occurs primarily as a result of movement of water over the surface of the soil, it follows that practices that reduce or eliminate such water flow will constitute effective erosion control. Therefore, all practices that increase the infiltration of water into the soil are important in controlling soil and water losses. Maintenance of good tilth and vegetative cover and use of contour tillage, strip cropping, grass waterways, and where necessary, water control structures, such as terraces, should be considered in the management of soils having an erosion hazard. The maintenance of a high state of fertility is conducive to effective erosion control through its effect on the amounts of crop residues returned to the soil and its effect on the vigor and density of the vegetative cover on the land.

Rotations

The use of a planned system of crop sequences is useful in the development of a sound soil management system for a particular farm. A crop rotation, however, is but a means to one or more objectives; it is a means to an end—not the end itself. Rotations are useful in distributing risks; in decreasing crop diseases, weeds, and pests; and in distributing labor and machinery demands on the farm. Rotations or cropping systems are intimately associated with soil fertility needs and with the maintenance of tilth and the control of erosion.

In the past the rotations that have been most productive and profitable and that have maintained satisfactory soil tilth have been those in which legumes and sod crops have been grown frequently. On sloping land the range of choice of cropping systems is restricted because of the erosion hazard. On level, nonerosive land the choice may be conditioned primarily by the effects of the cropping system on the air and water relationships of the soil. The latter are intimately associated with soil tilth and with the amount and activity of soil organic matter. Also, one of the functions of legumes in a cropping system is to supply nitrogen for subsequent nonlegume crops. Therefore, it is easy to understand why the increased use of commercial nitrogen has given rise to many new ideas that apparently contradict our previous concepts of the contribution of cropping systems to sound soil management.

Under present price conditions there are many situations where synthetic nitrogen can substitute for legume nitrogen in crop production. If crop yields are increased, the amounts of organic residues available for incorporation into the soil are normally increased. If sufficient nitrogen is supplied to satisfy both the crop and microbial demands, then a high level of nitrogen availability and organic matter activity is achieved. For many situations the functions of legume rotations can be achieved by nonlegume cropping systems and synthetic nitrogen except for the possible physical effects of the legume roots. It is possible that many of the other shortcomings of the more intensive rotations can be reduced or eliminated by intercropping or other modifications of crop production practices.

Rotations and legumes are not being repudiated. Rather, new techniques and materials that offer alternative routes to the same objectives have become available. Farmers now have a wider choice of cropping system and greater flexibility and reduced risk within the cropping system because for the first time, in a practical sense, the farmer has control of the nitrogen management of his farm. With proper fertilization, on permeable, nonerosive soils, even continuous corn production becomes a possibility.

There are many nearly level soils in Illinois where it is very doubtful that efficient levels of production can be maintained without the periodic use of cropping systems that include sod crops. Under most soil conditions—and particularly on the flat, slowly permeable, very fine-textured soils—

(*Turn to page* 40)

calcium supply to the plant is similar to the potash supply in its location in the soil profile.

It is perfectly obvious from the profile and data that the two soils differ tremendously in practically every respect, namely, difference in depth, water absorbing and supplying capacity, acidity (pH), plant nutrients, drainage, and other characteristics. The yellowish brown sandy loam was influenced by previous soil treatment, whereas the grayish brown sandy loam had been influenced to a lesser extent.

Summary

An effort has been made to point out that each layer of soil makes a contribution to the efficient production of a crop. The plowed layer supplied predominantly the nitrogen and phosphorus, potash and water. The layer immediately below supplies potash, water, magnesium, and calcium. The depth of the soil determines the extent of this supplying capacity of the soil. A true evaluation of the soil must be based upon the whole soil and not just the surface layer.

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the fertilization and cultural practices used in conjunction with a cropping system are equally as important as the system itself in determining its effects on productivity, organic matter, tilth, and erosion control.

In summary we can say that good soil management is the key to an efficient, productive farm business. Because the soil management problems of an individual field or farm may be unique to that particular field or farm, it is essential that farmers understand their management objectives and the alternative practices that are available for meeting those objectives. The care that the farmer uses in considering the various alternatives and the skill with which he combines them into a soil management program for his particular farm will in large measure determine his production efficiency.

Summary of Ten Years' Work . . .

(*From page* 14)

nitrogen with 40 pounds of P_2O_5 and 60 pounds of K_2O was 9.3 tons of cane and 1,581 pounds of sugar. The response to potash was very marked. At two locations with stubble cane on Iberia silt loam, 80 pounds of nitrogen with 40 pounds of P_2O_5 and 60 pounds of K_2O gave the highest yields.

The response of stubble cane on Recent alluvial soils to complete fertilizers, while not so marked as to nitrogen alone, is consistent, with approximately 2 tons of increase being derived from phosphate and potash and 7 tons of increase coming from 60 pounds of nitrogen alone. Six locations on Baldwin silt loam, Table V, returned an average increase of 5.1 tons of cane from 60 pounds of nitrogen alone and an increase of 7.7 tons of cane and 1,230 pounds of sugar per acre from 60 pounds of nitrogen with 60 pounds of K_2O. The averages of five experiments with stubble cane on Commerce very fine sandy loam show 8.5 tons of benefit from 60 pounds of nitrogen alone and