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5-1947

Fertility Maintenance and Management of South Dakota Soils

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CIRCULAR 68 MAY 1947

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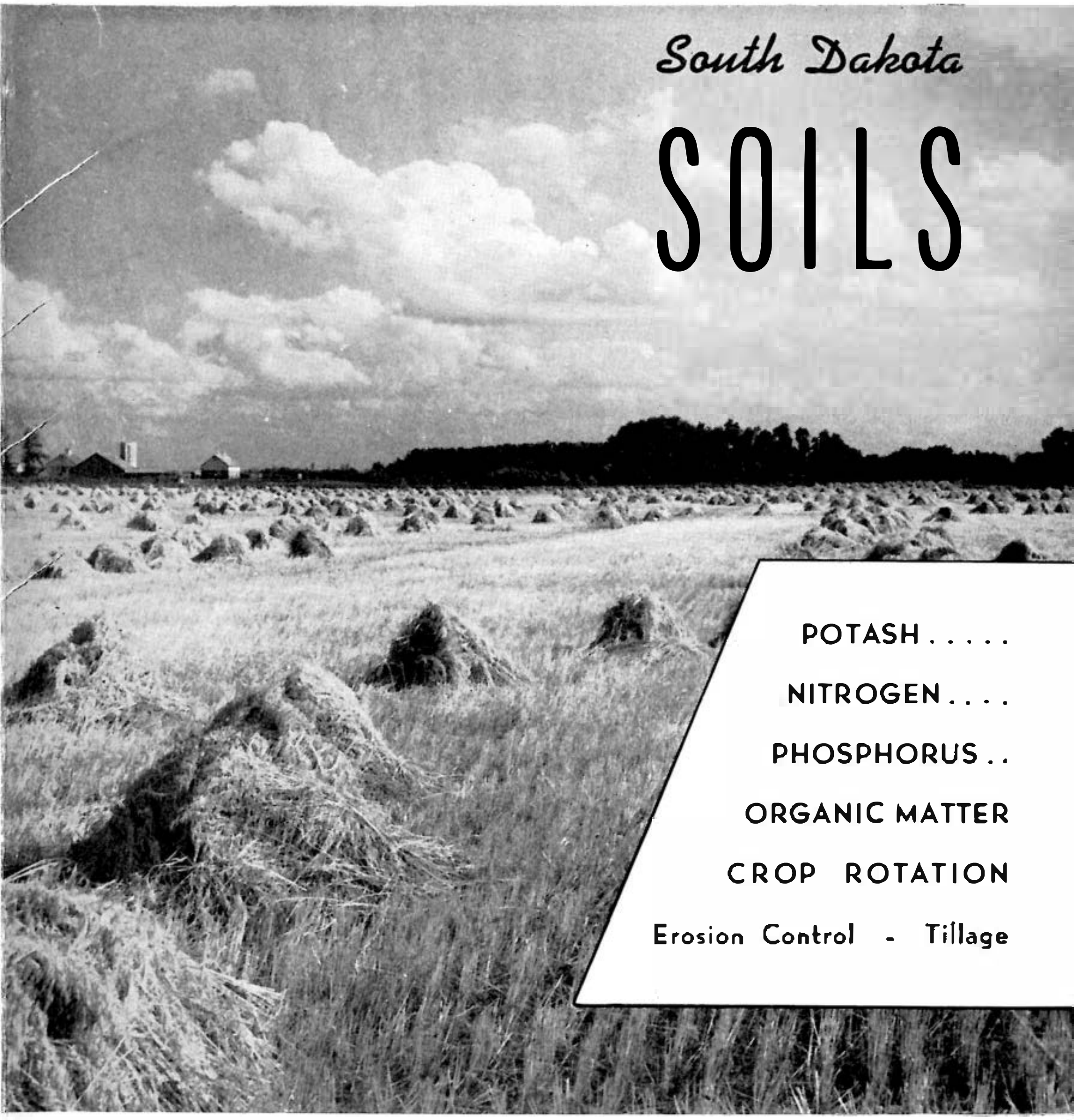

POTASH . . . . .
NITROGEN . . . .
PHOSPHORUS . .
ORGANIC MATTER
CROP ROTATION
Erosion Control - Tillage

S. Dak. Agricultural Experiment Station
AGRONOMY DEPARTMENT
SOUTH DAKOTA STATE COLLEGE ∴ BROOKINGS

Fertility Maintenance and Management of South Dakota Soils

By LEO F. PUHR *and* W. W. WORZELLA[1]

A successful and profitable agriculture must depend upon a sound and permanent system of soil management. A program of sound soil management is necessary to conserve our soil resources in order to insure present and future stability in agriculture. Changes in the soil which make it less suitable for crop production are gradual processes. Some of these changes are depletion of soil organic matter, appearance of nitrogen and other nutrient deficiencies, deterioration in soil structure, increased susceptability of the soil to wind and water erosion, failure of crops to grow and mature properly, and lower crop yields.

South Dakota soils are still relatively fertile but many of these signs of soil depletion are beginning to appear. These changes or signs of soil depletion must be recognized and measures adopted to restore and maintain the productivity of the soil.

Soil Formation

Soil is that more or less loose layer of material covering the land surface of the earth which is capable of supporting and nourishing plants. Soils are mixtures of particles of minerals, weathered rocks, organic matter, air, and water in varying proportions. The soil develops from the rocks, largely under the influence of climate and vegetation. The surface soil is the richest in organic matter, is darkest in color, has the greatest number of microorganisms, contains the greatest supply of soluble or available plant food and has the most favorable structure. The soil material below the surface layer is lighter in color, and different in physical properties largely because of the decrease in the amount of organic matter.

Many kinds of soil occur in South Dakota. The formation of different kinds or types of soil results from variations in the kinds of parent material, climate, vegetation relief, drainage and stage of development. Soil formation is a slow process. It has been estimated that it requires from 500 to 1000 years to produce an inch of top soil.

Soils are classified into groups called series according to color, depth of surface soil, character of subsoil, kind of parent material, slope, drainage and native vegetation. Soil series are given place names from the area in which they were first identified. For example, the Moody series was first identified in Moody county.

Soils derived largely from glacial drift are known as the Barnes soils (Fig. 1). The names Moody and Kranzburg are applied to soils developed from loess or wind deposited materials. Lamoure soils, derived from water deposited materials, occur in the bottom lands along streams. These are some of the important soils used for crop production in Eastern South Dakota.

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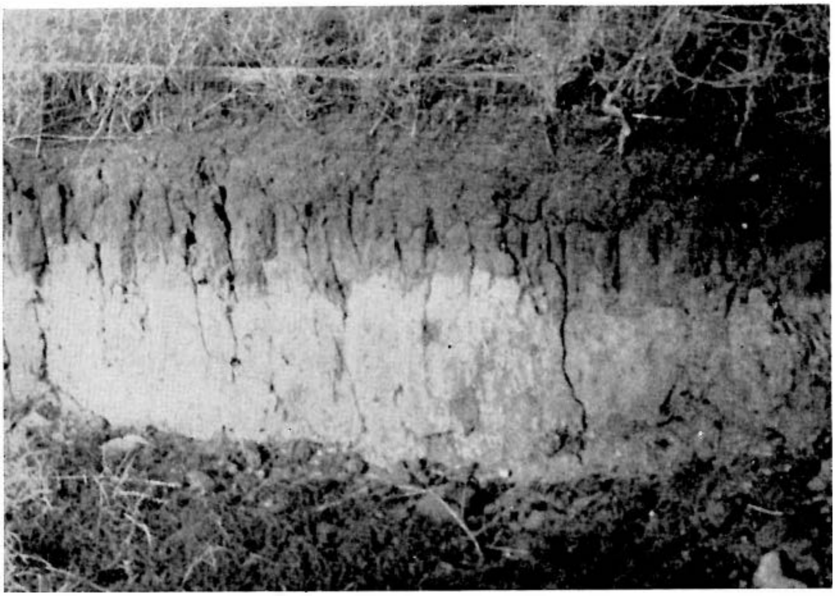

Figure 1. Photograph of a soil profile—Barnes loam. This soil occurs extensively in Eastern South Dakota.

Soil Texture

Soil is made up of various sizes of soil particles which is referred to as the texture of the soil. In order of their size beginning with the largest, the soil particles are designated as fine gravel, sands, silts and clays. Most soils are composed of a mixture of sands, silts, and clays in varying proportions. On the basis of which particle size predominates, soils may be classified into textural groups. Some of these groups are: sands, sandy loam, loam, silt loam and clay.

Many of the important physical properties of soil, including water holding capacity, resistance to erosion, drainage, and tilth, are influenced by the texture of the soil. Coarse texture soils have low water holding capacities, tend to be loose and friable and blow easily by the wind. The loams, silt loam and silty clay loams are considered the most favorable textural soil groups for general crop production.

Plant Food Elements

Certain elements are essential for the nutrition and growth of plants. Those elements are: carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, calcium, magnesium, iron, boron, manganese, copper and zinc.

Carbon, hydrogen, and oxygen are obtained by plants from the air and water, and, therefore, are not important from the standpoint of soil fertility. Of the other ten elements, only three, nitrogen, phosphorus and potassium, may be lacking in the soil. The other essential elements occur in South Dakota soils in such large quantities in proportion to the amounts required by crops that for the present their supply is not a matter of much concern in crop production.

Nitrogen, phosphorus and potassium are taken from the soil in large amounts by crops and are, therefore, of much importance from the standpoint of soil management. Because these elements occur in limited amounts in soil and are frequently the limiting factor in crop production, they are designated as the major or primary elements of plant food.

Nitrogen. Soil nitrogen is present only in the organic matter portion of the soil. Nitrogen occurs in unlimited quantities in the atmosphere but only legumes which have nitrogen fixing bacteria on their roots can make use of the nitrogen in the air. Since the soil organic matter serves as a store house for soil nitrogen, any system of soil management which does not provide for a return of organic matter to the soil will hasten the depletion of soil nitrogen. The average South Dakota soil has from 3000 to 6000 pounds of nitrogen in the plow layer of surface soil per acre. Only a small part of this nitrogen, approximately two percent, becomes available each year to crops. Soil bacteria slowly change the nitrogen in the organic matter to the soluble or available nitrate nitrogen which can be used by plants. The amount of total nitrogen in the soil decreases rapidly from the surface soil to the subsoil. The availability of the nitrogen in the subsurface soil is also much less than in the plowed layer.

The maintenance of an adequate supply of available* nitrogen in the soil is one of the most important soil fertility problems. The loss of nitrogen from the cultivated soils of South Dakota is a serious problem. This loss may be illustrated by referring to Figure 2.

The loss of soil nitrogen is largely the result of removal by crops, soil erosion and decay processes. Under the climatic conditions in South Dakota, crop removal is the important factor in the loss of nitrogen. For example, a 50 bushel crop of corn removes 80 pounds of nitrogen per acre. The decline of soil nitrogen is indicated by the soil changing from a dark to a lighter color. This change in color is due to the loss of organic matter with the associated decline of nitrogen. Certain plant symptoms indicate soil nitrogen deficiencies. Plants which are not getting sufficient nitrogen from the soil will be light green to yellow in appearance. The lower or older leaves will usually be first to show these symptoms. The rate of growth will be retarded and the size of the plant reduced also by a lack of nitrogen.

Phosphorus. Phosphorus occurs in soil in relatively small amounts. For this reason low crop production is frequently caused by a lack of available phosphorus. Phosphorus is essential for the nutrition of both plants and animals. It is present in seeds in larger amounts than in any other part of the plant. An adequate supply of available phosphorus stimulates the rate of growth of plants, hastens maturity, enables the plant to develop a strong root system, and increases the yield and quality of the grain. Lack of available phosphorus is indicated by stunted plant growth, delayed maturity, and low phosphorus content of plants.

Phosphorus is found largely in the mineral portion of the soil. In the process of soil development a considerable portion of the mineral phosphorus was absorbed by plants and is now stored in the soil organic matter. This is especially true for the surface layers of soil.

The total phosphorus content of South Dakota soils ranges from approximate-

*The term available refers to that part of the plant food which can be immediately used by plants. The unavailable plant food exists in compounds or materials which are not readily changed to a soluble or usable form.

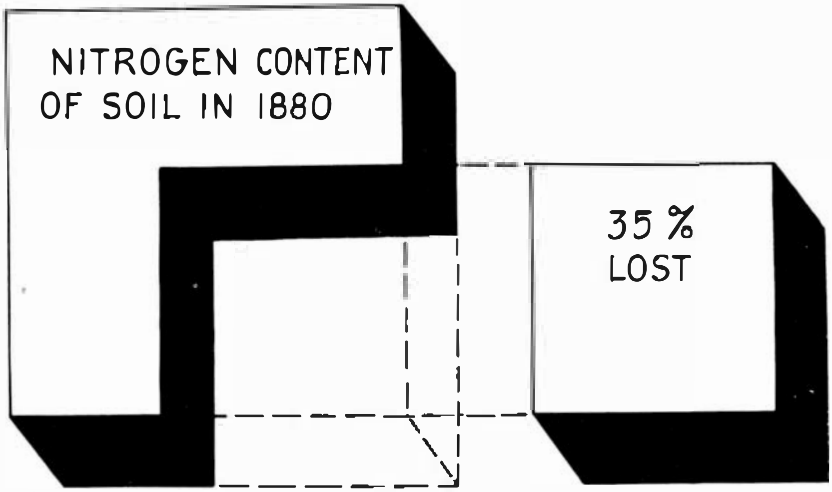

Figure 2. Loss of total nitrogen from the South Dakota soils in 65 years of farming.*

ly 1200 to 1600 pounds per acre in the surface soil to a depth of seven inches. The surface soil is usually higher in phosphorus than the underlying subsoil. This is due to the removal of phosphorus from the lower part of the soil by plant roots and concentrating the phosphorus in the plant residues on the surface soil. Under natural conditions as the decaying plant residues accumulate in the surface soil, the phosphorus content of this layer is increased.

There are two kinds of phosphorus in the soil from the standpoint of crop production: total and available. In a soil which contains 1400 pounds of total phosphorus approximately 50 pounds is available to growing crops in the surface soil. It can be readily seen that the available or usable portion of the soil phosphorus to plants is small in proportion to the total amount in the soil. The surface soil contains a much larger quantity of available phosphorus than the subsoil. This is due to the presence of organic matter and the chemical nature of the phosphorus compounds in this layer.

The depletion of phosphorus in the soil is largely the result of removal by crops. A fiftybushel crop of corn removes about 12 pounds of the element phosphorus. This is equal to 130 pounds of superphosphate fertilizer. The 12 pounds of phosphorus required to produce the corn crop would be taken only from the portion of the soil phosphorus which is in the available form.

There is a slow transfer of the total phosphorus in the soil to the available form. But under most cropping systems the available phosphorus is being depleted faster than it is replenished from the total supply. In other words, available phosphorus in soils decreases more rapidly than the total phosphorus.

The loss of phosphorus from the cultivated soils of South Dakota is shown by Figure 3.

*Data for this and following illustrations taken from South Dakota Experiment Station Bul. 314 and Technical Bulletin 4.

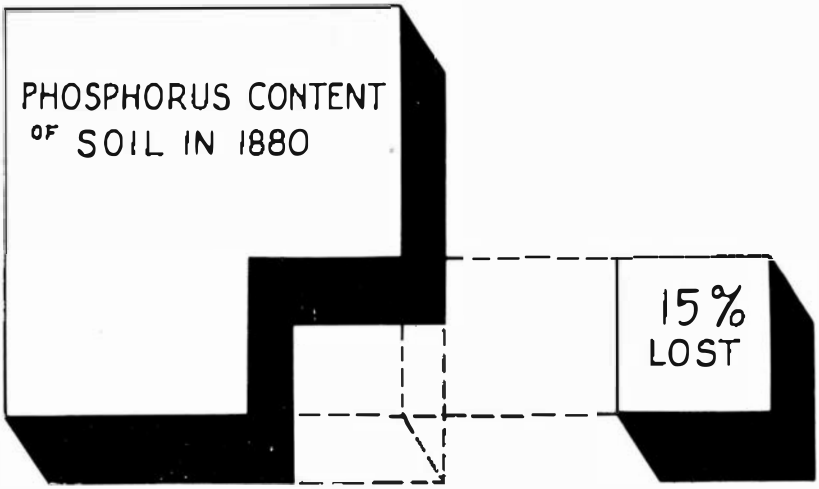

Figure 3. Loss of total phosphorus from South Dakota soils in 65 years of farming.

The portion of the soil phosphorus which has been lost due to crop removal represents that part which is most readily available to crops. The maintenance of an adequate supply of available phosphorus is essential for maximum crop production.

Potassium. South Dakota soils are well supplied with potassium. At the present time there seems to be sufficient available potassium for normal yields to meet the needs for general crop production for some time to come. Crops require large amounts of potassium. Potassium is found largely in the stems or leaves of plants. A fifty bushel crop of corn requires about 55 pounds of potash. About one-third is in the grain and about two-thirds in the stem or stover. It can, therefore, be observed that the return of the crop residues to the soil will be effective in conserving the supplies of available potassium in the soil.

Organic Matter

Organic matter is that portion of the soil which has been derived principally from accumulated plant material. This material in varying stages of decomposition ranges from the undecomposed plant materials to that which is in the advanced stages of decomposition in the soil. The portion which is in the advanced stages and gives the soil dark color is known as humus.

Because of the relationship between the organic matter of the soil and its productivity, this material has been called the life of the soil. The high productivity of virgin soils has been attributed to their high content of organic matter. The decrease in soil organic matter as the result of cultivation has been associated with a corresponding decrease in productivity.

Loss of organic matter from soils. The store of organic matter in soils represents the accumulation of decaying remains of plants over long periods of time. Soils developed under a grass vegetation accumulate the largest amounts of organic matter. Under natural conditions the accumulation of organic matter is the difference between additions through plant growth and decay by soil microorganisms. When soils are cultivated this natural balance is disturbed because less plant material is returned to the soil in the form of crop residues or manure.

The content of organic matter in dark soils ranges from 40 to 60 tons per acre in the surface soil to a depth of seven inches. From one half to three fourths tons of organic matter per acre is lost each year from most cultivated soils even though there is some addition each year from the roots of crops and stubble.

The effect of cultivation on the organic matter content of South Dakota soils is shown in Figure 4.

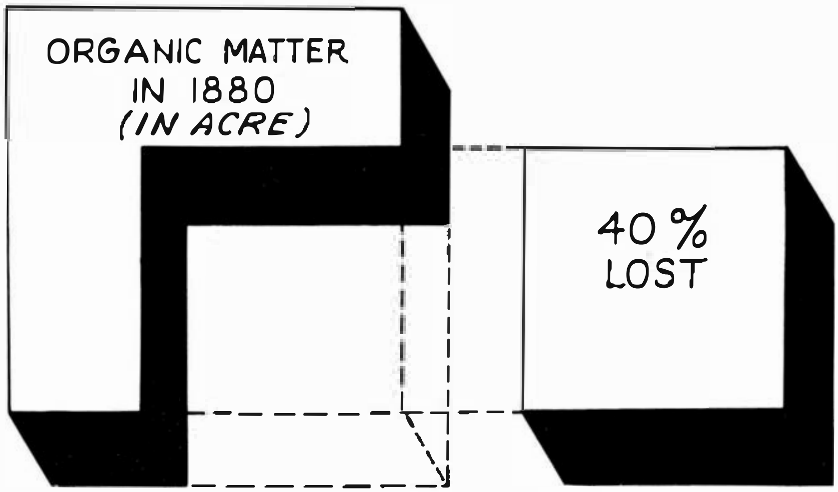

Figure 4. Loss total organic matter from South Dakota soils in 65 years of farming.

The cultivated soils of South Dakota have lost approximately 40 percent of their virgin content of organic matter. The organic matter which has been lost from the soil represents that portion which is most active or most easily decayed by soil microorganisms and, therefore, most beneficial to the soil. The remaining organic matter is less active and, therefore, not so valuable to the soil.

The depletion of soil organic matter with consequent reduced efficiency of the soil for crop production constitutes one of the most important soil management problems. Any system of permanent agriculture must maintain the organic matter in the soil.

The important functions of organic matter:

1. Organic matter improves the structure of the soil or the tilth. Soil tilth refers to the physical condition of the soil which affects the growth of plants. A soil in good tilth is easily cultivated, friable, permeable and the soil particles are arranged in granules or clusters. The regular addition of fresh organic matter increases the number, size and stability of the soil granules. A granular soil structure is most favorable for the development and extension of the root systems of plants.

2. Soil losses by erosion and loss of water for crop production are reduced by an adequate supply of soil organic matter. When rain falls on a soil containing a good supply of organic matter the soil can rapidly absorb the water because organic matter produces a coarsely aggregated structure having large pores or openings. This gives the soil a greater intake capacity for water. In addition, water distributes itself freely through a granulated soil. Actual measurements of the rate of intake of water by soils have shown in general higher rate of intake for those soils which have been so managed that they have an adequate supply of organic material.

Organic matter in the form of crop residues on the soil surface is very effective in preventing runoff of rain water because it prevents the soil surface from forming an impervious layer as the result of the impact of rain drops. For the control of wind erosion, organic matter is valuable because crop residues on the soil surface reduces the wind velocity at the soil surface and the organic matter which is mixed and decomposed in the soil, binds the soil particles into larger granules which resist movement by the wind.

3. From the standpoint of fertility, organic matter improves the soil by making plant food available and by serving as a store house for plant nutrient elements. The plant residues and manure which reach the soil carry nitrogen, phosphorus and potassium in organic forms. Organic matter provides food and energy for the bacteria in the soil. These organisms are capable of decomposing organic matter. This process of decay produces weak acids which attack the mineral portion of the soil, making available the plant food nutrients. The availability of the element phosphorus is particularly determined in this manner. The nitrogen in the soil organic matter is the only source of soil nitrogen for crops. The nitrogen in organic matter is converted by decomposition processes into the available nitrate form. This is accomplished by the soil microorganisms. The higher fertility of the dark colored soils is directly related to their contents of nitrogen and organic matter.

Maintenance of soil organic matter. The maintenance and restoration of soil organic matter is an important problem. The methods vary, depending upon the soil and climatic conditions. Since the value of organic matter to the soil is largely during the period in which it is undergoing decay, the soil should have a steady supply of new organic matter. All crop residues and manures should be returned to the soil. The practice of burning crop residues, including stubble, straw, and stalks, should be avoided. Crop rotations should be designed to provide for the maximum return of organic matter to the soil. Long time rotations which include grass or grass-legume mixtures are particularly valuable. A considerable amount of grass roots die each year and in this manner the soil organic matter is built up. A grass crop greatly improves the physical conditions of the soil for succeeding crops. When a legume is grown with the grass, nitrogen is added to the soil. The plowing under of legumes as a green manure crop is a recomended practice. For every ton of sweet clover plowed under approximately 50 pounds of nitrogen is added to the soil. The use of fertilizers, which increases crop growth and consequently makes possible the return to the soil of larger quantities of organic matter, may sometimes be advisable.

Methods of Maintaining Soil Fertility

The fertility of South Dakota soils may be improved and maintained by proper crop rotations which include grasses and legumes, maintenance of soil organic matter and nitrogen by the return of all possible crop residues to the soil, applications of manure derived from the feeding of crops to livestock, protecting the soil from fertility losses caused by erosion, proper use of land according to its capabilities, and the use of fertilizers.

The value of the various factors concerned in soil fertility maintaince are discussed separately in the following pages.

Crop rotations. From the fertility standpoint, crop rotations help to maintain the nitrogen and organic matter supply in the soil. In order to accomplish this, legumes and grasses must be included in the rotation. More effective use may be made of manures and fertilizers when applied to crops in a rotation. The physical condition of the soil is improved by growing crops with different types of root systems and through the addition of different amounts and kinds of organic matter to the soil. The rate of organic matter loss from soils is reduced by the proper crop sequence. A rotation which has a row crop too frequently in the rotation tends to deplete the soil very rapidly in organic matter and bring about a deterioration in soil structure.

In a rotation consisting of corn, grain and legumes, the rate of nitrogen and organic loss is balanced by the return of nitrogen and organic matter in the legume crop. From one fourth to one third of the crop land should be in legumes and grasses. The deep rooted plants such as clover and alfalfa grown in a rotation with shallow rooted crops improve the physical condition of the soil and subsoil. In contrast to the shallow rooted crops, the deep rooted crops withdraw plant food elements from the lower parts of the soil, which tends to prevent the exhaustion of available plant food in the surface soil. Row crops in the rotation conserve soil moisture through the accumulation and storage of water which is used by the succeeding crop of grain.

Crop rotations that keep the soil occupied with close growing crops such as the grasses and legumes reduce soil fertility losses caused by removal of the surface soil through erosion. It must be emphasized that crop rotation alone will not maintain fertility but must be supplemented by the use of manure and fertilizers.

Legumes. For the maintenance of soil fertility, the legumes (clovers and alfalfa) are the most valuable of all crops. Legume crops, when properly innoculated, can utilize nitrogen from the atmosphere. In this manner the nitrogen content of the soil is increased by plowing under a legume crop. The amount of nitrogen added by a legume depends upon yield of dry matter per acre and the stage of maturity. The earlier stage of growth of legumes is higher in nitrogen but the yield is lower. Legumes contain from 40 to 50 pounds of nitrogen per ton of hay or dry matter. An average crop of sweet clover averaging from one to three tons of dry matter per acre will gather from 50 to 100 pounds of nitrogen from the air per year. If the amount of nitrogen in the soil is increased by 100 pounds per acre by the plowing under of the sweet clover crop, it is equivalent to the application of 500 pounds of ammonium sulphate fertilizer. In addition, the legume crop adds fresh organic matter to the soil. This improves the physical condition of the soil and increases the availability of other plant food elements.

Grasses. Grasses help to maintain the supply of organic matter in the soil. Because grasses have a heavy yearly root growth and considerable portion of the root growth dies each year, there is a regular addition of organic matter to the soil from grass crops. Grass improves the structure of the soil, making it more porous, aids aeration and increases water absorption. A grass-legume mixture is particularly valuable for soil improvement because nitrogen as well as organic matter is added to the soil.

Crop residues. Crop residues have three important values. (1) They contain fertility or plant food, (2) supply organic matter to the soil and (3) protect the soil from erosion. A ton of straw has a fertilizing value almost equal to a ton of barnyard manure. A ton of straw contains approximately ten pounds of nitrogen, five pounds of phosphoric acid and 20 pounds of potash. The return of straw to the soil, either directly or in manure when fed to livestock, is an important factor in conserving the fertility of the soil and reducing organic matter losses.

Value of manure for maintaining soil fertility. The value of manure for maintaining soil fertility lies in the fact that it contains plant food, adds active organic matter, which improves the physical properties of soils, and contains certain organic constituents which may stimulate plant growth. Decomposing manure in the soil also tends to increase the availability of the mineral plant food in the soil. An average ton of barnyard manure contains ten pounds of nitrogen, five pounds of phosphoric acid and ten pounds of potash. About one half of the nitrogen, one fifth of the phosphoric acid and one half of the potash are readily available to plants. As the manure decomposes in the soil the rest of the plant food contained in the manure gradually becomes available. For this reason, the effects of the application of manure to soils may be evident for several years.

Fertilizers

Fertilizers are carriers of plant food in an available and concentrated form. The plant food elements, nitrogen, phosphorus and potassium, are the principal elements in commercial fertilizers. In fertilizers they are expressed chemically as nitrogen (N) phosphoric acid (P_2O_5) and potash (K_2O). These three elements may become deficient in soils because they are used heavily in crop production and occur in limited quantities in soils.

Phosphorus fertilizer materials. The principal phosphorus fertilizers are superphosphate and treble superphosphate. The phosphorus in these materials are readily available to crops. Superphosphate contains approximately 20 percent of available phosphoric acid and treble superphosphate contains approximately 43 percent available phosphoric acid. Rock phosphate, which does not contain any readily available phosphorus, is sometimes sold as a phosphate fertilizer. On South Dakota soils which are neutral to alkaline in reaction, the use of raw rock phosphate is not recommended.

Nitrogen fertilizer materials. The nitrogen fertilizer materials may be classified according to the manner in which the nitrogen is combined with other elements. Sodium nitrate or nitrate of soda has the nitrogen in the nitrate form. It contains 16 percent of available nitrogen. Ammonium sulphate contains nitrogen combined in the form of ammonia. Ammonium sulphate contains about 20 per cent available nitrogen. Ammonium nitrate contains nitrogen in both ammonia and nitrate forms. Ammonium nitrate contains approximately 32 percent available nitrogen. These are some of the common nitrogen fertilizers.

Potassium fertilizer materials. The principal potassium fertilizer is potassium chloride or muriate of potash. This material contains from 50 to 60 percent available potash (K_2O). All potash fertilizers contain their potash in a water soluble or available form.

Mixed fertilizer materials. The carriers of nitrogen, phosphorus and potash may be combined to form what is known as a mixed fertilizer. The composition or analysis of a mixed fertilizer is expressed by means of a formula such as 10-20-10. The first figure of the formula refers to the percent of available nitrogen, the second figure to the percent of available phosphoric acid and the third figure to the percent of available potash.

Field Trials with Fertilizers in South Dakota

Experimental procedure. During the past three seasons experiments were conducted throughout the state in order to study the effect of the application of plant food in the form of fertilizer on the yields of crops. Soil fertility plots were located in 15 counties. Plots were so distributed that the locations would be representative of the major crop and soil areas.

The plot was farmed in the same manner as the rest of the field, receiving no special cultural practices except the application of the fertilizer. The fertilizer applications and the samples of the crop taken for yield were made by members of the Experiment Station staff. From time to time during the growing season the plots were inspected to note the condition of the crop or any damage which may have occurred due to insects, hail or excessive water, etc.

Fertilizers and rate of application. The plant food was applied to the fertilizer test plots in the following forms: nitrogen in ammonium sulphate; phosphorus in treble superphosphate; and potash in muriate of potash. The rates per acre for the grain crops were 100 pounds ammonium sulphate, 100 pounds treble superphosphate and 50 pounds muriate of potash, respectively. For potatoes, the amount of phosphorus and potash were doubled. The same rates were used whether the fertilizer was applied alone or in combination.

Results from fertilizer tests. In Table 1 are presented the average yields for 1944, 1945 and 1946 for all crops from all locations.

Table 1. Average acre yields of crops from 1944-1946 following fertilizer treatments.

Treatments	Barley 2 Experiments	Oats 10 Experiments	Wheat 4 Experiments	Corn 15 Experiments	Potatoes 9 Experiments
None	35.4	46.7	25.3	52.0	154.7
Nitrogen	45.7	56.3	29.3	58.3	166.0
Phosphorus	44.0	51.2	29.5	60.1	210.0
Potash	43.6	50.2	28.5	56.0	184.1
Nitrogen-Phosphorus	52.6	64.8	31.3	61.2	218.0
Nitrogen-Phos.-Potash	55.3	72.6	32.0	63.3	225.0

Results for small grains. The small grain fertility plots were located in Clay, Day, Grant, Lincoln, McCook, Spink and Union counties.

Increases in the yields of small grain, as shown in Table 1, followed the application of fertilizer containing nitrogen and phosphorus. While either nitrogen or phosphorus alone increased the yield of small grain, the largest increases were ob-

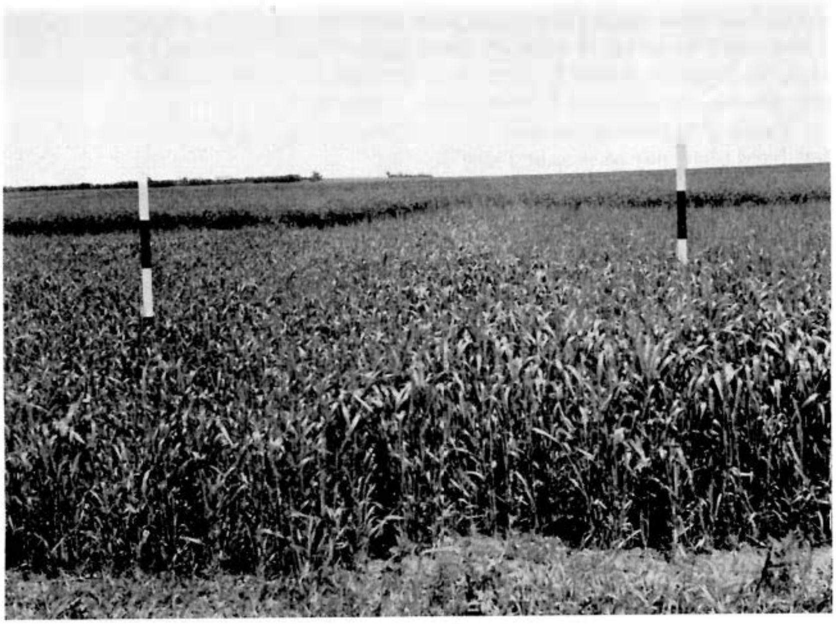

Figure 5. Effect of fertilizer on oats in Eastern South Dakota in 1945. Plot on left received no fertilizer and the plot on right received nitrogen and phosphorus.

tained when the two elements were applied together. In some instances, potash gave some increase in grain yield, but the data indicates that South Dakota soils are relatively well supplied with potash for small grain production. For the oats crop, the average increase in yield following nitrogen + phosphorus was 18.1 bushels and following nitrogen + phosphorus + potash, the increase is 25.9 bushels. The yield of barley was increased 17.2 bushels by a combination of nitrogen and phosphorus fertilizer.

The fertilizer trials for small grains were conducted on several different soil types having considerable variation in fertility. For this reason, the response to fertilizers varies in the different counties. The soils which were deep, dark and level gave the least response, while the shallower, lighter colored soils developed on rolling land gave the most response. For this reason, farmers must be guided by the condition of their soil in determining the kind and quantity of fertilizer to be used on the small grain crop.

Fertilizers for corn. The corn plots were located in Brookings, Clay, Grant, Lincoln, Moody and Union counties. The effect of fertilizer treatments on the yields of corn are given in Table 1. The largest increases in yield were obtained where the fertilizer treatment included nitrogen + phosphorus or nitrogen +

phosphorus + potash. The average increases in corn yields for all counties was 9.2 bushels for nitrogen + phosphorus and 11.3 for nitrogen + phosphorus + potash.

Fertilizers for potatoes. Potato plots were located in Clark, Codington and Hamlin counties. Data in Table 1 gives the results of fertilizer trials for potatoes. Each of the three major elements of plant food—nitrogen, phosphorus and potash—increased the yields of potatoes when applied alone or in combination. However, the largest increases in yield were obtained by combinations of nitrogen + phosphorus, and nitrogen + phosphorus + potash.

Yields of hay and grass seed. The yields of hay and grass seed from variously fertilized plots may be seen in Table 2.

Table 2. Average hay and grass yields in pounds per acre on Fertility plots (1944—1946)

Treatment	Hay yields (9 experiments)	Grass seed (6 experiment farms)*
None	1362	62
Nitrogen	1901	98
2 Nitrogen	2385	136
Nitrogen-Phosphorus	1958	115
2 Nitrogen-Phosphorus	2395	137

*On three experiments, no seed was obtained.

The grass fertility plots were located in Deuel, Brookings, Brown, Hand and Jackson counties. The application of nitrogen had the greatest effect on increasing hay and grass seed yields.

Methods of applying fertilizers for corn. In Table 3 are presented the results of various methods of applying fertilizer to the corn crop.

The amount and kind of fertilizer applied was the same for each treatment. The results of this test show that the placement of fertilizer in a narrow band in the plow sole with a fertilizer attachment on the plow is superior to all other methods. This method of application has the distinct advantage of placing the fertilizer where the soil is usually moist and where the plant roots may easily reach the fertilizer. The corn planter attachment which places the fertilizer close to the soil surface near each hill was found to be the least effective.

Table 3. Method of applying fertilizer for corn in Brookings County.

Method of Applying Fertilizer*	Average Yield Bushels/Acre 1945-1946
None	29.4
Broadcast on surface and disked in	36.0
Corn planter attachment	35.7
Broadcast on surface and plowed under	40.6
In plow furrow with plow attachment	41.4

*250 pounds of 10-12-6 analysis fertilizer per acre was used.

Effects of fertility treatments on the yields of corn under irrigation. In Table 4 are presented the effects of fertilizer treatments on the yield of corn grown under irrigation in 1946.

An examination of the dates in Table 4 shows that the most effective soil treatment for increasing the yield of corn under irrigation is a combination of complete fertilizer with manure.

Table 4. Corn yields on fertility plots under irrigation—1946.

Treatment*	Average Yield in Bushels Per Acre on 15% Moisture Basis
No treatment	56.8
Nitrogen	63.5
Phosphorus	54.3
Nitrogen-Phosphorus	61.0
Nitrogen-Phosphorus-Potash	68.2
½ NPK + ½ Manure	80.2
Manure	70.9

*Manure applied at the rate of 25 tons per acre. Ammonium sulphate 300 pounds, Treble superphosphate 200 pounds, and potash 100 pounds.

It is often necessary to level land before irrigation practices can be carried out. This process results in removing the surface soil and exposing the subsoil. The subsoil is lacking in nitrogen and available phosphorus. In Table 5 are presented the effects of various soil treatments on the yield of corn grown on subsoil under irrigation. The data indicates that soil treatments which return nitrogen and phosphorus, either in commercial fertilizer or manure, are very effective in increasing the yields of crops growing on the subsoil.

Table 5. Yield of corn under irrigation on subsoil in Lawrence County—1945.

Treatment*	Average Yield in Bushels Per Acre on 15% Moisture Basis
No treatment	6.7
Nitrogen	4.5
Nitrogen-Phosphorus	51.1
Nitrogen-Phosphorus-Potash	40.4
¾ NPK + ¼ Manure	45.2
½ NPK + ½ Manure	39.2
Manure	41.8

*Manure applied at the rate of 25 ton/acre, Ammonium sulphate 300 pounds, Treble superphosphate 200 pounds, and Potash 100 pounds.

Recommendations

Fertilizer rates. The following general recommendations for fertilizer are made for South Dakota.

Crops	Amount per acre	Analysis
Small grains	100 to 150 lbs.	10-20-0 or 10-10-0
Corn	100 to 200 lbs.	10-20-0 or 10-10-0
Hay and Pasture, and grass seeds	100 to 200 lbs.	20-0-0
Potatoes	200 to 300 lbs	4-24-12

The above recommendations are for loams and silt loam soils. On sandy soils the use of a complete fertilizer such as 10-10-5 or 10-10-10 is recommended for small grain and corn. For soils where the nitrogen content has been well maintained by manure and legumes, the use of treble superphosphate at the rate of approximately 100 pounds per acre is advisable.

On soils prepared by leveling for irrigation, heavy applications of fertilizer and manure must be used to produce a crop. About 200 to 400 pounds per acre of a complete fertilizer, containing a 10-10-5 analysis, plus manure and crop residues, are recommended.

Methods of applying fertilizers. A combination of fertilizer-grain drill or a broadcast fertilizer spreader is recommended for applying fertilizers to small grains or grass seedings. For corn, the placing of fertilizer in a narrow band in the plow sole has proven best. The corn planter attachment was found to be the least effective. For potatoes, the fertilizer attachment on the planter, or plow sole application with the attachments on the plow are recommended methods.

Summary

In conclusion, it should be emphasized that commercial fertilizers are not a substitute for other well established soil management practices. A complete program for the fertility management of South Dakota soils should include these practices.

★ Maintenance of soil organic matter by means of

Crop resides
Farm manure

★ Soil Nitrogen supply conserved and increased by

Crop residues
Farm manure
Legumes
Nitrogen fertilizers

★ Application of phosphorus to soils in superphosphate or other phosphate fertilizers

★ Maintenance of an adequate supply of available potash by means of

Farm manure and crop residues
Decay of organic matter
Potash fertilizer

★ Reduce soil fertility losses by the application of erosion control practices.