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Fertility Maintenance and Management of South Dakota Soils

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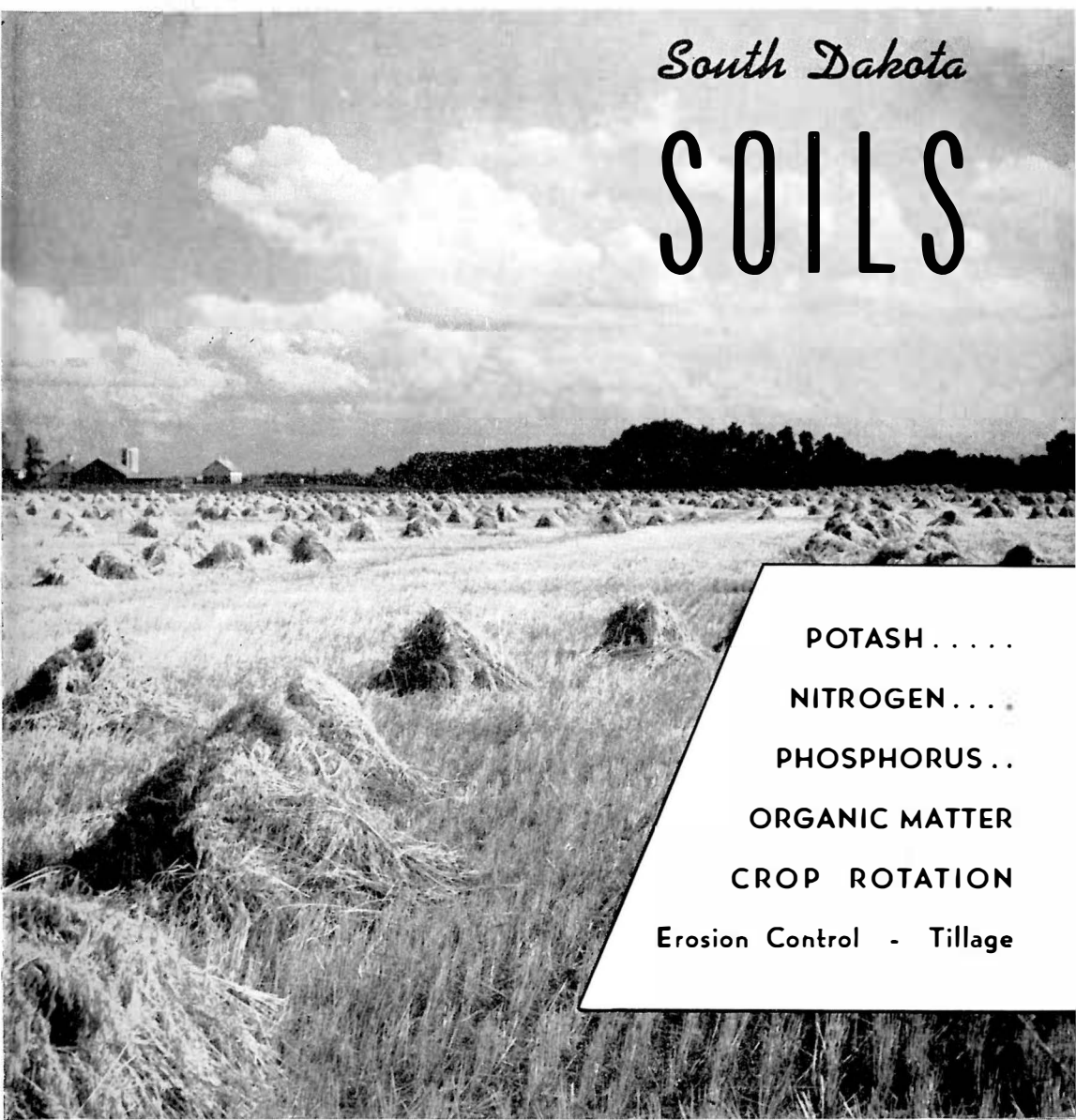
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fertility

MAINTENANCE and MANAGEMENT OF

South Dakota

SOILS



POTASH
NITROGEN
PHOSPHORUS
ORGANIC MATTER
CROP ROTATION
Erosion Control - Tillage

S. Dak. Agricultural Experiment Station

AGRONOMY DEPARTMENT

SOUTH DAKOTA STATE COLLEGE ❖ BROOKINGS

Table of Contents

Soil Formation	3
Soil Texture	4
Organic Matter and Plant Food Elements	5
Value of Organic Matter to the Soil	5
Plant Food Elements	5
Loss of Organic Matter and Nitrogen From Soils	10
Maintenance of Organic Matter	11
Management Practices	12
Crop Rotations	12
Manures and Crop Residues	16
Protecting the Soil From Erosion	17
Tillage Moisture Conservation	17
Fertilizers	17
Fertilizer Trials and Recommendations	18
Small Grains	18
Corn	21
Grasses and Legumes	22
Recommendations	23
A Program for Soil Management	24

Fertility Maintenance and Management of South Dakota Soils¹

By LEO F. PUHR and W. W. WORZELLA²

The soil is our most valuable natural resource. Under proper management the soil will last indefinitely, because its fertility and productivity will not only be maintained but may actually be increased.

Changes in the soil due to cropping which affect fertility and productivity are gradual processes. These are the cumulative effects of cropping on the soil:

- (1) Depletion of soil organic matter
- (2) Deterioration of soil structure or tilth
- (3) Appearance of nitrogen and phosphorus deficiencies in crops
- (4) Increased tendency of the soil to erode by wind and water
- (5) Failure of crops to grow and mature properly.

This bulletin, with its suggested management and maintenance practices, hopes to help the South Dakota farmer counteract these disastrous effects of cropping.

Soil Formation

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. Surface soil is richest in organic matter, is darkest in color, has the greatest number of microorganisms,³ 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 under natural conditions 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 vegeta-

¹This is a revision of Circular 68, bringing the soil fertility data up to date.

²Agronomists, South Dakota Agricultural Experiment Station.

³The term "microorganisms" includes bacteria, fungi, actinomyces, algae, and other microscopic forms of life found in the soil.



Fig. 1. A soil profile of Barnes loam. This soil occurs extensively in eastern South Dakota

tion. These 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.

Soil Texture

Soil is made up of various sizes of soil particles. 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, drainage and tilth, as well as resistance to erosion, are influenced by the texture of the soil. Coarse-textured soils have low water-holding capacities, tend to be loose and friable and are easily blown by the wind. The loams, silt loams and silty clay loams, are considered the most favorable textural soil groups for general crop production.

Organic Matter and Plant Food Elements

Organic matter is that portion of the soil which has been derived from the accumulation of plant materials. This material occurs in soils in varying stages of decomposition ranging from the undecomposed plant materials to that which is in the advanced stages of decomposition — forming humus. (Humus gives the dark color to soils.) Because of the relationship between the organic matter content of soils and its productivity, this material has been called the life of the soil. Soils of high productivity have a high content of organic matter. A decrease of soil organic matter as the result of cultivation, is always associated with a corresponding decrease in crop yields.

Value of Organic Matter to the Soil

From the physical standpoint, organic matter influences the structure or tilth of the soil. Tilth, in turn, determines the rate of infiltration of water, movement of soil moisture and air and the growth and extension of root systems of crops. The regular addition of all types of fresh organic matter to the soil improves the soil structure by increasing the number, size and stability of the soil granules.

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 surface from forming an impervious layer as the result of the impact of rain drops. For the control of wind erosion, organic matter is also valuable. Crop residues reduce the wind

velocity at the soil surface, and the organic matter which is mixed and decomposed in the soil binds the particles into larger granules which resist movement by the wind.

From the standpoint of crop production, one of the most important contributions of organic matter to the soil is that it serves as a storehouse for plant food elements. The crop residues and manure which reach the soil carry nitrogen, phosphorus and potassium in organic form. Organic matter also provides food for the soil microorganisms which decompose it. It is by this process of decomposition that plant food is released to the growing crops.

Plant Food Elements

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

Carbon, hydrogen and oxygen are obtained by plants from the air and water and are, therefore, not important from the standpoint of soil fertility. Of the other 11 elements, only three, nitrogen, phosphorus and potassium, may be lacking in the soil of South Dakota. As these three elements are taken from the soil in large amounts by crops, special consideration should be given to them in any management program. The other essential elements occur in South Dakota in

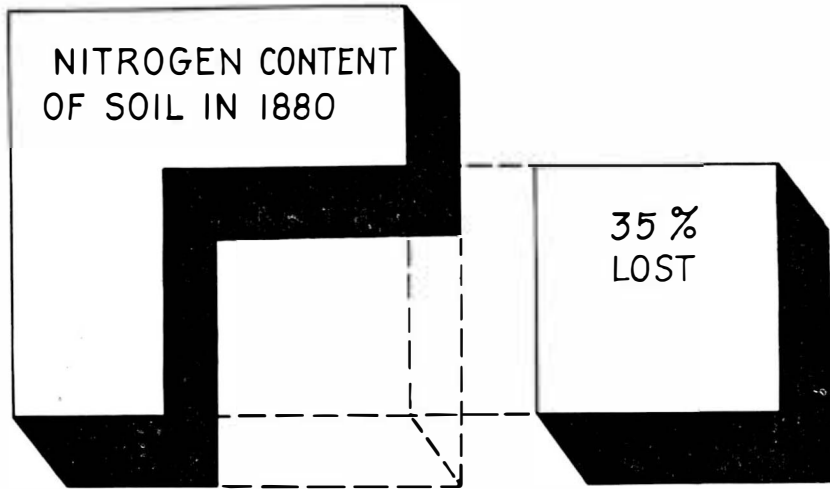


Fig. 2. Loss of total nitrogen from South Dakota soils in 65 years of farming

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. Soil nitrogen is stored in the organic matter portion of the soil. It 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 organic matter serves as a storehouse for nitrogen, any system of soil management which does not provide for a return of organic matter will hasten the depletion of soil nitrogen.

An average acre in South Dakota has from 3000 to 6000 pounds of nitrogen in the plow layer. Only a small part of this nitrogen, approximately 2 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. From surface soil to subsoil there is increasingly less total nitrogen. The availability of the nitrogen in the subsurface soil is also much less than that in the plowed layer.

Maintenance of an adequate supply of available¹ nitrogen is one of the most important soil fertility problems, and the loss of nitrogen from the cultivated soils of South Dakota is a serious matter. This loss is illustrated in Fig. 2.

Loss of soil nitrogen is largely the result of cropping and erosion. For example, a 50-bushel crop of corn removes 50 pounds of nitrogen per acre, and a 30-bushel wheat crop removes 75 pounds per acre (Figs. 3 and 4).

¹The term "available" refers to that part of the plant food which can immediately be used by plants. The unavailable plant food exists in compounds or materials which are not readily changed to a soluble or usable form.

TO PRODUCE 50 BUSHELS of CORN

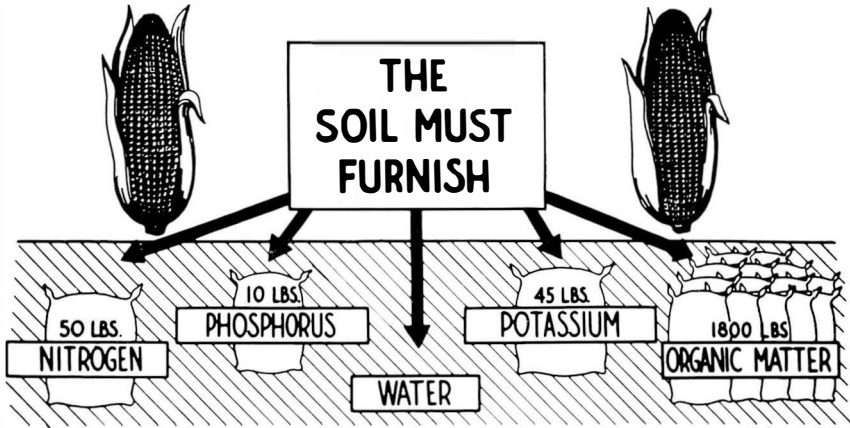


Fig. 3. Plant food required to produce 50 bushels of corn (grain only)

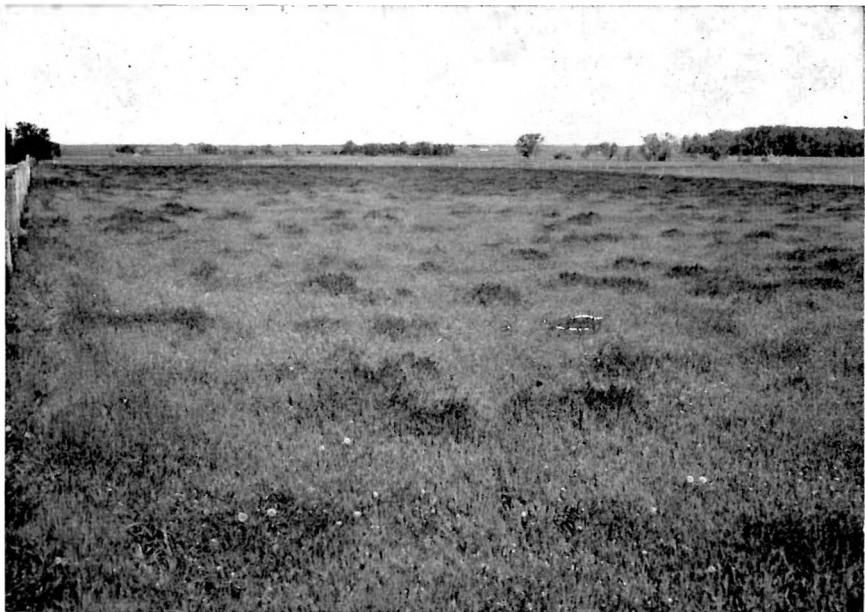


Fig. 4. Uneven appearance of growing crop due to lack of nitrogen

This decline of soil nitrogen is indicated by the soil changing from a dark to a lighter color, due to the loss of organic matter with the associated decline of nitrogen. Plants which are not getting sufficient nitrogen from the soil will be light green to yellow in appearance. The older or lower leaves will be the first to show these symptoms. Also the rate of growth will be retarded and the size of the plant reduced.

Phosphorus. Phosphorus, which is essential to the nutrition of plants as well as animals, occurs in soil in relatively small amounts. From the standpoint of crop production there are two kinds of phosphorus: total and available. In a soil which con-

tains 1400 pounds of total phosphorus, approximately 50 pounds or less may be available to growing crops in the surface soil. It can readily be seen that the available or usable portion of the soil phosphorus to plants is small in proportion to the total amount in the soil.

Lack of available phosphorus is frequently the cause of low crop production. It is indicated by stunted plant growth, delayed maturity and low phosphorus content of plants. Seeds store a larger amount of phosphorus than any other part of the plant. An adequate supply of available phosphorus, on the other hand, will stimulate the rate of growth of plants, hasten maturity, enable the plant to develop a strong

3 TONS OF ALFALFA

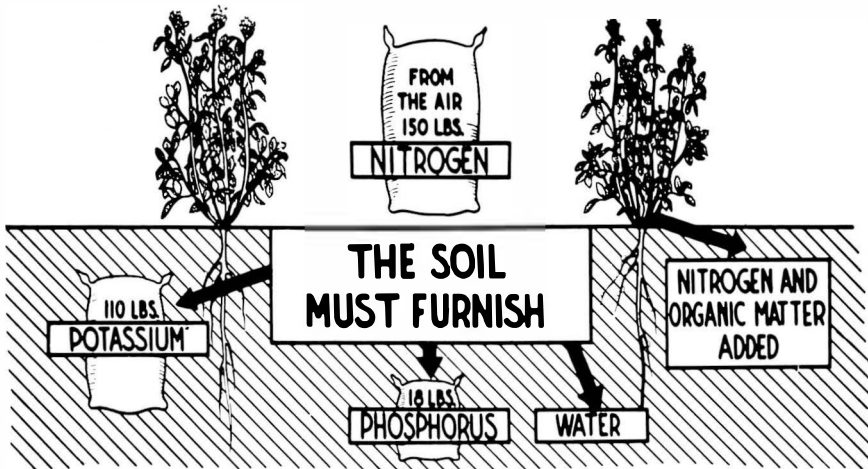


Fig. 5. The amount of plant food required to produce 3 tons of alfalfa hay

TO PRODUCE 30 BUSHEL OF WHEAT

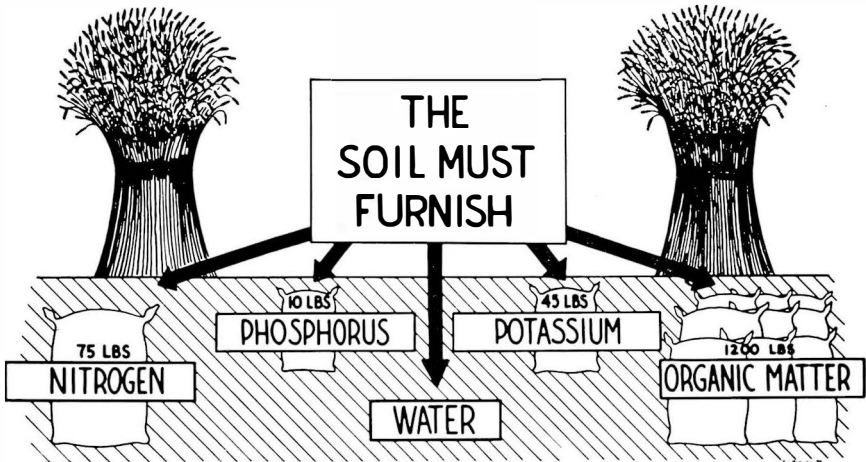


Fig. 6. The amount of plant food required to produce 30 bushels of wheat

root system and increase the yield and quality of the grain.

Phosphorus is found largely in the mineral portion of the soil. In the process of soil development a considerable amount of the mineral was absorbed by plants and is now stored in the soil organic matter. The surface soil is usually higher in phosphorus than the underlying subsoil, due to the removal of phosphorus from the lower part of the soil by plant roots and the concentration of it in 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.

The total phosphorus content of South Dakota soils ranges from approximately 1200 to 1600 pounds

per acre to a depth of seven inches.

Depletion of phosphorus in the soil is largely the result of removal by crops. A three-ton crop of alfalfa removes about 18 pounds of phosphorus (Figs. 5 and 6). This is equal to about 200 pounds of superphosphate fertilizer. The 18 pounds of phosphorus required to produce the alfalfa crop would be taken only from the portion 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.

Potassium. South Dakota soils are well supplied with potassium. Though crops require a large amount of it, there seems to be sufficient available potassium to meet the needs for general crop production for some time to come. A 50-bushel crop of corn requires about 45 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.

Loss of Organic Matter and Nitrogen From Soils

Normally, the soil maintains a natural balance between the accumulation of plant materials and the decay processes by soil microorganisms. When soils are cultivated, this natural balance is disturbed be-

cause much of the crop or plant growth is harvested and not returned to the soil in form of crop residues or manure. In addition, tillage increases the rate of decomposition by soil microorganisms and also causes losses by erosion.

The amount of organic matter in dark soils ranges from 40 to 60 tons per acre to a depth of seven inches. Approximately one-half to three-fourths of a ton of organic matter is lost each year from cultivated soils. In addition, the organic matter which has been lost from the soil represents that portion which is most easily decomposed by soil microorganisms and, therefore, most beneficial for crop production.

The average long-time effects of cultivation on the organic matter content of South Dakota soils is shown in Fig. 7. The present rate of decline of soil organic matter and nitrogen depends on the crop or

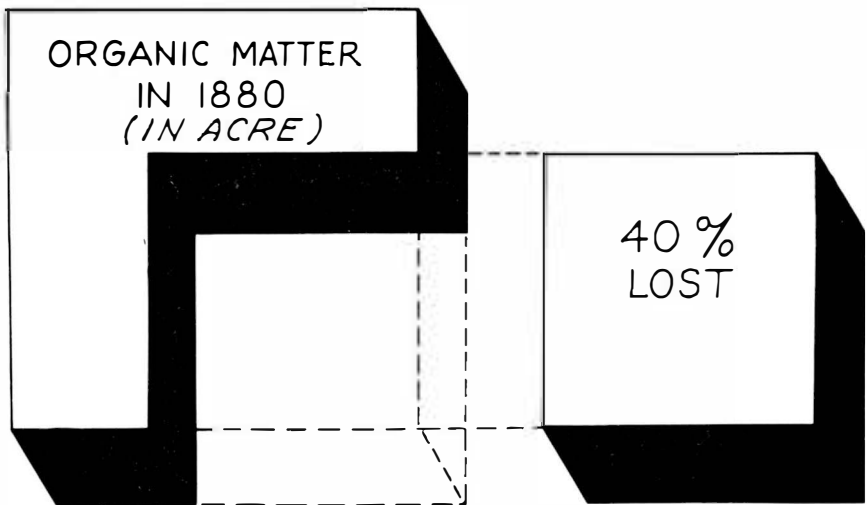


Fig. 7. Loss of total organic matter from South Dakota soils in 65 years of farming

crop rotation and on how much of the crop residue is returned to the soil as shown in Table 1.

Table 1. Changes in Nitrogen and Soil Organic Matter as Influenced by Crop Rotations for the Period, 1942—1950, Brookings

Crop Rotations	Nitrogen Loss Lbs./A. From Surface Soil*	Organic Matter Loss Lbs./A. From Surface Soil*
Continuous corn	880	15136
Continuous wheat	320	4206
Continuous oats	400	8620
Corn-oats-wheat rotation	540	8600
Corn-oats-wheat (straw returned to soil)	202	2940
Sweet clover-corn-wheat (sweet clover plowed under for green ma- nure, wheat straw removed)	300	7680
Bromegrass, 6 years (corn 1 yr., wheat 1 yr., hay and straw removed)	160	2940

*The soil analyses are an average for all plots.

It is evident that the continuous row crop, corn, caused a much greater loss of soil nitrogen and organic matter than continuous small grain. In a corn-oats-wheat rotation, the loss of soil nitrogen and organic matter was much reduced when the crop residues were returned, as compared to the same rotation when the residues were removed. Returning all the straw to the soil reduced the loss of nitrogen by 338 pounds and that of organic matter by 5660 pounds.

In the sweet clover-corn-wheat rotation, the nitrogen loss per acre of surface soil was 240 pounds less than for the corn-oats-wheat rotation during the same period. During the period of this study, three crops of wheat and two crops of

corn were grown on the sweet clover-corn-wheat rotation. Two crops of sweet clover were plowed under for green manure. On half the plots, this was done in June. On the other half of the plots in this rotation, the sweet clover was mowed in June, allowed to grow until August and then plowed under. The wheat straw was removed.

On the bromegrass plots, all of the hay was removed and one crop of corn and one of wheat was produced. Here a loss of only 160 pounds of nitrogen and 2940 pounds of organic matter was found during the 8-year period.

Maintenance of Soil Organic Matter

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, and the quality as well as the quantity should be considered. Organic matter high in nitrogen like that derived from legumes is more effective for building up soil organic matter than lower quality organic materials containing smaller amounts of nitrogen. A good organic matter program should include the following practices:

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. Rotations which include a legume or legume-grass mixture are particularly valuable. As much as



Fig. 8. Plowing under legumes restores soil organic matter and nitrogen

possible of the legume or legume-grass crop should be returned to the soil either directly or in manure. Plowing under sweet clover for a green manure crop has outstanding

value for adding nitrogen and organic matter to the soil (Fig. 8). For every ton of sweet clover plowed under, about 50 pounds of nitrogen is added to the soil.

Management Practices

Fertility and productivity of South Dakota soils may be improved and maintained by the application of certain basic practices. These practices include crop rotations, utilization of manures and crop residues, protecting the soil from erosion, proper tillage and moisture conservation and use of fertilizers. The application and the extent to which these practices are used may vary with the type of

farming, soil types, rainfall and cropping systems. Recommended practices for soil fertility, maintenance and conservation are discussed under their respective titles.

Crop Rotations

A good crop rotation is an essential part of a sound soil management program. There are many crop rotation systems, and the selection of a particular rotation will de-

pend upon the type of farming, soil, climate and adaptability of crops.

Desirable rotations preserve and restore soil structure or tilth, restore fertility, and increase soil productivity. A good rotation provides cash crops and forage, as well as pasture for livestock. Crop rotations that keep the soil occupied with close-growing crops such as grasses and legumes reduce soil fertility losses caused by removal of the surface soil by erosion. Row crops in the rotation control weeds and conserve soil moisture.

Good rotations should make the fullest use of legume and grass crops. For maintaining soil fertility, the legumes are the most valuable of all crops, as they supply the soil with nitrogen and organic matter. Deep-rooted plants such as clover and alfalfa improve the physical

condition of the soil and subsoil. These legumes 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 (Fig. 9).

Grasses have outstanding value for creating favorable structure or tilth in soils and for helping to maintain the supply of organic matter. Grasses have a heavy yearly root growth, and since a considerable portion of the root growth dies each year, there is a regular addition of organic matter to the soil. A grass-legume mixture is particularly valuable for soil improvement because nitrogen as well as organic matter is added to the soil.

Rotations should be flexible to meet specific needs and permit efficient use of labor. It is essential that the favorable place in a rotation be



Fig. 9. Legumes in a rotation increase crop yields. The oats yielded 95 bushels to the acre in the alfalfa-corn-oats rotation compared to a yield of 45 bushels to the acre in the corn-oats rotation

given the crop that will profit most by it. Under most conditions it is desirable to start all legume or legume-grass seedlings in a small grain. Since corn requires large amounts of nitrogen it should follow the legume crop. Sufficient pasture should be provided to take care of the livestock during the summer grazing period and during open weather in the winter.

Grasses such as brome and crested wheatgrass provide valuable early pasture. Alfalfa and grasses have a definite place in a rotation, but usually these crops are kept for a few years and then plowed under when the stand becomes thin. In the range areas, the need for soil-building crops or practices has not been so evident in the past; however, recent results indicate that fertility is becoming a greater factor in producing satisfactory yields. Most rotations will produce high yields only when adequate manure and fertilizers are applied.

Because of the varied climatic conditions and different soil types present in the state, many kinds of rotations are possible. Only a few desirable short-time and long-time rotations for the various areas are suggested as follows:

Corn Area

First Year: Corn
Second Year: Small grains plus clover
Third Year: Clover⁵
First Year: Corn
Second Year: Corn or soybeans
Third Year: Small grain plus clover
Fourth Year: Clover⁵

First Year: Corn
Second Year: Corn
Third Year: Small grain
Fourth Year: Alfalfa-brome (2 to 4 years)

First Year: Corn
Second Year: Small grain plus clover
Third Year: Corn
Fourth Year: Small grain plus clover
Fifth Year: Clover⁵

First Year: Corn
Second Year: Small grain plus clover
Third Year: Corn
Fourth Year: Small grain
Fifth Year: Alfalfa-brome (2 to 4 years)

Small Grain Area

First Year: Small grain
Second Year: Small grain plus sweet clover
Third Year: Row crop
First Year: Small grain
Second Year: Row crop
Third Year: Small grain plus sweet clover
Fourth Year: Sweet clover⁵

First Year: Row crop
Second Year: Small grain plus sweet clover plus rye (planted in fall)
Third Year: Clover and rye pasture
Fourth Year: Small grain plus sweet clover
Fifth Year: Sweet clover⁵

First Year: Small grain
Second Year: Row crop
Third Year: Small grain plus sweet clover
Fourth Year: Sweet clover⁵
Fifth Year: Small grain or row crop
First Year: Small grain
Second Year: Row crop
Third Year: Small grain
Fourth Year: Small grain or row crop
Fifth Year: Small grain
Sixth Year: Alfalfa-brome (2 to 6 years)

Range Area

First Year: Row crop
Second Year: Small grain plus sweet-clover
Third Year: Sweet clover-fallow

First Year: Row crop
Second Year: Small grain plus sweet-clover
Third Year: Sweet clover-fallow
Fourth Year: Small grain
First Year: Row crop or fallow
Second Year: Small grain
Third Year: Small grain
First Year: Row crop
Second Year: Small grain
Third Year: Row crop
Fourth Year: Small grain plus sweet-clover
Fifth Year: Sweet clover-fallow

⁵Refers to sweet or red clover for forage, pasture, green manure and seed.



Fig. 10. Plowing under straw is a good method for conserving soil organic matter

Manures and Crop Residues

As has been pointed out, 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 10 pounds of nitrogen, 5 pounds of phosphoric acid⁶ and 20 pounds of potash. The return of straw to the soil is an important factor in conserving the fertility of the soil and reducing organic matter losses (Fig. 10).

Manure 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. An average ton of barnyard manure contains 10 pounds of nitrogen, 5 pounds of phosphoric acid and 10 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 (Fig. 11).

⁶Phosphoric acid (P_2O_5) is frequently referred to as phosphorus or phosphate.



Fig. 11. Manure adds organic matter and plant food elements—nitrogen, phosphorus, and potash to the soil

Protecting the Soil From Erosion

Proper land use according to its capabilities is one of the basic considerations in reducing the hazards of soil erosion. The cropping systems should be so designed that the soil will have the greatest possible protection at all times. For example, on sloping land, row crops should not occur too frequently in the rotation.

The conservation of organic matter by returning all possible crop residues to the soil and a rotation which includes legumes and grasses are essential to a soil erosion control program. Where necessary for the control of water erosion, the use of grass waterways, contour farming and strip cropping are recommended practices. On some sloping land the use of terraces in conjunction with other erosion control practices may be necessary.

Conservation practices recommended for the control of wind erosion are: Tillage methods that leave a protective cover of crop residues on the surface, strip cropping, rough tillage and cultivation, and vegetative cover. Fall plowing should not be practiced on soils which are easily eroded by wind.

Tillage and Moisture Conservation

Proper tillage fulfills a number of requirements for good crop production. It prepares a suitable seed bed, mixes crop residues and manures with soil, controls weed growth and improves the physical condition of the soil. From the fertility standpoint, tillage creates favorable conditions for the development of soil bacteria which change the nitrogen

in the soil organic matter to the available nitrate form.

Types of tillage implements vary widely in their effect on the soil. The plow is the most effective implement to pulverize, loosen and to mix crop residues with the soil. The one-way disk plow and the subsurface tiller are also used. Crop residues are only partially mixed with the soil when a one-way disk plow is used, and are left largely on the surface with a subsurface tiller. The last two methods of tillage are especially effective for controlling rolling wind erosion. The type of tillage practice will vary, depending on climatic conditions, soil type and cropping systems.

The water supply available to crops may be conserved by reducing the amount run off. This may be accomplished by tillage practices, contour farming and use of crop residues on the surface, which enable the soil to readily absorb the rain. Control of weed growth is also a moisture-conserving practice.

Row crops in a rotation leave a reserve of moisture in the soil which is available to the succeeding small grain crop. Summer fallow is the most effective means for the storage and carry over of soil moisture from one year to the next. In South Dakota, summer-fallowed soils should always have a protective covering of crop residues to prevent soil erosion.

Fertilizers

Fertilizers are carriers of plant food in an available and concentrated form. The principal plant food elements in commercial fertilizers

are expressed chemically as nitrogen (N) phosphoric acid (P_2O_5) and potash (K_2O). Fertilizers are used to supplement the natural supplies of plant food in the soil and the plant food which is returned to the soil in crop residues and manures. They are most effective for increasing crop yields when used along with all of the good soil management practices.

Phosphorus fertilizer materials.

The principal phosphorus fertilizers are superphosphate and treble superphosphate. The phosphorus in these materials is readily available to crops. Superphosphate contains approximately 20 percent of available phosphoric acid and treble superphosphate contains approximately 43 percent of available phosphoric acid. Rock phosphate, which contains little readily available phosphorus, is sometimes sold as a phosphate fertilizer. On South Dakota soils, which are neutral to alkaline, 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, which contains nitrogen combined in the form of ammonia, contains about 20 percent available nitrogen. Ammonium nitrate contains approximately 32 percent available nitrogen. These are some 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. All potash fertilizers contain 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 16-20-0. 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 to available potash.

Fertilizer Trials and Recommendations

South Dakota soils have declined in fertility as the result of cultivation and crop production. For this reason the use of fertilizers on small grains, corn, legumes and grasses is a recommended practice. Fertilizer recommendations, result of fertilizer trials, and methods of application

will be taken up separately for the various types of crops.

Small Grains

Nitrogen deficiencies are more general and widespread in the soils of South Dakota than the phosphorus deficiencies. These deficiencies

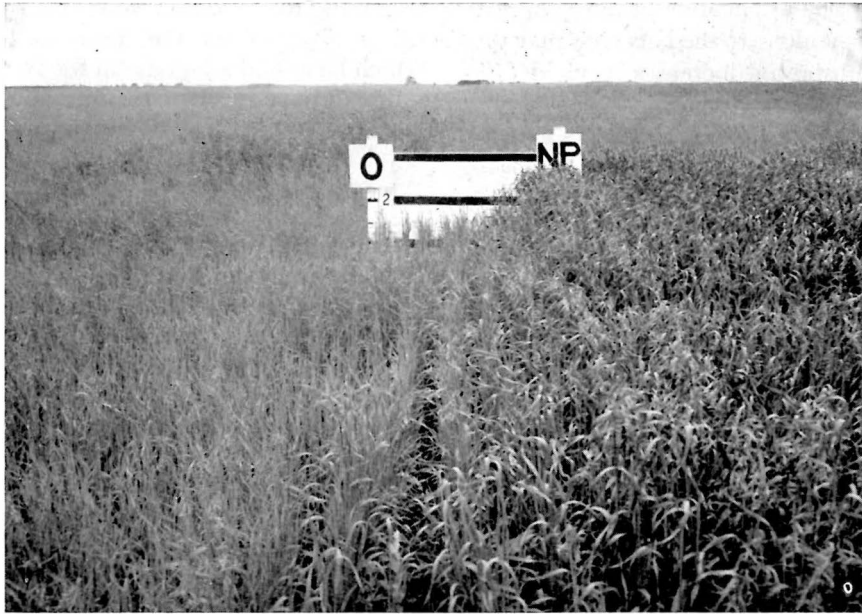


Fig. 12. Effect of fertilizer on oats, Moody County, 1951

are more common on soils which have had no legumes, or have had a considerable amount of row crops in the rotation and where little or no manure and crop residues have been returned. The effect of fertilizer treatment on oats, barley and wheat is presented in Tables 2, 3 and 4.

Table 2. Effect of Fertilizer Treatment on Yield of Oats, 1951

Treatment	Bon Homme County	Clay County	Lincoln County	Moody County
Lbs./A.*	Bu./A.	Bu./A.	Bu./A.	Bu./A.
None	52.5	36.7	42.3	33.5
20-0-0	68.5	69.4	69.0	49.8
0-40-0	49.1	39.7	43.3	39.8
20-40-0	74.2	64.0	73.3	59.2
40-40-0	84.0	77.5	91.7	71.7
60-40-0	80.0	69.7	86.7	66.0

*The first figure refers to the pounds of nitrogen; second, to pounds of phosphoric acid; and third, to pounds potash applied per acre.

Table 3. Effect of Fertilizer Treatments on the Yield of Barley

Treatment	Brookings County 1950	Davidson County 1951
Lbs./A.*	Bu./A.	Bu./A.
None	33.6	27.9
20-0-0	38.9	35.7
0-40-0	43.5	28.3
20-40-0	51.9	44.8
40-40-0	53.4	50.5
60-40-0	62.2	53.8

Table 4. Effect of Fertilizer Treatment on the Yield of Spring Wheat, 1951

Treatment	Hand Co.	Ed-munds Co.	Ly-man Co.	Sully Co.	Bea-dle Co.	Brown Co.	Spink Co.
Lbs./A.	Bu. /A.	Bu. /A.	Bu. /A.	Bu. /A.	Bu. /A.	Bu. /A.	Bu. /A.
None	7.8	11.5	11.2	14.4	12.7	32.1	22.7
20-0-0	9.3	16.8	11.7	18.4	17.5	41.3	29.1
0-40-0	8.3	12.5	15.7	15.8	14.2	35.0	25.8
20-40-0	12.5	18.4	18.1	18.1	25.6	46.7	29.6
40-40-0	17.5	18.7	17.2	21.0	27.9	44.0	29.6
60-40-0	20.8	22.9	19.8	23.2	31.5	52.1	27.8

The application of nitrogen fertilizer alone to the oats crop may give substantial increases in yield (Fig. 12). For barley and spring wheat, nitrogen fertilizer alone is generally not very effective for increasing yields. The highest yields of barley, oats and wheat will generally be obtained from fertilizer treatments containing both nitrogen and phosphorus.

A recommended rate of fertilizer application for small grains would be approximately 20 pounds of nitrogen and 20 pounds of phosphorus per acre. On soils of lower fertility and in the higher rainfall areas, a higher rate of application could be made.

Past soil management practices should be also used as a guide in de-

termining the kind and rates of fertilizer applications. On those soils which have had a legume in the rotation or have received manure, the need for nitrogen will be much less. A mixed fertilizer containing nitrogen and phosphorus is very desirable to use on small grains where the soil needs both. The 10-20-0 and 16-20-0 are desirable mixtures. Rates of application for these mixtures should correspond approximately to the recommended amounts of nitrogen and phosphorus per acre and the state of fertility of the soil.

Winter wheat and rye are very responsive to nitrogen fertilization (Fig. 13). On most soils the application of straight nitrogen fertilizer is sufficient. On these crops, nitrogen fertilizer should be applied at

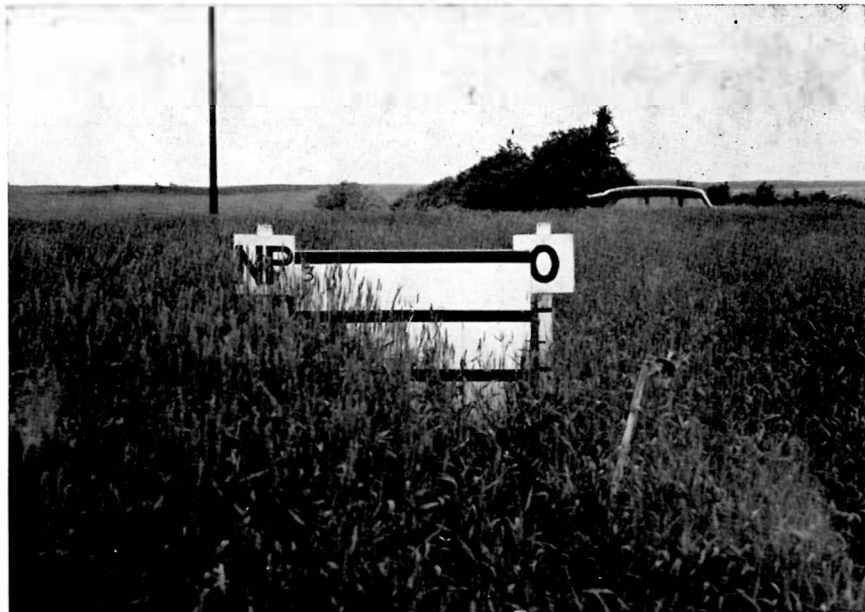


Fig. 13. Response of wheat to fertilizer treatment, Beadle County, 1951



Fig. 14. Fertility of soil was built up by adding nitrogen and phosphorus fertilizers. Corn on right was not fertilized

the rate of 25 to 40 pounds of nitrogen per acre, either in the fall or spring. This is equivalent to 80 to 125 pounds of ammonium nitrate per acre. Some soils need both nitrogen and phosphorus for wheat and rye. Winter grains may be fertilized with a mixed fertilizer such as 10-20-0 or 16-20-0 at the rate of 100 to 150 pounds per acre in the fall. Additional nitrogen may be applied in the spring as a top dressing.

A fertilizer attachment on the grain drill is the most efficient device for applying fertilizer to the small grain crop. The grain drill attachment places the fertilizer close to the seed without mixing too much with the soil. This method is especially valuable for the place-

ment of phosphate fertilizer or mixtures containing phosphates. Fertilizer may be applied also by broadcasting and then mixing with the soil by discing or harrowing before planting the small grain. Nitrogen fertilizer may be applied to winter wheat and rye as a top dressing by broadcasting early in the spring.

Corn

Nitrogen is commonly the deficient element for corn production since corn uses large quantities of it. Unless the nitrogen requirements of the corn crop have been supplied with a good rotation, including a legume or manure, nitrogen fertilizer will usually increase corn yields (Fig. 14). In Table 5 are presented

some yields of corn obtained under fertilizer treatment in 1950.

Table 5. The Effect of Fertilizer Treatment on the Yield of Corn (Fertilizer Plowed Under), 1950

Treatment	Lincoln County	Minnehaha County	Moody County
Lbs./A.*	Bu./A.	Bu./A.	Bu./A.
None	42.0	36.8	35.9
40-0-0	53.3	47.0	33.7
0-40-0	45.8	34.2	44.5
20-40-0	49.5	43.1	47.8
40-40-0	50.3	48.9	50.2

*The first figure refers to the pounds of nitrogen; second, to pounds of phosphoric acid; and third, to pounds potash applied per acre.

Table 6. The Effect of Fertilizer Treatment on the Yield of Corn, 1950 (Fertilizer applied at the time of the second cultivation)

Treatment	Lincoln County	Minnehaha County	Moody County
Lbs./A.*	Bu./A.	Bu./A.	Bu./A.
None	42.0	36.8	35.9
20-40-0	49.8	42.7	49.5
40-40-0	56.3	52.6	47.8

*The first figure refers to the pounds of nitrogen; second, to pounds of phosphoric acid; and third, to pounds potash applied per acre.

The results of the fertilizer trials indicate that corn yields are influenced most by the application of nitrogen. An application of a starter fertilizer containing nitrogen and phosphorus at planting time, using a fertilizer attachment on the corn planter, will stimulate the early growth of corn and hasten maturity.

Nitrogen fertilizer may be applied to corn by side-dressing with an attachment on the cultivator at the time of the second cultivation, or when the plants are 15 to 20 inches tall. Nitrogen fertilizer may also be applied by plowing it under. For the application of small quantities of fertilizer the corn planter attachment is satisfactory. Phosphate fer-

tilizer in mixtures containing nitrogen and phosphorus or nitrogen alone may also be applied by plowing under.

Grasses and Legumes

Grasses are very responsive to nitrogen fertilization (Fig. 15) and use of nitrogen on bromegrass for seed and forage production is a recommended practice. The results of fertilizing grasses are presented in Table 7.

Table 7. Effect of Nitrogen Fertilizer on Yield of Grass for Seed and Forage

Treatment	Lyman		
	Brookings County—1950		Co.—1951
	Seed Yield	Hay Yield†	Hay Yield‡
Lbs./A.*	Lbs./A.	Tons/A.	Tons/A.
None	243	1.2	.74
50-0-0	700	2.6	1.22
80-0-0	812	2.9	1.38
120-0-0	877	3.1	1.71

*The first figure refers to the pounds of nitrogen; second, to pounds of phosphoric acid; and third, to pounds potash applied per acre.

†Bromegrass

‡Crested wheatgrass

Results of experimental work on bromegrass indicate that the application of 40 to 60 pounds of nitrogen per acre per year is about the optimum fertilizer rate. Efficiency of the fertilizer for increasing seed and forage will also be influenced by the available soil moisture. Nitrogen fertilizer may be applied by broadcasting on grasses early in the spring or in the late fall after growth has ceased.

Clover and all other legumes are usually very responsive to phosphate fertilizer. For a new seeding of alfalfa the soil should be fertilized with phosphorus before planting (Fig. 16). This may be done by plowing the fertilizer under or

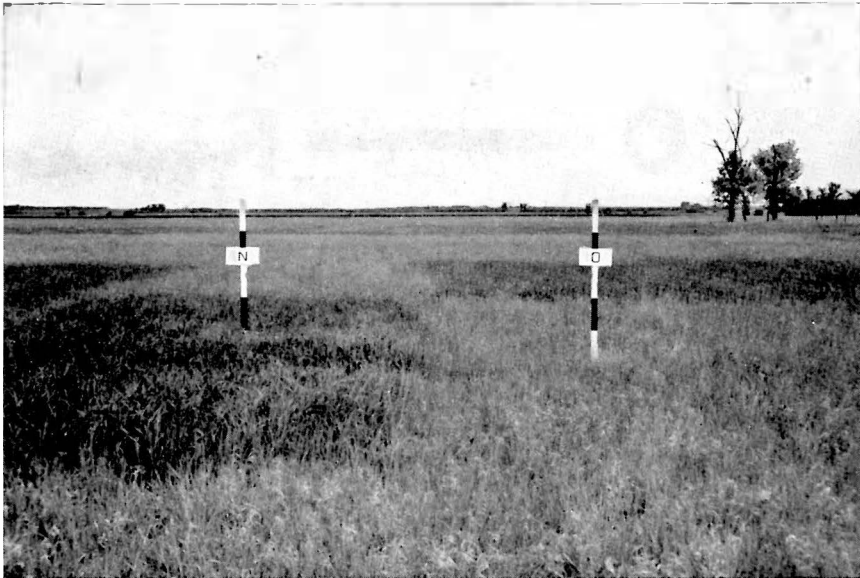


Fig. 19. Effect of nitrogen fertilizer on grass, Brookings, County, 1949

broadcasting on the surface and working lightly into the soil. After the alfalfa stand has been established, it may be fertilized by broadcasting the phosphate fertilizer on the surface in the spring just before, or at about the time, growth starts. Phosphate fertilizer may also be applied to alfalfa late in the fall. About 40 pounds of phosphoric acid should be applied yearly, or 80 pounds every two years, per acre to alfalfa and clover.

Recommendations

The following general recommendations for fertilizers are made for South Dakota. The amounts will

vary from place to place depending upon the fertility of the soil and rainfall. The lower amounts of fertilizer are suggested for the less humid areas.

Table 8. Recommended Amounts of Fertilizers

Crops	Amount Per Acre	Fertilizer Grade
Small grain	100 to 150 lbs.	10-20-0
		16-20-0
		33-0-0
Corn	100 to 200 lbs.	10-20-0
		16-20-0
		33-0-0
Alfalfa or other legumes	100 to 200 lbs.	0-43-0
		0-20-0
Grasses for forage, pasture, hay and seed ..	100 to 150 lbs.	33-0-0
		16-20-0
Potatoes	100 to 200 lbs.	0-43-0
		0-20-0

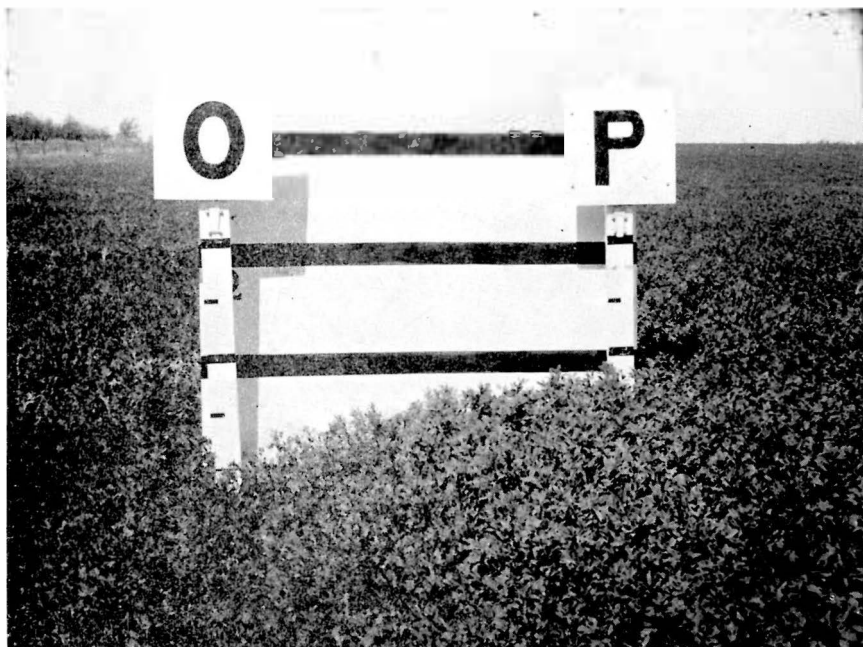


Fig. 16. Alfalfa needs an abundant supply of phosphorus. The first cutting of this field yielded 2.7 tons of hay per acre where phosphate fertilizer was applied and 1.1 tons per acre where no fertilizer was used

A Program for Soil Management

A complete program for the management of South Dakota soils should include these practices:

1. Use a good crop rotation, including a legume or a legume-grass. A good rotation is the foundation of a sound soil fertility and soil building program.

2. Maintain a balance between soil depleting crops (corn and small grains) and soil conserving crops (legumes and grasses) in the rotation.

3. Maintain soil organic matter by legume and grass-legume rotations and by the return of all crop residues and manure to the soil. Do not burn straw or grain stubble. Soil

organic matter is essential for high productivity.

4. Apply phosphate fertilizer on legumes, nitrogen on grasses, and nitrogen and phosphorus on small grains and corn. The amount of fertilizer used will depend on climatic conditions of area and the present state of soil fertility, as well as the past crops and soil management practices.

5. Protect the soil from water and wind erosion by good conservation practices.

6. Use sound cultural practices, including use of adapted crop varieties, proper tillage and moisture conservation.