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# Irrigated Crop Rotations on the Clay Soils of Western South Dakota

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CIRCULAR 83 ✦ DECEMBER 1950

**IRRIGATED CROP**

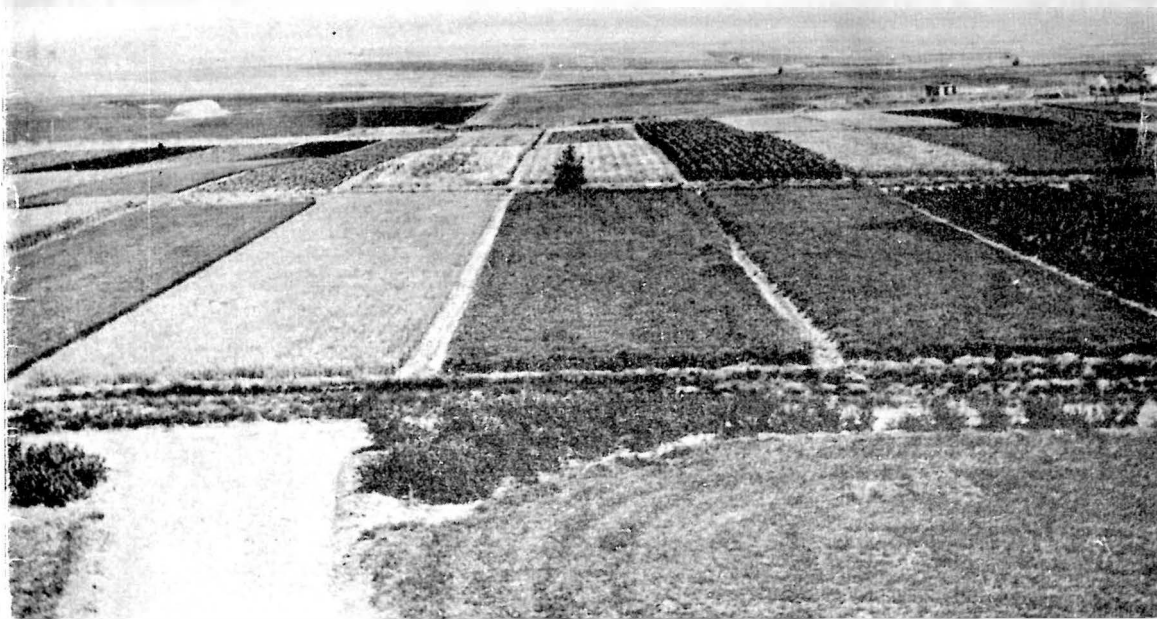
*Rotations*

ON THE CLAY SOILS

OF WESTERN SOUTH DAKOTA

BUREAU OF PLANT INDUSTRY, SOILS AND  
AGRICULTURAL ENGINEERING · SOUTH  
DAKOTA STATE COLLEGE EXPERIMENT  
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**Cover: 38 Years of Irrigated Crop Rotations And Their Management On The Clay  
Soils In The Belle Fourche Irrigation Project At The  
U. S. Belle Fourche Field Station**

# Irrigated Crop Rotations on the Clay Soils of Western South Dakota<sup>1</sup>

HARRY E. WEAKLY and L. B. NELSON<sup>2</sup>

Soil management and crop production present many problems on the irrigated farms of western South Dakota. The farmer on the clay soils has a particularly vicious set of these. That the seriousness of these problems was recognized early is evidenced by the establishment of research on the irrigated clay soils at the United States Belle Fourche Field Station in 1912. During the past 38 years much valuable information has been gained. Whether this information is yet suf-

ficient to guide the development of a profitable and stable agriculture on the clay soils is still questionable. However, it is believed that the information gained may be of considerable help. New work on many of the more pressing unsolved problems is now underway.

It is the purpose of this circular to present the more important findings<sup>3</sup> as they apply to the irrigated clay soils of the region.

## Objectives of Rotation Studies

The United States Belle Fourche Field Station has investigated the crop and soil problems of the irrigated clay soils by means of long-time crop rotation studies. In these studies, various rotations or sequences of crops with various manuring and pasturing practices have been evaluated by their effect upon yields and, to some extent, upon the chemical and physical properties of the soil. In addition, much other information has been gained. This information includes complete weather records, observations on adaptability of various crops, irrigation and cultural practices, and incidence of plant diseases and insects as they affect the growth of crops.

The original objectives of the rotation studies at the time they were started in 1912 were as follows:

1. To obtain information useful to farmers engaged in crop production on the Belle Fourche Irrigation Project and other irrigated areas where the soil and climatic conditions were comparable.
2. To compare yields of crops grown continuously with crops grown in rotations of two, three, four, and six years duration.
3. To determine the effect of alfalfa upon other crops in the rotation.
4. To determine how effectively crop yields may be maintained or improved by applications of manure.
5. To determine the extent that crop yields may be improved by pasturing alfalfa and harvesting the corn crop with livestock.

<sup>1</sup>Prepared for publication by the South Dakota Agricultural Experiment Station as a cooperative enterprise.

<sup>2</sup>Superintendent and Associate Agronomist, and Agent (Soil Scientist) respectively.

<sup>3</sup>Detailed results are being prepared for publication as a U. S. Technical Bulletin.

6. To evaluate sweet clover and red clover as substitutes for alfalfa.

Since the Belle Fourche irrigated rotations were started, 21 continuous cropping systems, 13 two-year, 8 three-year, 7 four-year, and 8 six-year rotations have been studied.

No attempt will be made here to list all of the rotations studied. Examples of some of the more important are as follows:

Continuous Cropping

Corn

Oats

Alfalfa

Sugar beets

Two- and three-year rotations

Corn-oats

Oats-sugar beets

Corn-oats-sugar beets

Corn-barley (seeded with sweet clover and pastured)-sweet clover

Four- and six-year rotation

Oats-sugar beets-alfalfa-alfalfa

Barley (seeded with sweet clover)-sweet clover-sugar beets- sugar beets

Corn-oats-sugar beets-alfalfa-alfalfa-alfalfa

Potatoes-oats-sugar beets-alfalfa-alfalfa-alfalfa

In many instances, a duplicate rotation was conducted in which barnyard manure was applied. The plan for applying manure was this: In a

continuous cropping rotation, 12 tons of manure per acre were applied every year; in two-year rotations, 12 tons were applied every second year; in three-year rotations, 12 tons every third year; in four-year rotations, 12 tons every fourth year; and in six-year rotations, 12 tons per acre were applied every sixth year.

In the experiment, each rotation is represented by as many one-fourth acre plots as there are years in the rotation. That is, each crop in the rotation is grown each year such as is generally done by the farmer. The entire experimental area occupies 131 one-fourth acre plots. The same variety for each crop was grown on all rotations for any particular year. Cultural treatments between rotations were kept as nearly the same as conditions at the time would permit. However, changes were made from year to year when improvements in crop varieties, tillage methods, and irrigation practices were clearly desirable.

In addition to the above, a series of maximum production rotations were started in 1920 and continued to 1948 for the purpose of determining the maximum crop yields that could be produced on the clay soil. Here the best known cultural, cropping, and management practices were incorporated.

## **The Climate as it Affects Irrigated Farming**

The irrigation farmer naturally is less concerned with weather than the dryland farmer. However, the importance played by the weather should not be underestimated. Precipitation greatly influences the irrigation farmer since it modifies and in-

fluences his irrigation schedules, and sets pitfalls which may materially influence his crop yields. Winds, temperature, and evaporation are also factors that must be considered. For example, drought damage is most severe during windy days of high

temperatures and low humidity occurring when the moisture content of the soil is low. Keeping the soil moist minimizes such damage. Another weather factor of great importance is the length of the frost-free period. This period largely determines the crops and crop varieties that may be grown successfully in a particular region.

Inasmuch as detailed weather data obtained over a 40-year period at the Station will be presented in the forthcoming USDA Technical Bulletin, only some of the more pertinent general observations will be presented.

**Precipitation:** Adequate precipitation reduces the number of irrigations required, but light rains often create a false idea of the quantity of water in the soil. Such rains and accompanying cooler weather may maintain a crop in apparently good growing condition even though the soil moisture is approaching depletion. A sudden change to hot weather may cause crop damage before irrigation water can be applied. This is particularly true for a crop like alfalfa whose daily rate of water use is high.

Weather data at the station show an average annual precipitation of 16.10 inches of which approximately 77 percent is received during the April to September growing season. The annual precipitation varies greatly, ranging from a low of 6.64 inches in 1911 to a high of 28.21 inches in 1946. June, the critical month in the development of small grains, has been the wettest month of the year with an average of 3.01 inches. Rainfall during June also appears to be the most dependable. May follows June as a close second

with an average of 2.77 inches. Next high months are July with 2.15 inches and April with 1.77 inches. Drought may occur at any time during the year, and monthly precipitation varies widely from season to season. For example, precipitation in May ranged from 0.05 to 8.35 inches and in June from 0.29 to 6.07 inches.

Rains usually are slow and steady early in the spring until early in May and there is not much loss from runoff. They become heavier in midsummer. Many of the rains occur in amounts less than 0.5 inch and, because of evaporation, are of little benefit to crops when received during the middle of the growing season, but may be of value earlier in the spring for germination of seed and softening of soil crusts. Precipitation in the fall may influence the amount of water in the soil. This was strikingly illustrated in 1924, 1925, 1930 and 1947 when heavy rains in the preceding fall months built up substantial moisture reserves. Snowfall and winter rains appear to have little influence upon irrigation requirements. The amounts generally are too light to be of value, and when heavy snow does occur, high winds usually remove it from cultivated fields.

Irrigation needs vary greatly depending on the rainfall, but one can be misled by light rains. They do not remove the need for irrigating.

**Evaporation:** The amount of evaporation affects the amount of rainfall entering the feeding zone of the plant roots. Thus, during periods of high evaporation, light rains become very ineffective. Losses of water from the growing plant also are higher during

periods of high evaporation.

Although evaporation in western South Dakota is fairly high, it is not excessive except during certain days. The average evaporation from April through September from a free water surface is 35 inches. July, the month of greatest evaporation, averages 7.8 inches. June and August are also high months. Evaporation usually is not excessively high for more than 3 or 4 days consecutively.

**Wind Movement:** April and May are the months of highest wind velocities, averaging 7.3 and 6.5 miles per hour, respectively, during the 40-year period. July and August fortunately are the lowest with 4.4 and 4.2 miles per hour, respectively. Daily wind velocities of over 20 miles per hour have been recorded every month of the year except July and August.

High winds usually occur at intervals during the winter and spring months. They may prevail for 3 or 4 days but usually not more than a day. Mellowing of the heavy clay soil during the winter frequently permits drifting of soil, particularly during March, April, and May.

**Temperature:** Summers are generally mild with relatively few days with temperatures of 100° F or over. Winters are long and cold with temperatures sometimes falling to -30° F or lower. Temperatures of 32° F or lower have been recorded at least once for all months of the year except July. The annual mean average is 45° F and the seasonal mean temperature (April through September) is 60° F.

**Frost-Free Period:** The average frost-free period is 139 days, and ranged from 108 days in 1947 to 171 days in 1922. On the average, the last frost in the spring is May 11 and the first frost in the fall is September 27. The average 139-day frost-free period precludes the maturing of any but the earlier varieties of corn and sorghums, but is generally sufficient to permit the maturing of small grains and sugar beets, and permits the production of at least two good cuttings of alfalfa hay or one cutting of hay and a seed crop. In the shorter seasons, corn is frequently reduced in both yield and quality from frost damage before maturity is attained.

## The Soil

The soil on the United States Belle Fourche Field Station and much of the adjacent area is classified as Pierre clay. It is a soil developed from the Pierre shale that underlies most of the region. It usually extends to a depth of 6 or 7 feet, but may grade into decomposed shale as shallow as 3.5 feet. Soil samples from the upper 24 inches at the Station contained about 54 percent clay, 37 percent silt, and 9 percent sand

and fine gravel. These samples contained some but not excessive amounts of salts. Sodium, while present, was not present in sufficient amounts to cause an alkali problem. The soil is calcareous, containing calcium and magnesium carbonates.

This soil is extremely sticky and plastic when wet and must dry a longer time than coarser-textured soils before it can be worked satisfactorily. If

the soil is worked when too moist, tractors or other heavy equipment may pack it so firmly that it adversely affects crops, or the soil may turn up into lumps that dry and form hard clods. Land which is fall-worked when dry turns up large clods, but these usually break down over winter and little cultivation is required to prepare a good seed bed in the spring.

On a dry soil, water penetrates rapidly to a depth of 2 feet because of the cracked condition near the surface.<sup>1</sup> After this layer becomes wet, it swells and becomes nearly impervious and

<sup>1</sup>O. R. Matthews, "Water Penetration in the Gumbo Soils of the Belle Fourche Reclamation Project." *USDA Bulletin No. 447*, 1916.

further water intake is very slow. The depth of root penetration is less than on more pervious soils. Thus, water applications must be more frequent than on soils where water and roots penetrate to greater depths.

The Pierre clay by no means occupies the major portion of the Belle Fourche project. Another clay soil, the Orman clay, derived from clay laid down in a large body of water, occupies level areas in the Indian and Owl creek flats. This soil presents serious problems to farmers due to its lack of adequate drainage. Loams, fine sandy loams, and other coarser textured soils occur mostly near the streams.

## Results

### Rotations Alone Won't Maintain Yields

One of the most important lessons learned from the rotation experiments is this: Good yields can be maintained on the clay soils only when a good legume rotation is combined with adequate manuring and fertilizing. One won't work without the other.

A legume such as alfalfa is necessary to build up the nitrogen supply of the soil and to keep the soil in good physical condition. Manure is needed to add plant nutrients, particularly nitrogen and phosphate, and to help add to the soil organic matter. Even then, additional phosphate fertilizer probably will be needed since manure does not contain much phosphorus.

The above is strikingly illustrated by the graph in Fig. 1. In this graph, oat yields from four rotations are plotted. Oat yields from manured and unmanured six-year rotations, consisting

of potatoes-oats-sugar beets-alfalfa-alfalfa-alfalfa, are compared with those from manured and unmanured three-year rotations of potatoes-oats-sugar beets. Note that yields for the entire period have been highest on the manured six-year rotation—much higher than for the same rotation without manure. Also, during the last five-year period, yields are still declining on the unmanured land. The yields for three-year rotations without alfalfa are lower than for the six-year rotations; however, the manured land has again yielded higher than the unmanured land.

### Four- and Six-Year Rotations With Alfalfa

Four- and six-year rotations, particularly the six-year, permit the greatest diversification of crops. Such diversification provides against total crop failure since loss of one crop where several are grown is not as serious as where



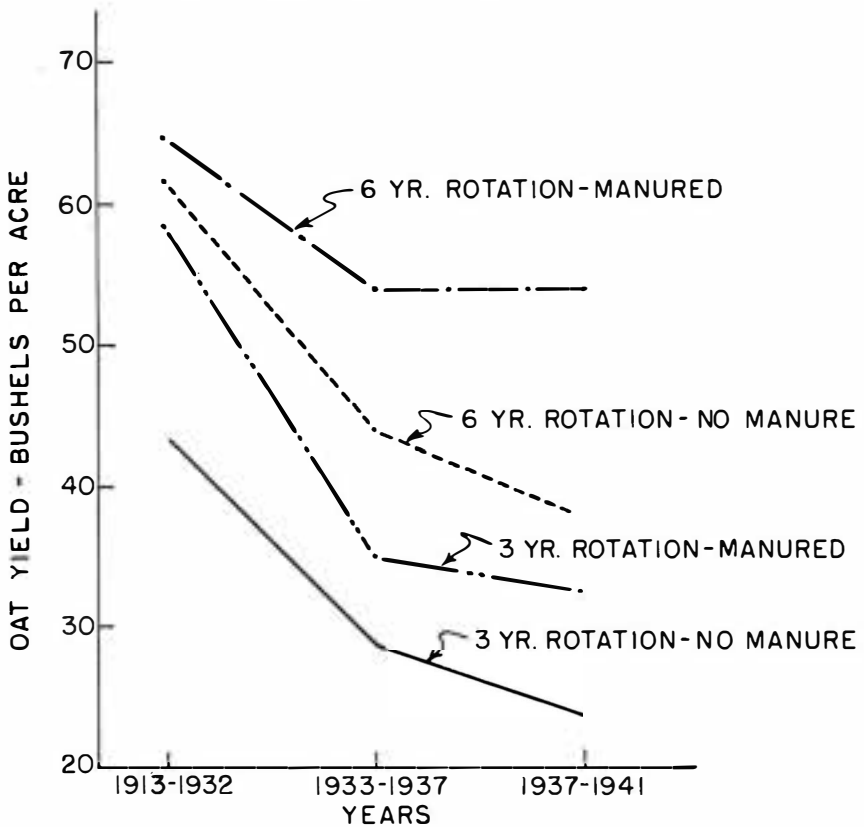


Fig. 1. Manure and six-year-alfalfa rotations together gave maximum oat yields. Both are needed for best results.

only a few crops are grown. Longer rotations thus provide a hedge against the risk of failure due to weather, pests, and unfavorable prices. Better seasonal distribution of labor also is an important feature in long rotations. Furthermore, long rotations permit the growing of alfalfa which helps maintain the supply of nitrogen and organic matter, and aids in keeping the soil in better physical condition. Crop diversification changes the location of the feeding range of the roots, and tends to diminish the possible

build-up of plant disease and insect populations.

All in all, longer rotations offer the best opportunity for a stable and profitable irrigation agriculture. But long rotations alone are not the answer. Such rotations must receive adequate manuring and fertilizing. Further, the plant disease and insect populations may build up and cause crop failures even with the best of rotations.

The effects of kinds of rotation and amount of manure upon crop yields

Table 1. Yields of Crops Grown in Manured and Unmanured Three- and Six-Year Rotations for the Five-Year Period Ending in 1941. These Rotations Have Been Followed Since 1913 on Same Land.

Rotation and crops	Yield per acre	
	Manured*	Unmanured
Six-year		
Potatoes .....	55 bu.	39 bu.
Oats .....	54 bu.	38 bu.
Sugar beets .....	15 tons	9 tons
Alfalfa .....	1.2 tons	1.0 tons
Alfalfa .....	3.5 tons	2.4 tons
Alfalfa .....	3.6 tons	2.7 tons
Three-year		
Potatoes .....	63 bu.	39 bu.
Oats .....	37 bu.	32 bu.
Sugar beets .....	10 tons	6 tons

\*Manure applied on oats at rate of 12 tons per acre. The manured six-year rotation received 12 tons once every 6 years while the manured three-year received 12 tons once every 3 years.

are given in Table 1. The yield data in this table are for the last 5 years that these rotations were followed. The yields are the reflection of the effects of 25 years of previous cropping under the same rotation and manuring system. Note that the addition of manure in both rotations has resulted in higher yields of all crops. Similarly, the yields of the non-legume crops of the six-year rotations are higher than for those of the corresponding three-year rotations.

Twice as much manure was applied on the manured three-year rotations as on the manured six-year rotations. Even so, yields are still highest on the six-year rotations, because of the effect of the alfalfa.

**Rotations With Sweet Clover as a Green Manure or Pasture Crop**

Sweet clover is well adapted for use in two- and three-year rotations, since it offers a way to introduce a legume into a short rotation. Sweet clover adds considerable nitrogen to the soil for use by the following non-leguminous crop or crops, and it exerts a decidedly beneficial effect on the tilth of

the clay soil. Furthermore, sweet clover makes a good pasture, particularly for sheep.

Since sweet clover is used where a large percentage of the land is to be in non-leguminous crops, this by necessity assumes either a limited livestock or a non-livestock system of farming. Such a system may be open to some question on the irrigated clay soils of western South Dakota. At the Station, sweet clover usually has been followed by sugar beets. The beet yields, however, have been low, probably because of the phosphorus deficiency in the soil. As with alfalfa, sweet clover alone will not do the job. It still takes manure and phosphate.

Figure 2 shows the effect of sweet clover upon the yields of the following sugar beet crop. Observe that only where manure was applied did the beet yields reach high levels.

**Continuous Cropping and Non-Legume Rotations Are Poor Practices**

Growing the same crop continuously on the same land is a poor practice, and the irrigation farmer of today seldom follows this practice. With the

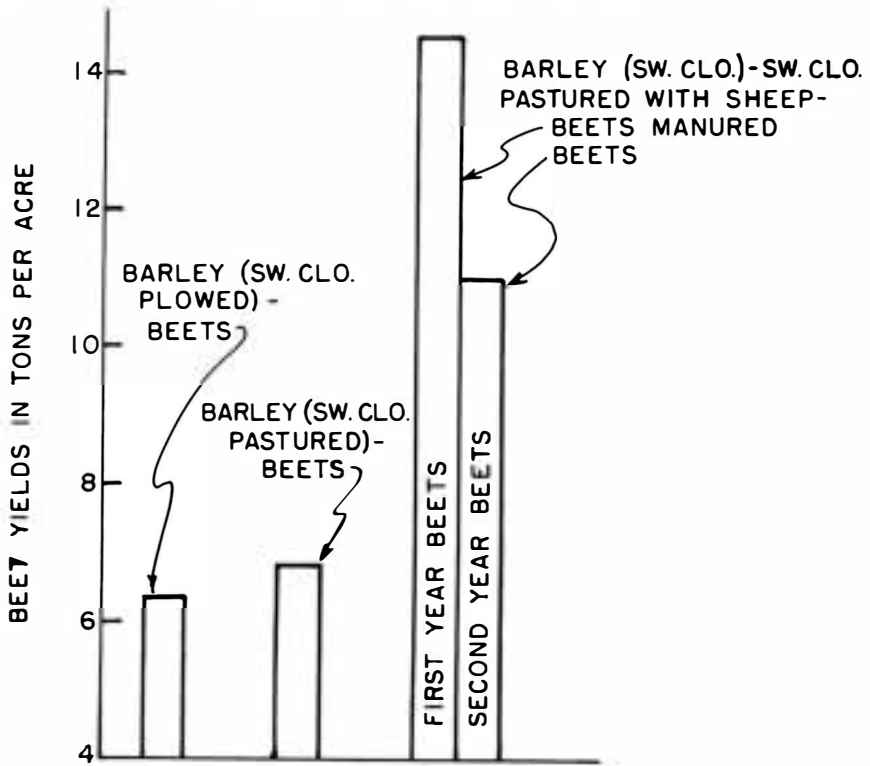


Fig. 2. The yields of sugar beets following sweet clover. Observe that only where manure was applied did the beets yield well. Yields are for the five-year period ending in 1941.

exception of alfalfa grown continuously, even adequate applications of manure and fertilizers will not maintain yields over a long period. Alfalfa, contrary to other crops, will produce well over a considerable period of time under continuous cropping, as long as the stand remains good, diseases do not build up, and there is sufficient phosphorus present in the soil.

Crop yields decline rapidly under continuous cropping for several reasons. On unmanured and unfertilized land, one of the major reasons for rapid yield decline is the depletion of

fertility. The roots of a single crop feed from a definite root zone and in a definite way. It is not long until the nutrients, particularly nitrogen and phosphorus, are exhausted to a point where the plant cannot obtain enough for normal growth. Secondly, even though adequate fertility is supplied, plant disease and insect populations usually rise to a point where continued production of that crop is unprofitable. Furthermore, the economy of one-crop farming is not so stable as systems involving more crops. All of the eggs are placed in one basket.

The use of a simple two- or three-



Crops growing in rotations at the United States Belle Fourche Field Station. Results from 38 years of cropping show that good rotations alone won't maintain yields. Adequate manuring and fertilizing also are needed.

year crop rotation without a legume, such as oats and sugar beets; or corn, oats, and sugar beets is also a poor practice. It is only one step advanced over the single-crop system. Results with such rotations at the Belle

Fourche Station show that yields decline about as rapidly as under the single-crop system.

Some of the crop yields for continuous and two-year rotations are given in Table 2.

**Table 2. Yields of Some Crops Grown in Continuous and Two-Year Rotations on Manured and Unmanured Land for the Five-Year Period Ending in 1941. The Rotations Have Been Followed on the Same Land Since About 1913.**

	Yield per acre	
	Manured	Unmanured
Continuous		
Barley .....		7.4 bu.
Beets .....	11 tons	4 tons
Corn .....		28 bu.
Alfalfa .....	5.1 tons	2.7 tons
Two-year		
Corn .....		20 bu.
Oats .....		26 bu.
Oats .....	44 bu.	36 bu.
Beets .....	15 tons	8 tons



These sugar beets, photographed in early August, are growing on land that has been cropped continuously to beets. Crop yields decline rapidly under continuous cropping even when manure and fertilizer are applied.

### Lack of Phosphorus One of Major Factors Responsible for Low Yields

Yield data from the continuous alfalfa plots and from the maximum crop production plots all show that high yields are obtained only where 12 tons of manure per acre per year were applied on the clay soil. This is a lot of manure—much more than the average farmer can obtain. Can high yields be obtained without the use of such high amounts of manure?

Look first at the phosphate analyses of the soil from some of the rotation plots. These are given in Fig. 3. For the particular method used,<sup>3</sup> about 10 parts per million of phosphate ( $\text{PO}_4$ ) is required for normal crop growth. Below this, and particularly below 2 or 3 parts per million, the amount of phosphorus in the soil may be quite

insufficient to meet the needs of the crop.

Note in the graph that the amount of phosphate in the soil is closely related to the amount of manure applied. Where either no manure or very little manure was applied, the available phosphate level has become dangerously low. Note particularly that 424 tons of manure applied over a period of 39 years to continuous alfalfa were required to build up the phosphate level to 23.7 parts per million. Assuming that the manure was of average quality and contained 5 pounds of  $\text{P}_2\text{O}_5$  per ton, then the total phosphate application equalled 2120 pounds or about 54 pounds of  $\text{P}_2\text{O}_5$  per acre per year. However, approximately one-half of this amount of manure applied over the same period to the two-year oats-beets rotation resulted in a phosphate level of only 5.4 parts per million—probably inade-

<sup>3</sup>The method consisted of extracting the soil by bubbling carbon dioxide gas through a soil-water mixture. This is the more or less standard method for measuring available phosphorus in western soils.

quate for good yields. Thus the equivalent of about 29 pounds of  $P_2O_5$  per acre per year was not enough phosphate to do the job.

One can reason from the above that about 50 pounds of  $P_2O_5$  per acre per year are required to obtain maximum crop production on the irrigated Pierre clay soil. It takes a lot of manure to supply this. But, it takes only 111 pounds of treble superphosphate (0-45-0) per acre to accomplish the same thing, and the latter amount is

not at all unreasonable. Usually a farmer has some manure, so it becomes merely a matter of making up the difference with superphosphate.

On a phosphorus-deficient soil, it often is desirable to make much larger initial applications of phosphate in order to build up the soil immediately to a desirable phosphorus level.

**Legumes and Manure Supply Nitrogen**

In a rotation having alfalfa for two or more years, lack of sufficient nitro-

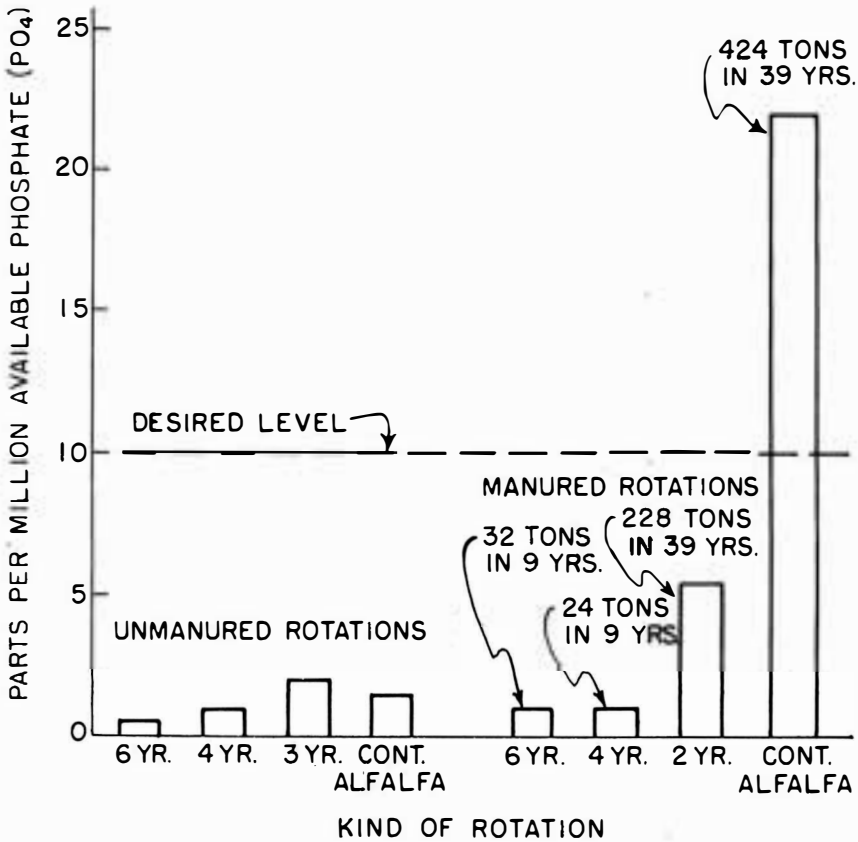


Fig. 3. Manure increases available phosphate content of the soil (plow layer depth).

gen in the soil to supply adequately the non-leguminous crops in the rotation should be no problem. Alfalfa takes considerable nitrogen from the air. Its roots and residues then add nitrogen to the soil which is available for the non-leguminous crops following. This is shown by the graph in Fig. 4. Manure also adds considerable nitrogen and, like phosphate, the

amount of nitrogen in the soil is roughly proportional to the tons of manure applied. Average composition manure contains about 10 pounds of the element nitrogen per ton, so 12 tons of manure add about 120 pounds of nitrogen per acre.

For a rotation of barley — alfalfa — alfalfa — alfalfa, no additional nitrogen either from manure or fertilizer is

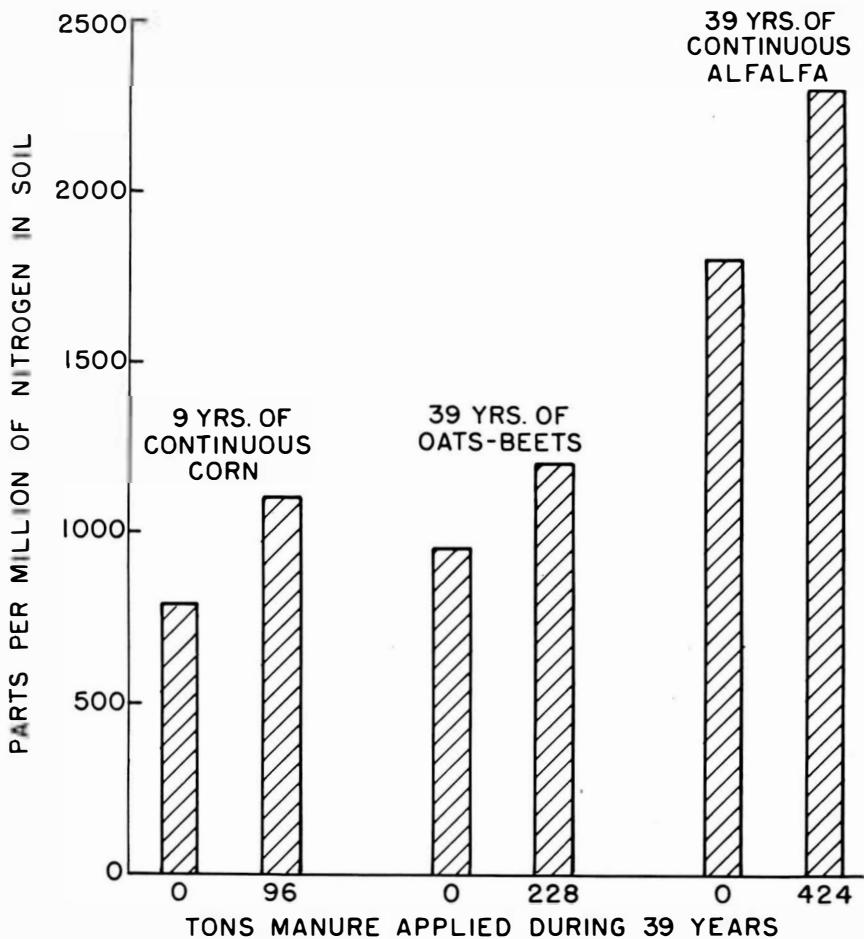


Fig. 4. Manure and alfalfa increase the nitrogen content of the soil.

needed. For a rotation of barley — alfalfa — alfalfa — corn — sugar beets, some additional nitrogen may be needed on the corn, but is particularly needed on sugar beets. If about 6 or 8 tons of barnyard manure are applied for the beets, then the nitrogen needs

of this crop and also the following barley crop should be taken care of adequately. If only a small amount of manure is available, then it may be necessary to supplement with commercial nitrogen fertilizer.

### Adaptability of Various Crops

Some crops are better adapted than others for use on the clay soils. However, soil fertility, management, and the use of the best adapted varieties determine to a large extent the size of yields to be expected. Given in Table 3 are the average yields obtained from the Maximum Crop Production Experiment on the Pierre clay soil at the Station. Each yield represents the average for a number of years, using the best known fertility and management practices as well as the best known crop varieties.

**Small Grains:** Small grain yields have been quite satisfactory when used in manured rotations with alfalfa. Small grains grown in non-legume rotations cannot be justified even where adequate fertility is supplied.

Table 3. Average Crop Yields Obtained on the Maximum Production Experiment Where Large Amounts of Manure Were Applied.

Crop	Average yield per acre*
Alfalfa .....	4.6 tons
Sweet clover hay .....	3.2 tons
Corn .....	52 bu.
Flax .....	14 bu.
Oats .....	66 bu.
Barley .....	49 bu.
Mangels .....	33 tons
Sugar beets .....	19 tons
Potatoes .....	203 bu.
Field beans .....	27 bu.
Field peas .....	13 bu.

\*Manure was applied at rate of 17 tons per acre, usually in 2 or 3 out of every 4 years for the yields reported.

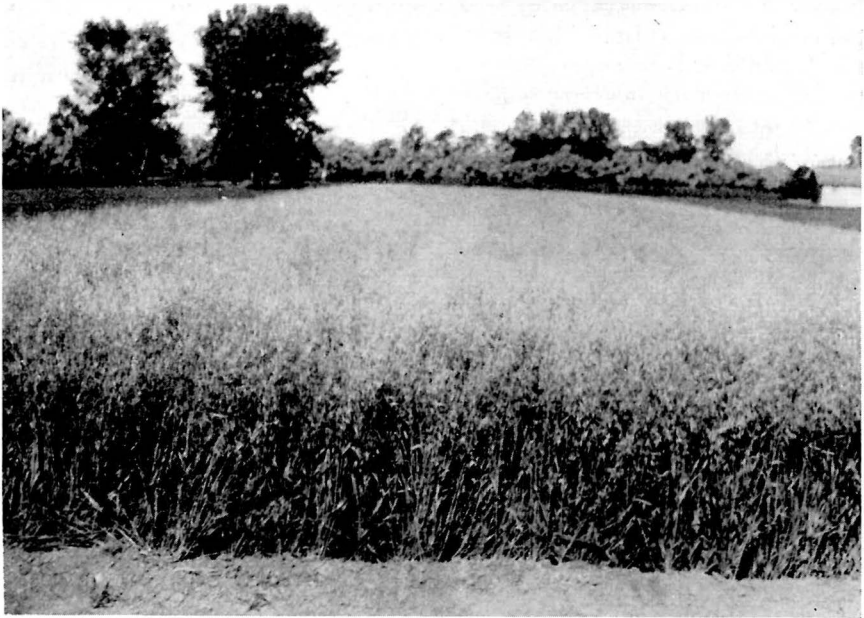
Results show that best yields are obtained in manured rotations with alfalfa (Fig. 1).

Small grains, too, fit in well with alfalfa and sweet clover since these crops can be seeded with the small grains. On the clay soils, barley is preferred over oats since better legume stands are usually secured under the barley. Also, barley produces as many pounds of grain per acre as oats and is a more desirable crop for fattening lambs. Spring wheat is not so dependable on irrigated land as either oats or barley.

**Alfalfa:** Alfalfa has long been one of the most valuable crops for the irrigated clay soils of western South Dakota. It has a decidedly beneficial effect upon other crops in the rotation through the fixation of atmospheric nitrogen by its root nodules. It also improves somewhat the workability of the clay soils.

Alfalfa produces good yields of high quality forage when grown on fertile soil. This forage is badly needed by the livestock of the area—not only in the irrigated areas but also as a supplement to feed produced on the range and on dryland farms. Alfalfa also makes excellent pasture, especially when mixed with brome grass or other hardy perennial grasses.





Small grain yields on clay soils have been quite satisfactory when grown in manured rotations having alfalfa.

However, good fertility is essential for high yields of alfalfa. Since the clay soils are low in available phosphorus, adequate phosphate must be supplied—probably through a combination of manure and superphosphate fertilizer.

Alfalfa yields increase on the clay soils from the first through the third year as the crop becomes better established. Three consecutive years of alfalfa in the rotation thus have some advantage over two. That alfalfa may yield still higher in the fourth and fifth consecutive years on fertile land is indicated by the high yields obtained on the manured, continuous alfalfa plots. Yield data for a 28-year period showing increase in alfalfa yields are given in Table 4.

Table 4. Alfalfa Yields Increase as it Becomes Better Established. Average of 28 Years Data.

Year	Yield tons per acre
First*	1.35
Second*	3.72
Third*	3.92
Continuous†	4.96

\*In a six-year rotation receiving 12 tons manure per acre on oats preceding the alfalfa.

†Continuous alfalfa receiving 12 tons of manure every year.

**Clovers:** Sweet clover is well adapted for use in short rotations. Growing this crop has presented some problems at the Station. It has often been difficult to obtain good stands. In recent years, an unidentified disease attacking the roots of the sweet clover has practically eliminated this crop.

Sweet clover has found favor as pasture, particularly for sheep. When

plowed under as a green manure, it has exerted a decidedly beneficial effect upon the tilth of the clay soil. As with alfalfa, considerable nitrogen is added to the soil.

Red clover has consistently failed.

**Sugar Beets:** This is often a difficult crop to grow successfully on clay soils. It is hard to obtain adequate stands because of crusting and cracking of the soil. Also, as has been the case at the Station since 1942, diseases may become so serious that poor stands and yields result.

Getting the beets planted at an early date, usually by April 15, appears to be the first step toward successful beet production. Secondly, adequate soil fertility must be present. For example, yields as high as 18.8 tons per acre have been produced on plots where large and frequent applications of manure were made. The beneficial effect of manure is shown in Fig. 5. Probably the benefit of manure for the beet crop has been two-fold: the adding of

plant nutrients and the improving of the physical condition of the soil.

Two other factors are essential for high beet yields. These are good stands and adequate moisture. Here is a good rule for stands: Plant in 20-inch rows and thin to a 12-inch spacing between plants within the row. Early irrigation is essential if spring rains are not abundant. This means irrigating to get germination where the soil is dry, or irrigating either before or soon after thinning. After this the soil must be kept moist until the crop is made. This usually requires more frequent irrigations than is commonly practiced.

The station data indicate that alfalfa has contributed very little toward high beet yields. Beets grown in two- and three-year rotations without alfalfa have yielded about as well as beets grown in six-year rotations with alfalfa.

In rotations with alfalfa, beets immediately following the alfalfa yield

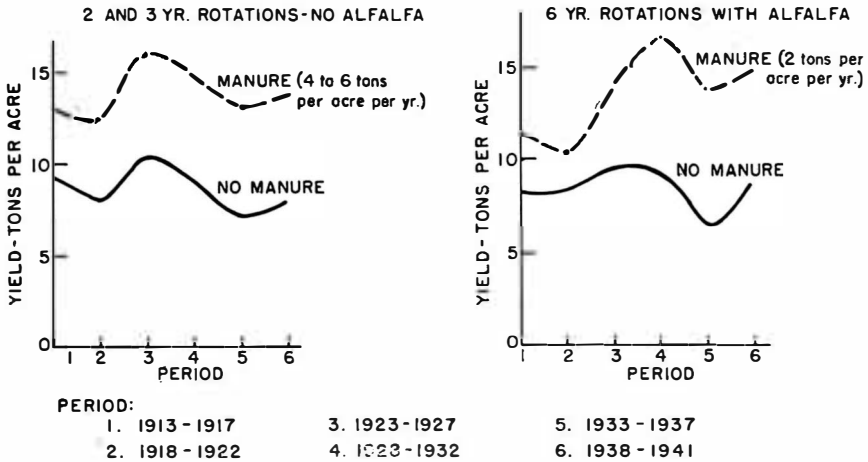


Fig. 5. Manure increases sugar beet yields.

less than following small grains or potatoes. (See Table 5.) It is also more difficult to obtain a good seed bed.

Beets grown in six-year alfalfa rotations have been somewhat less affected by damping-off fungi (*Pythium debaryanum*). On the other hand, beets grown in these rotations are more seriously affected by black rot (*Aphanomyces cochliodes*) and crown rot (*Rhizoctonia solani*) than in non-alfalfa rotations. This greater incidence of disease, however, may be due to the lower levels of soil fertility generally existing under long alfalfa rotations.

**Potatoes:** Potatoes generally have yielded very poorly on the clay soils. Low yields have resulted regardless of rotation or fertility. Maximum yields even during the best years have seldom exceeded 200 bushels per acre. Potatoes cannot be recommended as a satisfactory crop for these soils in western South Dakota.

**Corn:** All corn yields have been low. Satisfactory yields under the best of rotation and soil fertility conditions have seldom been obtained. The low yields are mostly due to the shortness of the growing season and slowness in early growth in the spring.

Highest and most stable corn yields have been obtained on the manured six-year rotations with alfalfa. These often approach the 50-bushel mark. On other, shorter rotations, yields seldom exceed 30 bushels. It is possible that future studies with adapted short-season hybrids and the use of commercial fertilizers may change the outlook for corn.

Table 5. Sugar Beets Yield Higher Following Potatoes and Oats Than Following Alfalfa. The Data Given Below Are 25-Year Averages From the Unmanured Four-Year Rotations.

Previous crop	Beet yields in tons per acre
Potatoes .....	10.7
Oats .....	7.8
Alfalfa .....	5.0



Alfalfa, alfalfa-bromegrass mixture, or sweet clover provide good pasture on clay soils.

## Irrigation Practices for the Clay Soils

Crops vary in their total water requirement and in the season of maximum demand. Either too little or too much water has an adverse effect on yields. In order to obtain maximum production, then, one must apply the right amount of water at the right time.

O. R. Mathews<sup>6</sup> has observed the following points relative to irrigating the clay soils of the Belle Fourche Project:

1. The quantity of water absorbed will depend upon the dryness and consequent cracked condition of the surface soil.

2. After a field has once been covered with water little further absorption takes place, and little benefit can result from having water stand or flow over the soil for more than a few minutes.

3. The depth to which water will penetrate depends upon the depth to which the soil has been dried or cracked.

Small heads of water are essential for successful furrow irrigation of row crops. Large heads result in the cracks swelling shut more rapidly and the total amount of penetration is less. Flood irrigation of crops such as small grains and alfalfa is a common practice. It is true that flooding requires large heads, but it is believed to be the easiest way to irrigate crops such as the latter. However, water should not be left on the fields any longer than is

necessary for complete coverage. Sprinkling may offer possibilities but this method is expensive. Sprinkling is well adapted to rough or partially leveled land since the costs of leveling are reduced.

Alfalfa requires a good supply of water during the growing season and needs more water than most other crops for maximum yields. About three to five irrigations per year have given good results at the Station. Because of its deep root system, it is desirable to soak the soil as deeply as possible.

Small grains in western South Dakota usually require only one to two irrigations. One of the irrigations should be made at about the time the grain is in the boot. Spring rains usually supplement to a considerable extent the irrigation needs of this crop.

Sugar beets often need a light irrigation in rows near the seed right after they are planted. If not done, the seed will be slow in germinating, and a considerable loss of yield will result. After germination, the main thing is to keep the beets growing fast. If wilting starts, they should be irrigated. This should be continued until a month or six weeks before harvest. One experiment conducted over a four-year period at the Station has shown that the first regular irrigation should come by June 20. Delaying this irrigation to July 1 resulted in a one-ton per acre loss of yield. In irrigating beets, it is important to keep the top foot of soil moist. This requires more frequent and less heavy irrigations.

<sup>6</sup>Mathews, O. R. "Water Penetration in the Gumbo Soils of the Belle Fourche Reclamation Project," *USDA Bulletin* No. 447. 1916.

## Recommended Rotations and Management Practices

The experience of nearly 40 years on the irrigated Pierre clay soil at the Belle Fourche Station indicates that success or failure of the farming enterprise depends to a large extent on the soil management and cropping systems and practices followed. These include:

1. The selection and use of well-adapted crops.
2. Placing these crops in good sequences in fairly long rotations.
3. Applying sufficient manure and phosphate and nitrogen fertilizer to maintain a satisfactory level of soil fertility.
4. Planting at the correct time, irrigating adequately and at the time when needed, as well as timeliness in other operations.
5. Control of plant diseases, insects, and weeds.
6. The use of good clean seed.

Success depends on observing all of these. Overlooking any one may result in greatly reduced crop production. While the research has been concerned entirely with the clay soils, the above points will apply to almost any irrigated soil.

### Crops Adapted to Heavy Clay Soils

Research and experience indicate that the following classification of crops is essentially correct. However, some farmers are more adept than others in growing a particular crop. Individual experience as well as the type of farming system practiced, therefore, will be a factor in crop selection. In all instances, the best varieties for the area must be selected, and these will change from time to time de-

pending on the plant diseases present as well as upon recent advances in crop breeding.

**Recommended Crops:** Those that will usually give dependable yields with the least effort and skills. Good fertility practices are still required.

**Barley**—A high yielding crop popular for fattening lambs.

**Oats**—High yielding and utilized for feeding bred ewes.

**Alfalfa**—High yielding and excellent quality hay and pasture. (Note: Alfalfa should be pastured only in its last year in the rotation. A single year of close grazing reduces future productivity and frequently damages the stand.)

**Alfalfa-Bromegrass mixture**—High producing pasture.

**Intermediate Crops:** Those where good yields may be produced but are more dependent upon the skill of the individual farmer and upon the use of good fertility and management practices.

**Corn**—A feed crop. Use short-season hybrids. Grow only in alfalfa rotations. May require nitrogen fertilizer.

**Sugar beets**—A good cash crop. Requires high-fertility, early planting, and disease-free soils.

**Spring wheat**—A good cash crop but failures are common.

**Sweet clover**—Used mostly for temporary pastures and as a green manure crop. Best for shorter rotations. Root disease may cause failure.

**Not recommended:** Those crops having low and undependable yields.

Potatoes	Winter wheat
Flax	Red clover

### **Crop Rotations for Heavy Clay Soils**

Selection of a particular rotation will depend largely upon the economic factors operating as well as upon the number and kind of livestock on the farm. It should be pointed out, however, that the clay soils are not adapted to a cash crop farming system. Production of feed for livestock system of farming offers the best and surest use of these soils. Row crops are not well adapted, but certain individual farmers may successfully use them in their rotations. Furthermore, one must not adopt a particular rotation with the idea of following it exactly. Economic conditions and values of crops change. A farmer must keep his system flexible enough to take maximum advantage of the possibilities open to him.

### **Rotations Best Adapted to Clay Soils**

The following rotations require a livestock system of farming. Part of the hay land will be pastured. Even so, additional grain from the farm may be required.

1. **Six-year:** Barley or oats with alfalfa seeding—alfalfa-alfalfa-alfalfa-alfalfa-alfalfa.

2. **Five-year:** Barley or oats with alfalfa seeding — alfalfa-alfalfa-alfalfa-alfalfa.

3. **Four-year:** Barley or oats with alfalfa seeding—alfalfa-alfalfa-alfalfa.

A combination of alfalfa-brome-grass, or other perennial grass with alfalfa, may be substituted for the straight alfalfa in the above rotations. The alfalfa, or alfalfa-grass mixture, may be either pastured or harvested as hay. The alfalfa may also be harvested for seed.

Manure and/or superphosphate

must be applied and worked into the soil preferably before the small grain is sown.

### **Rotations Involving Some Row Crops**

These still require a livestock system of farming but allow for more grain and cash crops. They may be used as an alternative for the farmer who has high-fertility soils or applies large amounts of commercial fertilizer and manure.

1. **Six-year:** Barley or oats with alfalfa seeding — alfalfa-alfalfa-alfalfa-barley-sugar beets.

2. **Six-year:** Barley or oats with alfalfa seeding — alfalfa-alfalfa-alfalfa-corn-sugar beets.

3. **Five-year:** Barley or oats with alfalfa seeding — alfalfa-alfalfa-alfalfa-corn.

### **Rotation With 50 Percent Row Crops**

This rotation is for the non-livestock farmer. It is not recommended for general use.

1. **Four-year:** Barley or oats with sweet clover seeding—sweet clover as pasture or green manure—corn—sugar beets.

**Not recommended under any circumstances:**

1. All two- or three-year rotations.

2. All continuous cropping systems.

(Note: Alfalfa apparently does well when grown continuously. However, under this system, the beneficial effect of the alfalfa for other crops is lost.)

### **Guiding Principles in Setting Up Rotations**

A few principles to use as guides in setting up rotations are as follows:

1. Start all legume or legume-grass seedlings in a small grain companion

crop, since better catches are assured and the crop reaches full production sooner.

2. Let corn follow the legume forage since corn requires large amounts of nitrogen.

3. Let sugar beets follow corn or a small grain. Beets do not yield as well when they follow alfalfa.

4. Do not have small grains following small grains, corn following corn, and, possibly, beets following beets.

5. Leave alfalfa down for at least three harvest years unless the stand is poor. Maximum production is approached only in the third year.

6. No rotation will produce high yields unless adequate manure and fertilizer are applied.

### Fertility Practices

**Barnyard manure:** Return all of the manure possible to the fields. For grain-alfalfa or alfalfa-grass rotations, apply all of the manure ahead of the small grains with the seedings and then plow it under.

For rotations with sugar beets, apply all of the manure ahead of the sugar beets or split the application and apply part of the manure ahead of the sugar beets and a part ahead of the small grain with seeding.

Manure is low in phosphorus and may need to be supplemented by superphosphate fertilizer.

**Pasturing:** Use of one or more years of the alfalfa or alfalfa-grass mixtures as pasture is a good way to get some manure on the fields. Similarly, harvesting corn with hogs gets manure onto the field.

**Fertilizers:** Since the irrigated clay soils are low in available phosphorus, adequate amounts of phosphorus must be applied either through manure or superphosphate fertilizer.

During the first few years, a rate equivalent to about 50 pounds of  $P_2O_5$  per acre per year should be applied. Manure contains phosphorus, but a ton of average quality manure contains only about 5 pounds of  $P_2O_5$ . Thus, for a six-year rotation, a total of 300 pounds of  $P_2O_5$  might be required. On this basis, it would take 60 tons of manure per acre to supply a satisfactory amount of phosphorus. This is more manure than most farms have. Therefore, figure the tons of manure being applied during the length of the rotation, allow 5 pounds of  $P_2O_5$  per ton, and subtract this from the total pounds of  $P_2O_5$  required. Make up the difference by applying that amount of  $P_2O_5$  from superphosphate fertilizer. One hundred pounds of 0-45-0 (treble superphosphate) contain 45 pounds of  $P_2O_5$ .

For a grain-alfalfa rotation, allow 50 pounds of  $P_2O_5$  for the grain year and each alfalfa year, then apply it as superphosphate all in one application ahead of the small grain with the seeding. It may be either broadcast and disked into the soil or drilled in with a fertilizer drill.

When corn follows the alfalfa, there will probably be sufficient residual phosphorus in the soil from the earlier application to meet the needs of this crop. The same should hold for small grain immediately following alfalfa.

Sugar beets following either corn or small grains after alfalfa, however, should receive an application of a mixture of nitrogen and phosphate fertilizer equivalent to 60 pounds of nitrogen and 60 pounds of  $P_2O_5$  per acre.

### **Irrigation**

Small heads of water are essential for successful furrow irrigation of row crops on the clay soils. Since

water penetrates the clay soils mostly through the cracks, small heads will give greater penetration than large heads. The latter will result in the soil swelling and in less penetration of the irrigation water.

In flood irrigating small grains, hays, and pasture, leave the water on the land only long enough for complete coverage. Ponding is of little value in increasing water penetration on these soils.