Soil Management

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Soil Management

By Howard E. Ray
Extension Specialist in Soils

Soil is "alive." It responds to good management by producing abundant crops of high quality. It responds to poor management by becoming unproductive.

Soil management is the phase of crop production which deals with the manner in which the soil is handled. The primary objectives of a soil-management program are to provide for a *permanent* as well as a *profitable* agriculture.

To attain these objectives, it is necessary to maintain the soil in good physical condition, keep biological activity on a favorable basis, and have available plant nutrient elements in adequate supplies during the growing season.

A good soil-management program includes proper tillage, irrigation, and organic matter turnover—together with the judicious use, where needed, of soil amendments and commercial fertilizers.

A good soil-management program must be flexible. Arizona soils vary much even on the same farm. Different soils call for different treatments, and even the same soil may require changing treatments from year to year, and from crop to crop. Economic conditions must also be taken into account. A soil-management practice which is good this year may be entirely unprofitable next year, and vice versa.

Soil conditions are extremely complex. It is impossible to prescribe blanket recommendations to cover the requirements of all soils and all crops. There are, however, certain basic principles which must be taken into consideration in planning any soil-management program.

It is the aim of this publication to call attention to these principles so that they can be applied to the conditions found on any farm in Arizona.

SOIL TILTH

Tilth refers to the physical conditions of a soil which affect plant growth. A soil to be in good tilth must have both good physical condition and available moisture for plants.

Soil Structure

The most important factor in tilth is *structure*. Good water penetration, efficient soil aeration, and satisfactory seedbeds are all largely dependent on a good soil structure.

Soil structure refers to the arrangement of the individual particles in the soil. In nearly all soils, these particles tend to group together into aggregates or granules. Soils having good structure are well-aggregated; that is, the particles are well-grouped into aggregates or granules so that water and air movement in the soil is good. Good structure can be maintained only by regular care.

Water and air enter the soil through spaces between the soil particles called pores. These form a network of connected passages through the soil. The number and size of the pores in a soil are determined by its texture (the size of the soil particles) and its structure. Soil with good structure has pores large enough to allow fairly rapid movement of air and water through it.

Under long continued cultivation, soil often tends to lose its ability to absorb water. Granules break up, the soil "runs together," and the soil pores become smaller. This prevents the easy entrance of water, air and plant roots. The soil structure has been destroyed.

Soil structure might be likened to a river bridge. The bridge is called a structure because it consists of many pieces of steel and other building materials fastened together. If properly designed, constructed, and maintained it will last for many years and will hold up the weight of the thousands of cars and trucks which cross it. If, on the other hand, the bridge is not properly constructed, it may collapse under the weight of a heavy truck, thus causing a disaster.

Trained engineers are employed to design and build structures such as bridges. The farmer is the engineer who supervises the building of structure in the *soil*. The structure that he builds will be strong and useful, or weak and undependable depending on how he manages his soil.

The "iron and steel" used in building soil structure are the individual soil particles. A close examination of the soil reveals that it consists of a network of particles of various sizes.

The larger particles, which can easily be seen by the unaided eye, are called gravel and sand. These particles are so large that they do not readily enter into the structure.

Slightly smaller particles, those which can easily be seen through an ordinary microscope, are called silt. They are rather like flour in the soil. Alone, silt particles cannot easily enter into the structure. When clay is also present, however, they are important building materials.

The smallest soil particles, called clay, may be too tiny to be distinguished through powerful microscopes. Clay particles are the most active building materials for the farmer engineer to use in building his soil structure.

Soil structure, then, is built by fastening together the individual soil particles into groups called aggregates. The nature of the particles and their environment determine the size, shape, and arrangement of these aggregates.

Soils which contain an extremely high proportion of silt are oftentimes problem soils. As they form relatively few aggregates, the pore spaces are so small that water and air penetrate very slowly. Soils which contain appreciable amounts of clay form aggregates readily, if properly managed, and water can enter through the spaces between the aggregates. If these soils are not managed properly, however, they "run together" and may be among the worst problem soils.

Organic matter turnover and proper tillage are two big factors in building and maintaining good soil structure.

Organic Matter

The steel girders in the bridge must be fastened in place by riveting or welding. Otherwise the

A GOOD PRACTICE! Plowing under crop residues conserves organic matter and helps maintain good soil tilth.

A POOR PRACTICE! Burning crop residues wastes organic matter which is badly needed in Arizona soils.

bridge will fall. In a similar manner, the aggregates which make up soil structure must also be securely fastened together. The best "welding" material for this purpose is organic matter.

Soil organic matter includes the partially rotted remains of plants in the soil and the materials formed by soil organisms. Arizona soils contain on the average only 0.1 per cent of organic matter. Even this small amount, however, can influence greatly the physical and biological condition of the soil.

Probably the most important function of organic matter is its influence on soil structure. Organic matter acts as a binding agent to hold soil aggregates together. This prevents the soil from running together and aids in water penetration and aeration. It also helps to prevent soil erosion.

Soil organic matter is the storehouse for practically all of the nitrogen found in soils, and also contains other plant-nutrient elements such as phosphorus, potassium, iron, etc. It serves as a food for soil organisms which in turn release the nutrients just mentioned in a form which is available to plants.

The organic matter in the soil is constantly decomposing. In fact, it can only be of benefit in increasing crop production when it is decomposing. Therefore, the supply must be replenished frequently. This is especially true in southern Arizona where the extremely hot summer temperatures result in a very rapid breakdown of organic matter.

A satisfactory organic matter supply can be maintained in Arizona soils by:

1. Returning all crop residues to the soil. As crop residues constitute about the largest source of organic material, they should *always* be turned under, and never destroyed (unless the control of insects or disease requires that they be destroyed).

2. Spreading barnyard manure on the fields. This practice is especially helpful in combating hard spots.

3. Growing and plowing under green manure crops such as sesbania, guar, Papago peas, clover or young barley. This practice is often of great value where soils are in a poor physical condition.

Tillage

Even a properly designed and constructed bridge will break down eventually if abused. Soil structure can also break down under the abuse of improper tillage.

Tillage includes all mechanical operations that are used to provide soil conditions which are favorable for the growth of crops. Tillage operations may be made for one or more purposes including:

1. Loosening the soil to improve water penetration, root penetration, and aeration.
2. Incorporating crop residues or other materials into the soil.
3. Preparing a seedbed.
4. Controlling weeds.

If performed properly and at the right time, tillage makes the soil a better home for crops by helping to keep the soil in good tilth. Too much tillage, on the other hand, may pulverize the soil until water penetration is severely restricted. Also, heavy equipment may compact layers in the soil until roots and water cannot penetrate through them.

It is a common practice to cultivate intertilled crops such as cotton or corn quite frequently. It is often assumed that a light cultivation forms a soil mulch which prevents capillary movement of water to the surface. This is assumed to stop the loss of water through evaporation. Experiments have shown, however, that little or no moisture is conserved in this manner and aeration may be decreased.

Cultivation for the control of weeds quite definitely conserves moisture, since weeds require moisture for their growth. Therefore, *cultivations should be made only as necessary for the control of weeds, and the breaking of hard surface crusts.*

The following precautions with tillage will help to maintain soil in good tilth:

1. Use the least amount of tillage which will provide a satisfactory seedbed and control weeds.
2. Use a two-way moldboard plow which leaves the land level. This eliminates the need for excessive land planning, etc.
3. Vary the depth of plowing from year to year to prevent formation of an impervious hardpan.
4. Till the soil at the proper moisture content. Do not work soil when too wet because of danger of puddling. Also do not work it when it is so dry that it powders.
5. Use special practices such as subsoil plowing, ripping, etc., only after a thorough investigation of soil conditions shows they are needed.

There are several tillage practices which should be used only for the correction of specific conditions. Among these practices are subsoil plowing, deep plowing, ripping, chiseling, and renovating.

Subsoil plowing (usually 18" to 36") refers to plowing to a depth well below the plow layer. The purpose of this operation is to (1) mix together surface soil and deeper zones when they differ in texture, or (2) break up cemented or compacted layers in the subsoil. Subsoil plowing is seldom profitable where the soil is uniform to a depth of two or three feet.

Deep plowing is the term used to describe plowing to a depth just below the plow layer (usually not more than 12 to 16 inches). The purpose of deep plowing is to break up and aerate compacted layers formed as a result of tillage, irrigation, or harvesting operations.

Ripping (subsoil chiseling) is an operation designed to break up hard or compacted layers existing in the soil below the plow layer. It is performed with an implement having one or more long, narrow, slightly curved teeth. Ordinarily results are most satisfactory when the soil is dry and will fracture widely.

Chiseling refers to an operation designed to break up hard or compacted layers in the plow layer. It is performed with implements having one or more narrow teeth which may or may not have sweeps.

Renovating is an operation performed to correct surface compaction. It is sometimes used in alfalfa fields to break up surface compaction and to help control weeds.

Spreading gypsum on a field before pre-planting irrigation for cotton.

Soil Conditioners

Poor tilth in soils may be caused by many things such as alkali, high clay content, etc. Materials added to soils to help improve tilth are called soil conditioners. They may be used to assist in the reclamation of alkali soils, or to improve the physical condition of soils which have poor water penetration or low water holding capacities.

Barnyard manure, since it is a good source of organic matter, is one of the best soil conditioners. Many chemicals are also used as soil conditioners and some of the more common ones are discussed briefly below.

Lime

As there are very few acid soils in Arizona, very little lime is needed for soil conditioning. In fact, practically all of the irrigated lands in the state contain rather large amounts of calcium carbonate as caliche. Lime (calcium carbonate) is used to correct the unfavorable soil conditions associated with soil acidity in areas where acid soils do occur.

Gypsum

Gypsum (hydrated calcium sulfate) is widely used to aid in the reclamation of alkali soils. If properly used it will oftentimes give excellent results.

Alkali soils have too much sodium attached to the surface of the clay particles. This causes the soil to disperse (run together), and results in high alkalinity, stickiness, and impermeability to air and water. Such a condition may exist naturally, or it may be caused by irrigation or seepage water containing too much sodium.

The calcium in gypsum can replace sodium attached to the clay particles. These particles then tend to group together into aggregates so that larger pore spaces are formed. Irrigation water can then pass through and wash out the sodium and other excess salts.

Gypsum and similar materials are of doubtful benefit unless a sodium problem exists. A chemical analysis of the soil will help to determine whether gypsum is needed and, if so, how much should be applied.

Alkali reclamation includes more than an application of gypsum to the soil. To obtain maximum benefit from gypsum the following conditions must be met:

1. The land must be well leveled so that water will be distributed evenly on all parts of the field.
2. The land must be well drained so that the salts can be leached below the root zone of crop plants.
3. The gypsum must be broadcast and disked into the soil or applied in the irrigation water.
4. Sufficient water must be applied to leach out excess salts.
5. The first crop will probably have to be one that is tolerant of alkali, such as bermuda grass, barley, or, possibly, cotton.

The quality of irrigation water that is relatively low in total soluble salts, but high in sodium can be improved by the addition of finely ground gypsum. This prevents a build-up of sodium in the soil, and may in some instances improve the rate of water penetration into the soil.

Sulfur

Sulfur furnishes calcium to the soil indirectly. It oxidizes in the soil to sulfuric acid which reacts with calcium carbonate to form calcium sulfate or gypsum.

It is evident that sulfur should not be used as a soil conditioner on those soils that do not contain calcium carbonate. A simple soil test will determine whether or not calcium carbonate is present. Another test will help to determine whether or not a soil amendment is needed.

In calcareous soils, when a sodium problem is present, sulfur should give the same response as gypsum, although the reaction will be much slower. One ton of sulfur is eventually of about equal value as a soil conditioner to 5 or 6 tons of high grade gypsum.

Other Sulfur Materials

Sulfuric acid, sulfur dioxide, polysulfides, and other sulfur-bearing materials are sometimes used as soil conditioners. Nearly all of these materials, like sulfur, do not contain soluble calcium, and furnish it only by reaction with calcium carbonate in the soil. To obtain maximum benefit in soil reclamation from sulfur compounds, the conditions described under *Gysum* must be met.

Polyelectrolytes

(Krilium, Aerotil, Fluffium, Agrilon, Polyack, etc.)

A group of synthetic organic compounds of this nature have recently been introduced as soil conditioners. When properly applied, these materials tend to stabilize the aggregates in almost any type of soil. They are probably of the greatest value in fine-textured soils. At present their use is restricted due to the high cost of the materials.

Land Preparation

One of the first requirements for successful production of crops is a satisfactory supply of water for each and every plant. The best way to meet this requirement is to level the land so that uniform water distribution is assured. Level land aids in obtaining better and more even water penetration in the soil, increases crop yields, helps reduce losses in water and plant food, and saves labor. It might be called the foundation for good water management.

It is impossible to discuss in this circular the technical phases of land leveling. Some problems in soil management that may arise as a result of leveling cannot be overlooked, however.

Before leveling operations are begun, a thorough investigation should be made of the soil. The type of leveling must depend upon the characteristics of the soil such as depth, texture, water-holding capacity, rate of water penetration, and hardpan formation. Deep cuts should not be made in shallow soils, because enough soil must be left in all parts of the field to support crop growth. Also, in some cases sand at rather shallow depths will be exposed if cuts are too deep. This

Level land insures even distribution of irrigation water.

will result in uneven water penetration.

Areas where cuts have been made in land leveling operations often yield rather poorly at first. This is to be expected, as the topsoil which contains most of the organic matter and soil organisms has been removed. To speed up the improvement of these areas, liberal amounts of organic matter should be incorporated into the soil. Where it is available, barnyard manure is excellent for this purpose. In some cases additional crop residues such as straw may be used.

In some instances, a form of deep tillage such as ripping or subsoil plowing may be of benefit due to improved soil aeration which follows. Liberal amounts of commercial fertilizer may also be of some benefit In any case, crop growth should improve rather rapidly on these areas so that in a few years they will produce as well as the rest of the field.

The county agricultural agent has more information available on how to level land.

SOIL FERTILITY

A soil in good tilth provides a desirable home for the healthy root systems that plants need to obtain mineral nutrients from the soil. Mineral nutrients, or "plant food" elements as they are often called, are essential for plant growth. Nitrogen, phosphorus, potassium, calcium, and sulfur are a few of these essential "plant food" elements.

Some soils are well supplied with available "plant food." They are the fertile soils, and are capable of producing excellent crops without any additional "plant food." Other soils, deficient in one or more of the essential elements, must receive extra "plant food" before maximum crop yields can be obtained.

In all soils, however, good crop rotations and the intelligent use of commercial fertilizers, where needed, will help to make the best use of the plant food already present.

Commercial Fertilizers

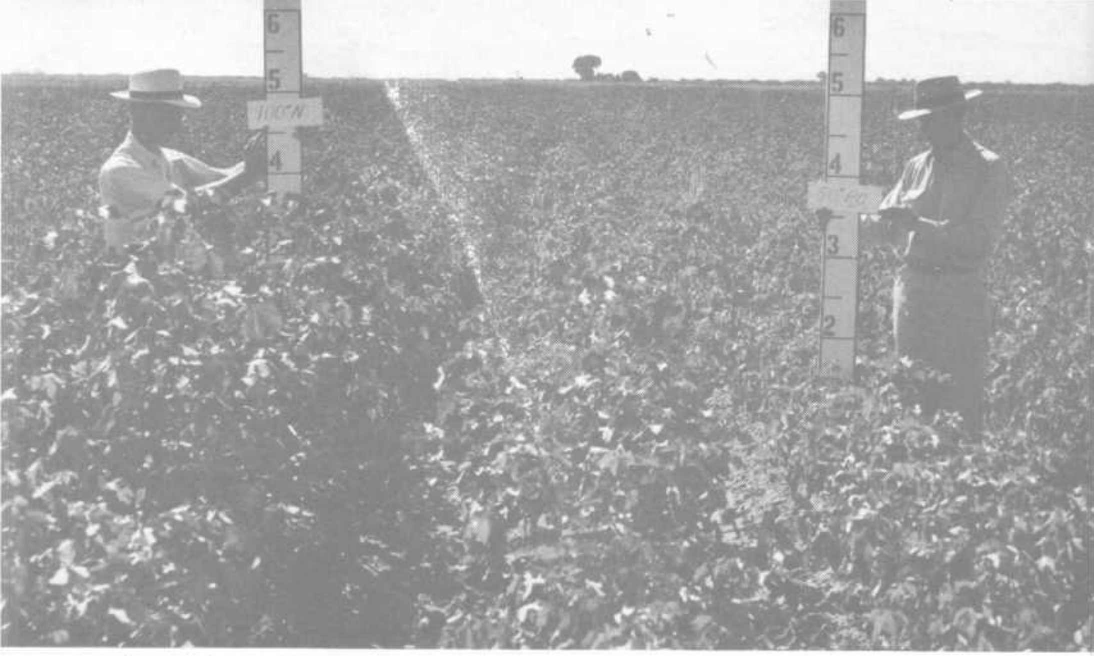
Sooner or later soils lose most of their available plant food and some type of fertilizer is needed by most crops.

Good crop rotations may decrease the need for nitrogen fertilizer, but increase the need for some other fertilizers.

Nitrogen

Soil nitrogen is nearly all in the organic form, and Arizona soils are extremely low in organic matter. Therefore, at present, nitrogen is the element that is most often needed in fertilizing Arizona soils, except when legumes are growing or have just been grown.

Nitrogen encourages aboveground growth and luxuriant dark green foliage if the supply of other nutrients is adequate. Plants short



A good fertilizer program can increase crop yields. In the Cochise County test, above, cotton shows a good response to nitrogen (on the left) but none to phosphate (on the right).

ON THE COVER is shown phosphate being broadcast on an old stand of alfalfa in the Safford valley.

of nitrogen are small, weak, and yellowish in color, and may not mature properly. Too much nitrogen tends to delay maturity and cause lodging (falling over).

As was previously mentioned, the proper use of legumes, green manure crops, and crop residues in the rotation will help to maintain a satisfactory supply of nitrogen in the soil, and less nitrogen in the form of commercial fertilizer will be needed.

Phosphorus

Although the total supply of phosphorus in most Arizona soils is rather high, the amount available to plants is often rather low. Therefore, additional phosphorus must be supplied for maximum yields of some crops on some soils.

For example, since legumes are heavy users of phosphorus, they will often respond to phosphate fertilization on soils which already have enough available phosphorus for good crops of cotton or citrus.

Phosphorus stimulates the early development of a healthy root system, and the production of seed. Field crops lacking in phosphorus are usually stunted and have poor root systems. A phosphorus deficiency is often rather difficult to detect by merely looking at a plant.

The phosphorus contained in fertilizers is commonly expressed as available phosphoric acid (P_2O_5) rather than as pure phosphorus. It is also sometimes called phosphate.

Fertilizer recommendations are nearly always expressed in the same manner.

Potassium

Potassium is also sometimes included in commercial fertilizers. It is commonly expressed on fertilizer labels as water soluble potash (K_2O) rather than as pure potassium. Arizona soils are, in general, well supplied with potassium; therefore, potash fertilizers are not recommended at the present time. It is probable that they will be needed sometime in the future, however.

Other "Plant Food" Elements

So far, crops grown on Arizona soils have not shown any shortage of the other "plant food" elements. (Iron is sometimes not available to plants, however, due to the alkaline nature of the soils.) It is likely that as more and more "plant food" is removed from our soils in harvested crops, some of these elements will be in short supply. When that time comes, they will have to be supplied in commercial fertilizers.

Buying "Plant Food"

Fertilizer requirements vary with different soils and crops. It is beyond the scope of this circular to give specific recommendations as to kinds and amounts of fertilizers to apply. Such recommendations are given in another Extension Circular, No. 208 — "Fertilizer Recommendations for Arizona."

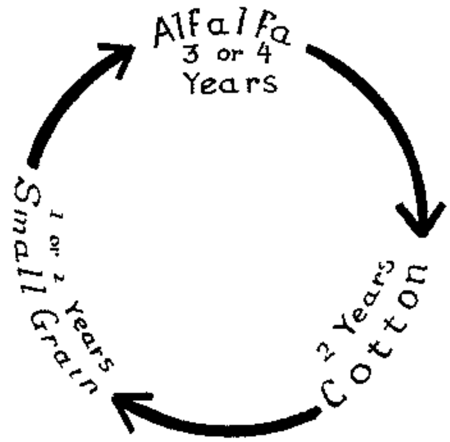
Fertilizer should always be purchased on the basis of the "plant food" that it contains. The nutrients contained in the common fertilizers are in general about equally available to crops. The most economical fertilizer to buy in most cases is the one which furnishes the desired nutrients for the lowest cost.

Crop Rotations

Crop rotation means growing several crops on the same farm in a more or less definite order over a period of years. For general farming in the irrigated sections of Arizona, a good crop rotation adapted to local conditions is practical, and is essential to maintain soil productivity at maximum efficiency.

A good crop rotation:

1. Improves soil tilth by maintaining a supply of active organic matter. This usually means higher crop yields.



An excellent crop rotation for sandy soils in Southern Arizona.

2. Decreases the need for nitrogen fertilizers because legumes can obtain nitrogen from the air if properly inoculated.

3. Encourages more efficient use of fertilizer. The plant food needs of all the crops in the rotation can be considered and the proper fertilizer applied to the crops giving the greatest response.

4. Distributes labor more evenly throughout the year.

5. Makes more efficient use of available water.

6. Aids in control of diseases such as Texas Root Rot.

7. Aids in the control of weeds.

8. Provides diversification, a buffer against sudden price drops in any one crop.

9. Helps provide for a permanent and profitable agriculture.

It is impossible to devise a single crop rotation that is suitable for all conditions in Arizona. The size of the farm as well as the interest and experience of the farmer help to determine the most desirable rotation for an individual farm. Also, the crop rotation plan must be flexible so that changing economic conditions can be met successfully.

Any crop rotation plan must be planned around the principal crop being grown. In southern Arizona, for example, this might be cotton. To accomplish the functions listed above, the rotation also should include a legume such as alfalfa. Small grains or grasses might also be desirable as their roots permeate the upper few feet of soil and help to maintain good soil tilth.

An example of a good crop rotation for southern Arizona, then, might be alfalfa followed by cotton and small grain. The number of years in each crop could be adjusted to fit changing conditions. *If at all possible, land should be in a legume at least three years out of every seven.* In northern Arizona corn might be substituted for cotton in the rotation.

In times of high prices it may be desirable to grow one crop nearly continuously for a period of several years. Under such conditions, green manure crops can often be used to help maintain high productivity.

For example, in the warmer valleys, a winter green manure crop such as Papago peas may be planted after cotton in the fall and turned under in time for cotton to be planted again the next spring. Sesbania or guar might be planted in the summer between winter vegetable crops in a similar manner.

It is sometimes desirable to combine more than one rotation on a farm. For example, during some years it may not be economical to grow enough alfalfa to keep all the land in a legume for three years out of every seven. In such times green manure crops could be used to supplement the alfalfa. In other words, two rotations would be used on the same farm.

Fertilizers

In the Rotation

Crops vary in their needs for certain mineral nutrients and in their ability to obtain those nutrients from the soil. Also, crops growing on land which was recently in alfalfa should require much less nitrogen fertilizer than crops growing on land which has not grown alfalfa for several years. A good fertilizer program must take into consideration the entire crop rotation.

In Arizona, legumes usually respond to phosphate fertilization more readily than many other crops such as cotton or corn. To get the greatest benefit from phosphate fertilizers on most soils, then, it is more profitable to phosphate the legumes rather heavily, and apply little or no phosphate to cotton or corn.

Since legumes, if properly inoculated, can obtain nitrogen from the air, no nitrogen fertilizer should be needed for these crops. Also, experience has shown that on most soils the crop immediately following alfalfa should not need nitrogen fertilization.

The second crop out of alfalfa may respond to a moderate amount of nitrogen fertilizer, and the full recommended amount is usually desirable for the third crop.

Green manure crops and crop residues sometimes present a special problem in fertilization. If large amounts of crop residue or nearly mature green manure are incorporated into the soil immediately ahead of another crop, that crop may suffer from a temporary shortage of nitrogen. When this happens, the bacteria in the soil that are decomposing the organic material are competing with the crop for the available nitrogen.

To prevent this condition, it may be necessary to broadcast some nitrogen fertilizer on the land before plowing under the residues or green manure. Usually about 40-50 pounds of nitrogen per acre are enough for this purpose.

The only sure way to determine the best fertilizer program for an individual farm is through trials by the farmer. The general recommendations of the agricultural experiment station should be used as a guide, but they must be modified by experience to fit individual circumstances.

MANAGEMENT

The successful production of crops depends upon many factors, some of which have been discussed. Some of the other factors which cannot be covered fully in this circular are:

Efficient irrigation.

(See Circular 205 — "Water Management"—for more information on this subject.)

Good cultural practices.

- Adapted varieties
- Inoculation of legumes
- Proper planting dates and methods
- Proper harvesting

Control of weeds.

Control of insects and diseases

Satisfactory drainage.

Efficient marketing.

MAXIMUM PRODUCTION

In outlining a good soil and crop management program, all of the factors concerned with growing and marketing crops should be considered. They must be related to one another so that they fit the circumstances found on an individual farm. The principles concerned with soil management which have been presented should be used in this manner.

HINTS FOR GOOD SOIL MANAGEMENT

1. Level the land to obtain uniform water distribution.

2. Provide good tilth by proper organic matter management and tillage.

3. Use the least amount of tillage which will provide a satisfactory seedbed and control weeds.

4. Use soil conditioners if needed for alkali reclamation or poor quality irrigation water.

5. Use a good crop rotation.

6. Provide an adequate supply of nutrients for all crops.

7. Consider the entire crop rotation when planning a fertilizer program.

8. Relate soil management plans to other crop production problems.