degree of pulverization needed, and the depth of plowing needed.

We feel that the research work in progress and the research that should be done will help us make progress in changing tillage from an art to a science.

The knowledge scientists and farmers are looking for involves the basic relationship between climate and soil physical conditions for optimum plant growth and how to apply force to soil to produce various physical conditions. Many specific problems are included in these broad needs.

One example is the problem of plowing each spring or fall. For row crops the farmer usually plows every year. He has a fair idea where he wishes to place the crop residue, such as cornstalks and wheat stubble, but does not have a satisfactory way to determine whether or not the soil needs pulverization, nor the best degree of pulverization for the particular plant he is growing. If he guesses the degree of pulverization needed, he does not know how to obtain it economically. Work on root ecology and soil mechanics will help answer these questions.

Another example of a specific problem, which needs coordinated research by the soil physicist, the soil chemist, the plant physiologist, the microbiologist, the plant pathologist, and the agricultural engineer, is a way to get plants to root deeper in certain areas. Subsoiling has been done in an attempt to increase water intake into the soil and to make plants root deeper to take advantage of a greater root feeding area and soil-water reservoir. Much good has been done, but much power has also been wasted in this operation, and results have been disappointing in many instances. So, while we have come a long way, we still have a long way to go in tillage.

The world-wide recognition of the importance of economical, efficient tillage is indicated by new research at the National Institute of Agricultural Engineering at Silsoe, England; the Agricultural Research Center at Braunschweig, Germany, and several places in the Soviet Union. The Japanese have an active program of research in tillage machinery and have completed a new tillage machinery laboratory like the one at Auburn.

This extensive development of interest in research in tillage apparently reflects world conditions: The rapid increase in population and the need for a larger food supply; the need to use power and machinery instead of hand labor to raise standards of living through industrialization; and international competition in the implement industry to supply the machines.

Preparing the Seedbed

W. G. Lovely, G. R. Free, and W. E. Larson

Merely placing some seed in the soil is not enough.

Seeds need a physical and biological environment in which efficient use is made of soil, water, and nutrients. Different crops require different soil conditions and climates.

Growers, farmers, scientists, and agricultural engineers have worked for a long time to determine the soil conditions plants need and to design and develop equipment and practices to create those conditions.

One approach has been to isolate physical and biological factors of soil to determine their separate and combined effects on plant growth and the physical condition of soil and then develop equipment and practices that will achieve the desired condition.

The physical conditions are described in terms of the status of gaseous, liquid,
and solid phases and the stability of the soil framework or structure. Cropping and weather changes the physical condition from year to year—even from day to day.

The soil is manipulated to promote the movement of air, water, and roots through the soil for the better growth of plants and to control runoff and erosion.

The movement of air, water, and roots is related primarily to the size and continuity of the soil pores.

Bulk density of soil is a measurement of space available in the soil for air and water. It measures the denseness of the soil but not the size and distribution of its pores. Soils of different textures can have the same bulk density and total air and water space but a different size and arrangement of soil pores. Soil bulk density thus is only a rough—but practical—measure of the general physical condition of the soil mass.

A specific soil density is hard to get and may be unnecessary. For medium-textured soils for corn and small grain, as in Iowa, a bulk density range of 0.9 to 1.4 grams per cubic centimeter seems to have little effect on crop growth. The soils at time of preparation and throughout the season were well within that range for most methods of seedbed preparation.

Crops do not grow well when seedbeds are too loose. Neither do they do well in high densities, as in some natural subsoils or in places where heavy loads drawn over wet fields have compacted the soil. The intake of water from rain or irrigation generally increases as the density decreases.

Soil temperature affects plant growth and can be modified by tillage practices. Tillage affects soil temperature through its effect on compaction, moisture, surface roughness, configuration, and shading and reflection by plant residues or other materials on the surface. They make it hard to separate the effects of temperature.

The early growth of corn increases with soil temperatures from a minimum of about 50° to 80–90° F. Then it drops. For many warm-season crops like corn, differences in soil temperature early in the growing season due to tillage methods become progressively more pronounced from south to north because temperatures in the north are oftener near the minimum level for growth.

Methods of seedbed preparation that leave plant residues on the surface usually cause reductions in soil temperature. Soil temperatures are lower in the crop row when seed is planted in furrows. They are higher in the crop row when planted on ridges. Rough surfaces also may raise the temperature of the soil.

Under normal growing conditions, most locally adapted crops tolerate greater changes in soil temperature than can be brought about by the manipulation of the soil during preparation of the seedbed. These differences in temperature may be critical only during abnormally cold and wet springs.

A major function of seedbed preparation systems is to control the soil moisture.

The problems in humid areas are concerned mostly with excesses at planting time, deficiencies later in the season, and adequate control of runoff and erosion at all times. The problem in the drier areas is largely one of conservation of needed moisture by preventing losses from evaporation and runoff.

Tillage systems that help get rid of excess water in the spring without erosion but retain sufficient moisture for full-season growth of crops are desirable in the humid areas. Seedbeds that absorb and retain maximum amounts of water without runoff and wind erosion are needed in the drier areas.

The microbial activity in the soil influences the availability of nutrients and soil structure. Tillage can affect markedly the microbial activity through its effect on the interrelationships of soil moisture, soil temperature, and aeration and also through
placement of plant residues. The requirements for high microbial activity are similar to those of growing plants. This means that the systems of seedbed preparation that create warm, moist conditions early in the season usually are best suited for both microbial activity and for growth of higher plants.

The properties in soils that influence conditions of plant growth determine the methods and equipment used for preparing the seedbed. Their interrelationships and relative importance depend on the conditions of crops, soils, and climate.

A large number of tools are used to prepare seedbeds.

Seedbed preparation can be broken down generally into primary and secondary tillage.

The moldboard plow is the tool most commonly used for primary tillage. It cuts the soil loose from the furrow. Then it shatters and inverts the furrow slice. Highly polished steel plow bottoms are used in places where scouring is a problem. Chilled cast-iron bottoms are more abrasion-resistant than steel bottoms and are used on gravelly or stony soils.

The shape of the moldboard determines the degree of soil pulverization and inversion that occurs during plowing. The shapes vary from a long, gradual curve, which gently inverts the furrow slice, to the short, abruptly curved moldboard, which shatters the furrow slice as it is being inverted. The general-purpose plow bottom falls about halfway between these extremes and does satisfactory work in many situations.

Many shapes of moldboards have been developed for specific needs. For example, the blackland plow with its small moldboard area improves scouring. The slatted moldboard is used for the same purpose.

Disk plows also cut, shatter, and invert the furrow slice. The inversion of the furrow slice is not so uniform or complete as with the moldboard plow. Disk plows leave plowed fields in a rough, cloddy condition. They operate well in hard, dry soils, in stony and stumpy fields, and in push-type soils, such as peat lands.

For shallow plowing, smaller disks, 20 to 24 inches in diameter, are uniformly spaced 8 to 10 inches apart along a common axle so that a gang of disks rotates as a unit. It is commonly called a vertical-disk plow or a one-way disk plow. It is used for shallow plowing and mixing crop residues with 3 or 4 inches of soil.

Tillage tools that cut and shatter the soil without inverting it are referred to as field tillers, field cultivators, subsurface tillers, and now and then as plows. They very often consist of a framework (pull-type or tractor-mounted) and standards to which are attached various soil-working implements, such as spring-tooth points, shovels, sweeps, and chisels. The standards may be ridged or made of heavy coil springs. The depth of operation, spacing of the shanks, and the soil-working tools that are used depend on the soil condition desired. Most of these implements are operated at plow depth. Where it is desirable to leave most of the trash on the surface, a few shanks with wide sweeps work best. Where there is less trash and some mixing is desirable, smaller soil-working tools placed close together are better and pulverize the soil more.

The secondary tillage operations are performed to pulverize the soil more, kill weeds, level the surface, and pack the soil into a firm seedbed. Of the several types of harrows, the most popular is the disk harrow. Heavy-duty disk harrows frequently are used as primary tillage tools to cut up and mix soil with crop residues and to control weeds. The lighter units are used to cut up crop residues before plowing and pulverize and pack the seedbed. Spring-tooth harrows and field cultivators are used for this same purpose.

The final field operation before planting usually is done to pulverize, level, and pack the soil surface. Spike-tooth and spring-tooth harrows, tread-
ers, and rollers are some of the tools. Special equipment is required for some tillage systems. Furrow planting requires listers, middlebusters, or disk furrow openers. These may or may not be attached directly to the planter. Bed or ridge planting requires tools to construct ridges. Plows, lister bottoms, disk hillers, and bedding tools are commonly used.

For loose, finely divided seedbeds for gardens, the rotary tiller, which cuts the soil into small clods and thoroughly mixes residues, has become popular.

Nearly every farmer has worked out his own special technique for preparing seedbeds. In general, crop residues are cut up or removed, and the land is plowed. Occasionally sod crops are plowed under without cutting or removing. This is followed by harrowing or rolling operations, or both; they make a firm, finely pulverized seedbed.

We can call this the conventional way. It works well over a wide range of soils and climates for many crops. Crop residues are turned under for rapid decomposition. The numerous field operations are rather expensive, but many of them can be accomplished during the off season—late fall or early spring. With no surface residues and a finely pulverized seedbed, the conventional system makes for efficient and effective planting.

It leaves the soil susceptible to runoff and erosion, though. It is costly, and often the many trips over the field destroy tilth, produce compact seedbeds, and tend to seal the surface and reduce water intake. This type of seedbed is ideal for weed growth. Excessive manipulation of soil became common when tractors became available to most farmers. The attitude was, “if a little is good, then a lot should be better.” Seedbeds were prepared by working the soil until a finely divided, packed condition existed at planting time.

The weight and movement of heavy equipment on soil at a moisture level suitable for compaction and even puddling and the excessive working of soil at the dry end of the moisture scale were the extremes of practices that prevailed. Sometimes soil was worked too much as a rather futile attempt to correct damage done by plowing when the soil was too wet. People soon learned that a lot of this working of the soil was unnecessary for good crop production and led to excessive runoff and erosion. The general trend now is toward less soil manipulation during preparation of seedbeds.

New tillage systems have been developed to aid in creating the desired seedbeds. Three general methods are used to utilize available moisture more efficiently: Surface roughness—rough, cloddy seedbeds erode less easily, have a more rapid rate of water infiltration, and tend to have less surface sealing than finely pulverized seedbeds; surface configuration—listing, ridging, and bed planting are examples of this type of seedbed that utilizes a surface shape to control water; surface mulching—to increase intake of water and prevent runoff and erosion.

Minimum tillage generally refers to a method that requires fewer field operations than the conventional practice. Plowing usually is delayed until planting time. The result is a rough, cloddy condition between the rows and a firm, finely pulverized seedbed in the row. On coarse or medium-textured soils at the proper moisture content, it is possible often to pull a planter directly behind a plow, thereby reducing seedbed preparation and planting to one field operation. Plowing at planting time and planting in the tracks of the tractor wheel or packing wheel is another form of minimum tillage. Various other schemes have been tried. Clodbusters, rotary hoes, treaders, or other similar tools are pulled directly behind the plow to break up the larger clods; planting is in the conventional manner or in wheel tracks.
The minimum-tillage systems that utilize surface roughness lower the costs of seedbed preparation by eliminating some of the field operations entirely and by combining others. Aeration and intake of water are increased. Weed growth is less in the loose, cloddy area between the rows.

These systems also have some disadvantages. Getting crop stands may be a problem. Excessively cloddy conditions, from plowing too wet, make it difficult to obtain good seed contact with the soil. The planting operation is slowed down to plow speed. Many farmers planting large areas cannot afford to prepare seedbeds during this critical planting time and prefer to plow in the fall or early spring. Control of weeds in the row frequently is a problem. Early cultivation with the rough, cloddy condition between the rows is sometimes difficult.

Listing, middlebusting, ridge planting, and bed planting can be classified as seedbed preparation systems that utilize surface configurations. With them the surface is manipulated so that a corrugated or ridge-furrow surface profile is obtained. With listing and middlebusting, crops are planted in the furrows; with ridging and bed planting, the crops are planted on top of the ridges. These systems were developed mainly to control runoff and erosion or to improve wet conditions. Some of them require fewer field operations than the conventional practice. Each has many variations in terms of practices and tools used.

Middlebusting and listing are similar in that the crop is planted in the furrow. When done on the contour, they hold the water well until it can soak in. Weed control by subsequent cultivations is made easier by having large amounts of loose soil to throw into the row to cover weeds. Often the temperature in the furrow is low, and the moisture is too high. This leads to poor emergence and slow early growth of crops. Sometimes the soil erodes into the furrow and forms a crust that reduces stands.

Ridge and bed planting have the same conservation features as listing. In addition, the soil temperature early in the season usually is higher on the ridges. Because of the ridged configuration, the soil tends to dry out more rapidly. This usually makes for more rapid emergence and faster earlier growth. Subsequent weed control is more of a problem with these two systems than it is with listing or conventional methods. Where beds or ridges are maintained for several seasons, plant residues may become a problem both with the planting and the cultivating operations.

The number of field operations required for the configuration systems varies considerably. Under some conditions only one field operation, such as diskin, is required before planting. At the other extreme, more operations are needed than for the usual way.

Mulch tillage utilizes a surface mulch for soil protection. The kind and amount of mulch varies according to the crop to be grown, the previous crop, the availability of mulch material, and other factors. Straw, wood chips, sawdust, paper, and plastic sheets are some of the materials that have been used as carried-in mulches for special situations, such as nursery plantings. Interseedings and finely pulverized surface soil have also been used as mulches. Some mulches protect the soil and suppress weeds. The commonest type is the residue from the previous crop.

Tilling or loosening the soil while leaving the previous residue on the surface can be accomplished with field cultivators, one-way disks, double-cut plows, and subsurface sweeps. This system has been most widely accepted and has frequently become the normal seedbed preparation practice for small grains in the regions where moisture conservation is essential and wind erosion is likely. The mulches reduce erosion and increase the rate of water intake. Often the number of field operations equals or exceeds that of the conventional practice.
PREPARING THE SEEDBED

This system has been used for corn with varying degrees of success in the more humid areas. Planting and cultivating operations are somewhat impeded because of the large amount of residue on the surface. The amount of soil moisture sometimes is excessive under these mulches early in the season, and temperatures tend to be reduced. Emergence and crop growth early in the season often are slowed down. Shallow-cultivating tools (such as weeders, rotary hoes, and drag harrows) and sweep-type cultivators work less well in mulches.

Some form of mulch tillage is rather widely used for seeding or renovating pastures. Grassland drills are used in the South to seed cereal crops in pasture. At the time such seedings are made, the erosion control resulting from residue mulch protection is highly desirable, and any depression of soil temperatures may be beneficial. The mulch is the growing, undisturbed sod between the drilled rows.

Most of the tillage methods we have discussed use the plow or cultivator as the basic or primary tool. Various forms of rotary implements have been used for preparing seedbeds. Early forms of this type of equipment damaged the structure of the surface soil, but newer tools leave the soil in a less finely pulverized state.

Much conflicting evidence is at hand as to the crop yields obtained with different methods of preparing seedbeds. With high levels of fertility, uniform stands, adequate moisture, and uniform control of weeds, yields of corn obtained with the various systems in Iowa have not been materially different. When those factors were not constant, the differences in the yield often were substantial. That also is true for other crops in other areas.

Most of the available data, however, do not include the long-term cumulative effects of less runoff, better erosion control, less field traffic, better drainage, and general improvement of soil structure that can be obtained with some of the methods we have discussed.

Under extreme conditions of moisture or temperature, yields from some of the systems are greater than from others. For example, listed corn, which starts slowly, has far outyielded conventionally planted corn when a critical shortage of moisture occurred during the pollination period of the conventionally planted corn but not during the pollination period of the listed corn. Similarly, ridge- or bed-planted corn has yielded 50 or 60 bushels per acre, compared to 5 or 10 bushels for listing or conventional tillage when flooding occurred shortly after the corn emerged.

Under normal conditions, the crop yields can be maintained at a high level with any of the systems discussed. It is difficult to generalize on the relative costs of the various practices. Preparation of the seedbed is only part of the whole farming operation. Tillage costs vary from farm to farm. Cost analyses of the various practices, however, indicate that the conventional practice is more costly than the others, particularly when charges are made for soil loss. With minimum-tillage systems, it is usually necessary to prepare the seedbed and plant at the same time. Where the planting seasons are short and acreages are large, speed of planting becomes critical. When a reasonable charge is assigned to these systems for this factor of timeliness, their costs approach that of conventional practices.

A farmer should choose his method of seedbed preparation on the basis of efficient and effective use of power and labor available as well as on soil conservation and crop yield.

How will seedbeds be prepared in the future? Engineers and crop and soil scientists generally concede that we have been doing too much rather than too little tillage. The soil should be worked only enough to insure satisfactory stands and to control weeds. Many of our field operations in seedbed preparation have been aimed at
weed control only. The recent and future developments in herbicides indicate that it may be possible to control weeds without tillage. This should lead to further reductions in field operations.

This type of approach has been successful to a limited extent in corn production. Where the soil factors of soil density, moisture, and temperature were not critical, it was possible to control weeds with chemicals and prepare seedbeds by attaching a cultivator sweep or a similar tool in front of the planter furrow opener. This system takes advantage of the conservation features of mulch tillage and provides a finely pulverized firm area in which to plant the seed with practically no tillage. Planter attachments for applying insecticides and herbicides in either the spray or granular form make it possible to control subsequent infestations of weeds or insects without additional field operations.

On steeper slopes where erosion is a problem, a surface configuration technique will probably be used. Contour ridging or contour listing could very well be the answer. Replanting in last year’s crop rows not only looks feasible but in some instances very desirable.

Sources of power are changing rapidly. Some day it may be economically feasible to utilize atomic or other similar power for farming operations. Unlimited power may make it feasible to mix soil to obtain a uniform mass ideally suited for a particular crop as well and to level and smooth large areas for more efficient use of large equipment.

The development of new methods and materials, particularly agricultural chemicals, along with this large source of power may make it possible to control soil temperature, soil moisture, biological activity, weed growth, soil insects, and nutrient supply.

For the immediate future, engineers and scientists will continue to study what is needed for a seedbed and how to prepare it. Advances in tillage techniques, fertilizers and their application, and pesticides and their application may make it possible to prepare a seedbed, plant, and control weeds and insects in one field operation.

Management of Fallow

J. S. Robins and B. D. Blakely

Summer fallowing is a land management system in which crops are produced every other year or two years in three rather than annually. The extended time between crops is designed primarily to store moisture for use by the succeeding crop. Buildup of nutrients in the soil is a second beneficial result.

Research and experience have led to general use of the system in the 10- to 20-inch rainfall areas of the Great Plains States, in the Pacific Northwest wheat area where rainfall is less than about 16 inches, and on extensive acreages in California. Even with summer fallowing, however, crop production throughout these areas is limited by insufficient moisture and recurring drought.

To store maximum moisture, the land must be kept relatively free of weeds and volunteer crop growth during the moisture-storage period. This usually means periodic tillage in excess of that necessary for normal seedbed preparation. This can be done in several ways. However, each tillage operation breaks up and covers crop residues and tends to destroy the cloddy structure of the surface soil. Severe wind and water erosion consequently are frequent byproducts of excessive tillage during the long cropless periods of summer-fallow systems.