Outline of Chapter 7

7. TILLAGE AND TILLAGE PRACTICES

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LEARNING OBJECTIVES

This chapter should enable a a student to:

- State the basic concept of tillage and tillage practices.
- Describe the main tillage implements used in Pakistan, and tell the most important uses for each of them.
- Given a specific location, soil type, and crop, decide on the most appropriate tillage practices and tillage implements.
- Discuss the concept of minimum tillage.

Tillage is usually defined as the mechanical manipulation of the soil aimed at improving its physical condition or **tilth**. Tillage can also be described as the practice of modifying the state of soil in order to provide conditions favorable to crop growth. According to Prihar (1990:253), tillage is defined as the physical manipulation of soil, and it is intended to destroy weeds, incorporate crop residues and amendments into soil, increase infiltration and reduce evaporation, prepare seedbed, and break hard layers to facilitate root penetration. In general, tillage is a group of field operations carried out in the process of field crop production, the main purpose of which is to increase crop yield and to prevent yield or economic losses by reducing the costs of production. Tillage practices differ from one area to another depending upon soil type, cropping pattern, soil moisture (rainfed vs. irrigation), and climatic factors.

The primary aims of tillage are generally described as:

- Production of a suitable tilth, or soil structure
- Control of weeds
- Control of soil moisture
- Incorporation of organic matter (manures and fertilizers), and agrochemicals for weed and pest control.

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For good plant growth and development, soil must be permeable to allow enough water to infiltrate and provide good aeration for gaseous exchange. The purpose of the tillage operation is to cut, loosen, granulate, and invert the soil; to bury residues; and to prepare a seedbed to provide appropriate soil and water environmental conditions for plant growth and development. In addition, tillage performs the following functions: breaking hard clay plough pans and compactions, roughening soil to prevent soil erosion by wind and water, bringing the subsurface soil layers to the surface, improving surface soil structure, and improving water-holding capacity.

7.1 Objectives of tillage

There are several major objectives of tillage.

1. Improve soil tilth and prepare a seedbed.
2. Manipulate plant residues and farm wastes.
3. Manage water and air in the soil.
4. Control weeds and soil-borne insect pests and diseases.
5. Establish a surface layer which prevents wind and soil erosion.

These are discussed in the following paragraphs.

7.1.1 Preparation of seedbed

The desirable characteristics of a seedbed are:

- Weed-free soil, which prevents the loss of precious water and plant nutrients to weeds.
- Granular soil structure, which allows close contact of the seed and the plant roots with soil particles. It also facilitates penetration of air and water. Different soil types require different management to produce a seedbed of desirable tilth.
- Soil free of compacted layers, which reduce air and water penetration and inhibit root development.
- Generally level soil surface which facilitates planting seeds at a uniform depth and is especially important for proper water management in irrigated areas.

There are many methods of seedbed preparation. As the number of acres farmed by one person and the cropping intensity increase, there is an increasing demand for more efficient tillage management.

7.1.2 Manipulation of plant residues and farm wastes

In some areas virtually all of the plant residues—straw, stubble, fodder, and even roots—are utilized for animal feed and fuel. However, with some crops there is a good deal of crop residue left in the field which, if buried in the soil, can increase its organic matter content. Incorporation of organic matter into the soil results in: (a) increased soil fertility, (b) increased water penetration and water-holding capacity, and (c) enhanced soil microbial activities. However, the problem of how and when to handle crop residues must be addressed.

Decaying organic matter ties up the soil nitrogen supply for some time, so a small quantity of chemical nitrogen fertilizer should be added to the soil. The presence of straw or crop residue causes mechanical problems in the irrigated areas, especially in cereal farming, as the straw and stubble clog the tillage implements and seeding drills. In rainfed areas, however, leaving some straw in the field as straw mulch is desirable for conserving soil moisture and preventing wind and water erosion.

7.1.3 Managing water in the soil

Tillage practices vary widely depending on the soil type, climatic regions, and crops. In irrigated areas tillage operations are mainly directed at destroying weeds, stubble, and root systems of previous crops and improving the physical condition of the soil for proper seedbed preparation. Tillage plays an important role in irrigated areas. Fields must be level and smooth with proper slope and drainage. Sometimes beds are prepared for growing various crops; this allows for both irrigation and drainage.

In areas of low rainfall, and where crops are produced under rainfed conditions, the main need is to conserve soil moisture and reduce evaporation and soil erosion. In the semiarid areas of Pakistan, water management is critical. Limited moisture for crop growth is often the major limiting factor for crop yields. Successful tillage systems and practices have recently been developed specifically for proper moisture conservation in the rainfed areas (Khan et al. 1986), and a large array of tillage implements has been tested.

Farmers of the barani areas normally do 8–10 shallow ploughings with a cultivator for moisture conservation of rainwater. But instead of rain moisture conservation, these excessive shallow ploughings cause compaction, and a hardpan is developed. They not only restrict water infiltration deep into the soil profile, but also restrict the penetrating roots searching for moisture and nutrients. Thus crop growth and development are affected. One deep ploughing with a mouldboard plough before the onset of the summer monsoon rains as primary tillage, and two ploughings with a cultivator along with planking just before the end of monsoon rains are the best tillage systems for better moisture conservation. This system is also effective for termite and weed control for the coming rabi season crops such as wheat, barley, lentil, and chickpea. Since dryland farming often involves large areas of open land, this is the area where large machines are most efficiently used.

7.1.4 Controlling weeds

For many centuries, little was done to control or eliminate weeds. A lot of backbreaking manual labor was devoted to weed control but with little success. Nowadays, with the use of mechanical tillage practices, weeds can be controlled effectively and economically. However, chemical weed control through various herbicides is also being practised successfully.

7.1.5 Preventing wind and water erosion

Since the semiarid lands are rainfed areas and are often subject to wind and water erosion, an acceptable and appropriate tillage system must provide for soil erosion prevention and control. For example, one mouldboard ploughing with planking followed by two ploughings with a cultivator and planking will create rough soil surfaces containing clods from .5–5 cm which will help control both wind and water erosion. The excessive ploughings done by barani farmers will destroy the soil structure resulting in soil and water erosion.

7.2 Effect of tillage on soil conditions

A large volume of scientific literature is available both in Pakistan and abroad on how tillage affects crop production under different agro-climatic conditions and farming systems. Tillage directly affects many elements of the biological complex in which crop plants grow. Some of the main effects of tillage are discussed in the following paragraphs.

Effect on soil moisture. Tillage practices and systems have been developed to facilitate water penetration into the soil and increase the amount of water retained for crop use later. Table 7.1 gives the results of a study on the effects of tillage treatment on soil moisture in the rainfed areas of northern Punjab (Hobbs et al. 1986). The soil moisture data in the table clearly show greater moisture differences at the 15–45 cm depth range. The higher moisture content with the mouldboard plough indicates that better water infiltration deeper into the soil profile resulted from loosening of the compact layer. This tillage method is preferable to continuous shallow ploughing with a cultivator.

Table 7.1 Effect of tillage treatment on soil moisture percentage (just before planting wheat in the 1984–85 rabi season in barani area)

Tillage treatments	Soil moisture at depth 0–15	15–30	30–45	Mean
MB plough	12.02	14.58	16.70a	14.43a*
Cultivator	11.74	11.22	10.36b	11.11b

* Figures followed by different letters are significantly different at the p<0.5 level using Duncan's multiple range test.
Source: Hobbs et al. (1986:10).

It is unfortunate that many farmers either do not understand the concept of moisture conservation and tillage and its importance, or they do not have the equipment required to do the job properly. Excessive shallow tillage operations result in increased soil compaction which restricts root growth, impedes air exchange, and also creates problems in soil drainage.

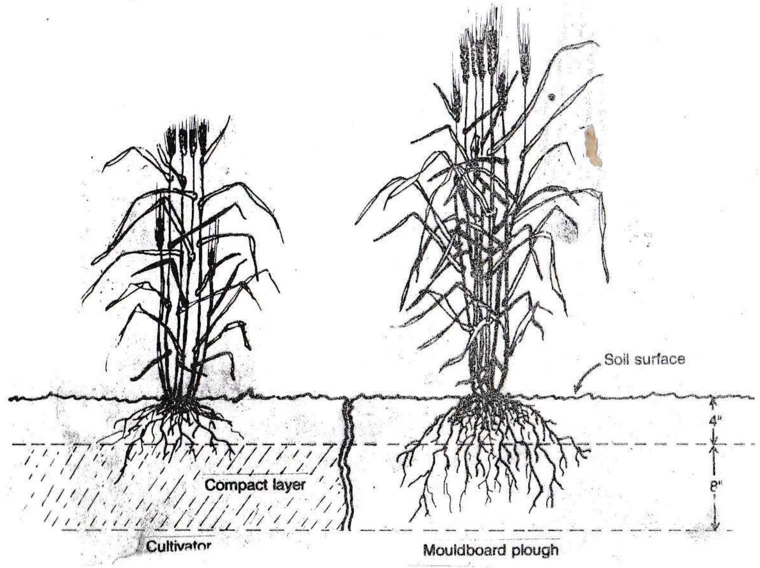

Figure 7.1 Wheat rooting profiles of cultivator and mouldboard plough treatments in February **following drought in the 1983-84** rabi season in Rawalpindi Distt. Redrawn by Habib-ul-Rahman Mian following Khan et al. (1986:145).

The soil contains not more but less water, and its physical structure is broken down. This prevents water infiltration and encourages soil erosion. Figure 7.1 illustrates wheat rooting profiles as influenced by shallow ploughing with cultivator and mouldboard plough treatment (Khan et al. 1986).

Soil water retention. The pore-size distribution resulting from loosening the soil affects its ability to retain moisture against applied suction as well as its water transmission characteristics. Tillage also affects soil water retention by changing surface tension, infiltration and redistribution, and evaporation of water from soil. However, the direction, duration, and magnitude of effect depends upon pre-tillage operations and climatic conditions.

The rough soil surface and depressions caused by tillage decrease runoff. Retention of rainwater in surface depressions increases the time available for water to percolate into the soil and, thus, water intake into the soil. This results in storing part of the rainwater in the soil profile. The nature and magnitude of soil surface roughness differs with soil type, implement used, the number of ploughing passes, and moisture status at which the tillage operations are performed. The effectiveness of the rough surface also depends on the intensity and amount of precipitation and the stability of soil aggregates. Soil with less stable aggregates on the surface is readily dispersed by high intensity rains, which reduces infiltration and increases runoff and potential soil loss.

Infiltration. Apart from prolonged retention in depressions, tillage also enhances infiltration of water if large voids are produced in a soil layer that is impeding infiltration, and if these voids are maintained for sufficient time. Tillage must penetrate the limiting layer completely, otherwise only surface storage is increased. Henderson (1979) stated that the major factor determining the effect of tillage in infiltration was the structural stability of the soil. In structurally unstable soils, the surface layer that slakes repeatedly under wetting and drying becomes relatively impervious, limiting infiltration.

Effect on soil structure. Tillage directly affects the roughness and bulk density of the soil. These factors in turn directly affect water infiltration, crusting, and compaction, which in turn affect seedling emergence, root development, and nutrient uptake. The immediate effect of tillage is to loosen the soil and decrease its bulk density. Different tillage practices produce different bulk densities, and alteration in the bulk density of soil changes its porosity, inter-particle contact, and volume of water content. Change in bulk density changes the fraction of all three soil components—mineral matter, organic matter, and water.

Effect on soil temperature. Research has shown that different tillage practices result in differences in soil temperature. For example, straw or stubble mulch usually decreases soil temperature. This may be an advantage in the fall season, allowing earlier seeding and promoting profuse tillering of wheat and barley. In the spring, however, it may be a disadvantage when seeding would be delayed or when the growth of fall-seeded crops would be retarded.

Effect on evaporation. Evaporation from the soil is a major pathway of water loss created by tillage. Surface roughness caused by loosening of the upper soil layer by tillage increases the area of soil exposed to the atmosphere and allows greater penetration of wind. This results in increased evaporation from tilled compared with untilled soil. Soil mulch and straw mulch tillage systems reduce these evaporation losses, which is extremely important in rainfed agriculture.

Effect on soil microorganisms. Soil microorganisms control and maintain the productivity of agricultural lands by continually recycling and regenerating essential plant nutrients from crop residues, humus, and other forms unavailable to plants. Consequently, if tillage affects temperature and moisture and manipulates crop residues, it will certainly affect soil microorganisms (Sommers and Biederbeck 1973). Appropriate tillage practices will improve the soil structure, moisture, air, and temperature, which will ultimately increase the number and activity of microorganisms. These microorganisms are responsible for degrading complex substances into simple ones, e.g. plant tissues into humus, and organic manures and fertilizers into inorganic mineral fertilizers through the process of mineralization. Soils with good structure and texture, having good porosity, aeration, moisture, and temperature, will have two to three times more microbial activities than poor tilth soils having low porosity and poor structure, air, and moisture.

Effect on soil nutrient uptake. Nitrogen (N) is probably the nutrient most affected by tillage, although both phosphorus (P) and potassium (K) are also influenced. Incorporation of organic matter and changes in the amount and location of soil water are the factors that cause most of the fluctuation in nutrient levels. The tillage effect can either be positive or negative for a given time and set of agro-climatic conditions. Warm moist soil has greater microorganism activity, which results in greater mineralization of N, and in turn results in its higher uptake by plants (Standford et al. 1973).

7.3 Effect of tillage on diseases and insects

Crop residues left on or near the soil surface often provide favorable conditions for disease and insects. Residues may be the main vector for the carryover of pathogens from one season to the other and from one crop to the next. Deep tillage of the soil with a mouldboard plough to bury wheat stubble reduces the incidence of root rot and termites (Khan et al. 1990). Table 7.2 displays the effect of tillage treatments on insect and disease damage to wheat. Deep tillage with the mouldboard plough is much more helpful in reducing losses from disease than shallow tillage treatment with a cultivator.

Table 7.2 Effect of tillage treatments on crops damaged by insects and disease (1983–84) (n = number of plants examined.)

Affected by	Percent of plants affected	
	Mouldboard plough (n=1732)	Cultivator (n=2522)
Root rot	7.1	19.3
Termites	1.0	10.3
Total	8.1	29.6

Source: Adapted from Khan et al. (1990:82).

7.4 Tillage implements

A variety of tillage implements are used to weaken soil strength, reduce compaction, and allow the free movement of air and water in order to promote plant growth. A wide array of different tillage implements are used in the country for primary tillage and seedbed preparation, and for crops. These tillage implements range from the light animal-drawn *desi* plough to heavy implements drawn by high-powered tractors. Different tillage implements have been designed and are used for various operations depending on the kind of soil, type of cropping, and agro-climatic conditions. These include the mouldboard plough, disc plough, disc harrow, chisel, subsoiler, cultivator, and rotavator. In selecting any set of implements for tillage practices, the farmer has to consider both energy requirements and tilth conditions. All the tillage implements are of great importance when considering their effects on crop production. Their characteristics are described in the following paragraphs.

7.4.1 Desi or local plough

This plough has been used for centuries and is still being used in many areas of the country. The whole plough is made of wood except for the iron share. This is a traditional multi-purpose plough. Its main uses are summarized as follows.

- Dry ploughing. In this case a large share is used. Ploughing is done under low soil-moisture conditions. It is generally done for turning crop residues into the soil after harvesting the crop and also to open up the soil for further field operations.

- Wet ploughing. Ploughing is done after a soaking irrigation when the land is in proper condition. A medium share is used.
- Drilling. For drilling and seeding, a drill tube is attached to the wooden handle and a small iron share is commonly used.
- Interculturing in cotton, maize, sugarcane, and other economic crops.
- Puddling or ploughing in standing water, especially in rice-growing areas, is done to break the hard crust of the soil before transplanting rice.

Although the local plough (*desi hal*) is drawn easily by bullocks or camels, it does not really perform the functions of a plough, i.e. cutting, opening, and inverting the soil. Some of the main advantages of an iron plough over the local or *desi hal* are given below.

- It cuts a rectangular furrow and leaves no uncut land between the contiguous furrows.
- It uproots weeds and buries them in the ground completely. It is, therefore, very effective for cultivating lands infested with grassy weeds.
- The lower soil is brought up to the surface and exposed to the action of air and sun. Grubs of insects are also exposed and eaten by birds. The Meston plough, Hindustan plough, Sindhi plough, and Sarhadi *hal* are some of the traditional ploughs still in use for cultivation in many parts of the four provinces of the country.

7.4.2 Meston plough

The Meston plough is similar to the heavy type in construction, but its parts are smaller and lighter. It is also a lighter draft. The plough has a wooden handle and a long wooden beam with an iron body. The share is a complete type, with the mouldboard on the left side. This plough is commonly used for both wet and dry ploughing, for land preparation, and for weed control. It is useful for the light soils which are found throughout almost all of the country, especially in the submountainous tracts where bullocks are small and weeds grow abundantly in the rainy season (Fig. 7.2).

In addition to the traditional local ploughs and other small tillage tools which have been in use for years, some new heavy mechanically drawn tillage implements have been designed for specific purposes.

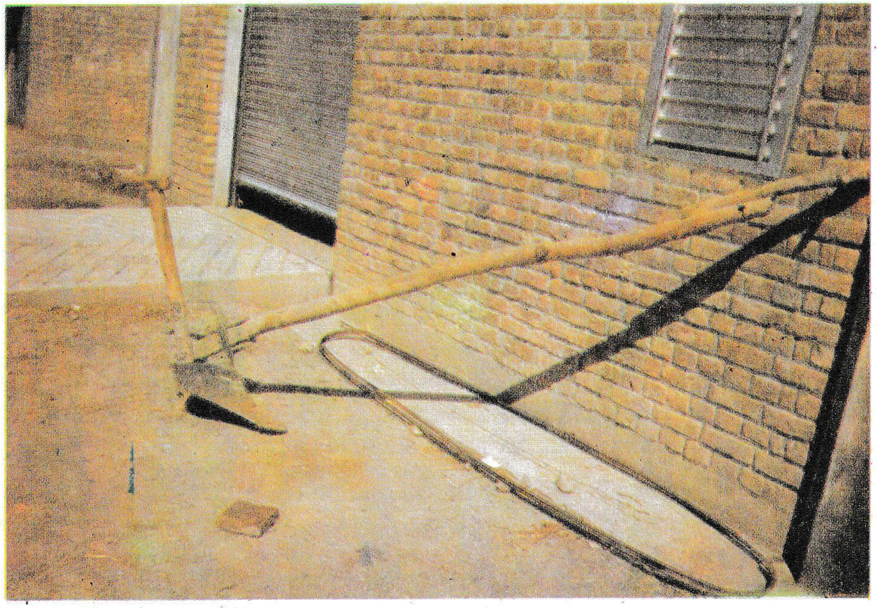

Figure 7.2 Local Meston plough

7.5 Primary tillage implements

Primary tillage is mainly an operation of cutting and pulverizing the soil to a desirable depth, and inverting it to bury crop stubble and weeds deep in the soil. The most common primary tillage implements and their specific functions are as follows.

7.5.1 Mouldboard plough

This is one of the most common and important primary tillage implements. It can effectively break many types of soil. Its basic function is to cut, invert, and pulverize the soil up to a depth of 20–30 cm. It has the ability to turn over and cover sod, crop residues, and weeds. The width of the ploughshare varies from 25 to 30 cm. This is the most efficient implement for loosening and pulverizing soil and eradicating deep rooted weeds (Fig. 7.3). The mouldboard plough consists of two to seven coulters that can be attached to the draught of a hitching tractor. Some mouldboard ploughs, also known as reversible ploughs, have two sets of opposed coulters that can be used selectively. The mouldboard plough is made up of the blade, share beam, furrow wheel, jointer, and three-point hitch to mount on a tractor.

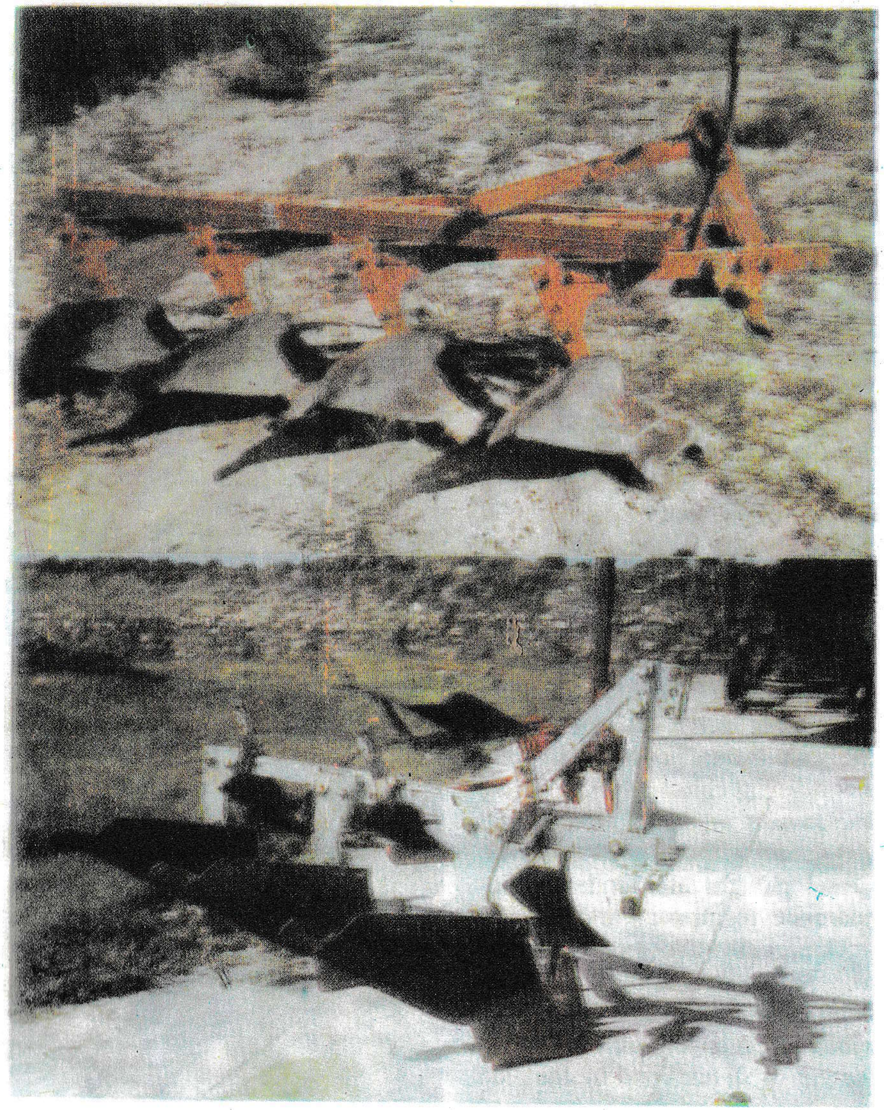

Figure 7.3 Front and side views of a mouldboard plough

7.5.2 Disc plough

The disc plough is another important primary tillage implement used throughout the country (Fig. 7.4). Because of its inclined disc blades it does not cut, invert, or pulverize the soil as deeply as the mouldboard plough. Thus it is less effective for those tasks than the mouldboard plough;

however, it is more effective in breaking clods in heavy soils. It consists of concave, round discs of hard steel, 50–75 cm in diameter. The unit draught of the disc plough is usually higher than that of the mouldboard plough. The disc plough penetrates the soil by its own weight and therefore impacts the soil. It leaves a rough soil surface and causes less uniform pulverization than the mouldboard plough. The disc plough is traditionally used for partial burial of crop residues and for soils with rocks, stumps, and tree roots. It is mainly recommended for dry ploughing conditions.

Figure 7.4 Disc plough

7.5.3 Chisel plough

A wide variety of tined implements is available in the market, ranging from multi-tine subsoilers to shallow-working chisel ploughs. These implements are used to open the soil deeply without turning it over. Chisel ploughs are similar in appearance to rippers and have a working depth more or less equal to the conventional ploughing depth (Fig. 7.5). The degree to which tined implements break up the soil is determined by the tine spacing, working depth, type and width of share, and the condition of the soil. These ploughs are used for a special purpose. After two to three years of normal agricultural practices, particularly in an irrigated area with heavy clayey soils, the pan in the root zone becomes hard, reducing water infiltration and root penetration. This ultimately affects crop growth. Chisel ploughing is usually recommended every three years to break the established hardpan.

Figure 7.5 Chisel plough

7.5.4 Subsoiler

A subsoiler is a form of chisel plough designed to penetrate to a greater depth (Fig. 7.6). This implement can penetrate to a depth of 50 cm to loosen deep soil layers and promote water movement and root growth. The subsoiler shatters the soil but does not invert, pulverize, or bring it to the surface. A lot of power (40–60 hp) is needed to pull one shank of a subsoiler at a depth of 50 cm in heavy soil.

Figure 7.6 Subsoiler

7.5.5 Rotavator

The rotavator or rotary plough can be used both as a primary and secondary tillage implement. It consists of a set of 'L'-shaped blades which are normally mounted with three right-handed and three left-handed blades per flange, but coarser work may be done by using only two right and left-handed blades per flange. These blades, tines, or rods are rotated on a horizontal shaft and covered by a sheet-metal hood. The soil is cut, sheared, and thrown to the hood for pulverization. The rotavator is mostly used for hard, sticky, clay soils in the rice-growing areas to prepare the land for sowing wheat following a rice crop. It is also used for fine seedbed preparation for vegetable production. Although the depth of the tillage does not exceed 20 cm, the power requirement is quite high.

7.6 Secondary tillage implements

Secondary tillage operations are usually performed after the primary tillage operation. Secondary tillage is done to improve seedbed preparation, increase soil pulverization, conserve moisture, destroy weeds and crop residues, and perform final field leveling. Different types of harrows, field cultivators, land levelers, pulverizers, packers, rotary weeders, and rollers are the main secondary tillage implements.

7.6.1 Harrows

Harrows are used for a great variety of purposes, such as preparing seedbeds, covering seeds, destroying weeds, and aerating grasses. Many types and sizes are used to carry out these widely differing functions.

Disc harrow. This is the most common secondary tillage implement. It pulverizes the soil, breaks clods, kills weeds, chops and incorporates organic matter into the soil, and mixes soil amendments. The heavy-duty harrow is

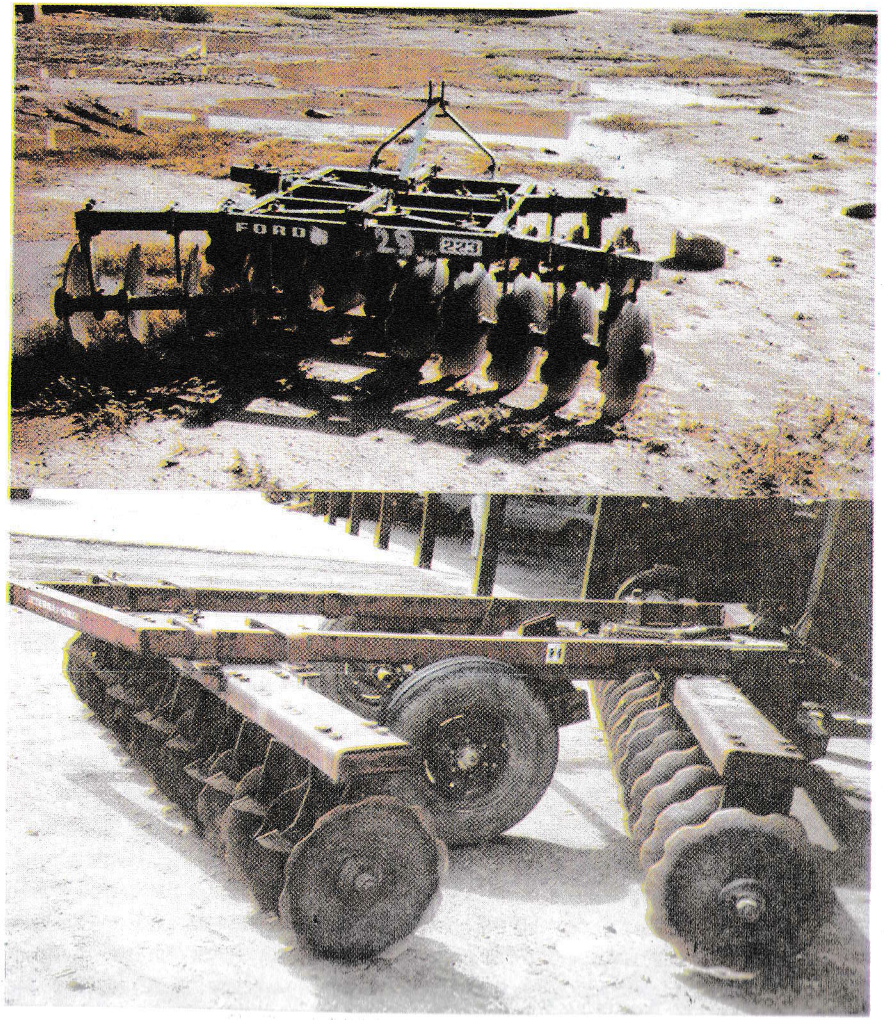

Figure 7.7 Disc harrow

the most common tillage implement today because of its multi-use characteristics. The tillage depth is limited to 15–20 cm, and the soil is compacted below 20 cm by the action of the discs. The disc harrow has a number of saucer-shaped discs mounted on one or more axles, which may be set at variable angles to the line of draught. The discs are generally from 18–24 inches (45–60 cm) in diameter (Fig. 7.7). They rotate as the harrow is pulled along. The precise action and operation, however, depend on the size of the discs, the depth of work, and especially upon the angle at which the disc gangs are set relative to the line of travel.

Spring-tined harrows. The spring-tined/toothed harrow is really a light cultivator which can be adjusted to produce variable effects. Spring-tooth harrows are satisfactory for light tillage with little surface penetration and without much soil compaction. These are effective for light soils like sandy and sandy loam.

Spike-toothed harrows. Spike-toothed harrows are useful secondary tillage implements for pulverizing cloddy soils in a friable state and for breaking up soil crust. They are also used together with a plough or harrow for one-pass primary and secondary tillage combinations.

Figure 7.8 Cultivator

The field cultivator is a spring-tined secondary tillage implement with shovel, sweep, or chisel points which stir the soil and rearrange soil aggregates (Fig. 7.8). Cultivators for light or medium duty tend to use some type of spring tine or spring-mounted tine. A common type for light

'C'-shaped but with a reverse bend at the top where the tine is fixed to the implement frame. Spring-tined cultivators are the most common tillage implements for shallow ploughing, leveling, preparing fine seedbeds, and for interculture to control weeds in standing crops. Spring-tined cultivators are available in 9–13 coulters. Its parts are the shares, coulters, springs, main frame, and three-point hitch. These cultivators require a low draft compared to the mouldboard plough and only cut the soil to a depth of 10–15 cm.

7.6.3 Rollers

The main objectives of rollers are to consolidate the soil, crush clods, and smooth the surface. Consolidation is necessary on some soils to give plants a firm roothold and to ensure continuity between the topsoil and subsoil.

7.7 Crop response to tillage practices

Farmers in Pakistan plough their fields with either animal-drawn ploughs or tractor-drawn, spring-tined cultivators. Farmers are accustomed to doing repeated shallow ploughing for moisture conservation and weed control; in the barani (rainfed) areas of Punjab, they do an average of 7.5 ploughings before planting wheat, and as many as 22 ploughings were reported by some farmers (Hobbs et al. 1986). Similar figures for the rice–wheat areas of Punjab (Byerlee et al. 1985) and the maize–wheat irrigated areas of Mardan, NWFP (Hussain et al. 1985) are six and three ploughings, respectively. The number of tillage operations depends on the previous crop, and is higher for those rainfed areas where wheat follows fallow. This repeated shallow tillage is done to help conserve moisture and control weeds, but this practice develops a compacted, hard plough pan (hardpan) below the ploughed layer. This hardpan not only hinders the percolation of rainwater into the soil, but also affects root growth and emergence of rainfed crops. Moreover, repeated shallow tillage is not an economical practice, and reduction in tillage operations would lower production costs.

Keeping this in view, numerous research studies on different tillage practices have been conducted to determine the most efficient and cost-effective, site-specific tillage practices. Various primary and secondary tillage implements have been tested and evaluated by comparing these practices with traditional tillage practices in the rainfed and irrigated areas of Pakistan. Results of some recent research on deep tillage indicate improvement in soil; reduced weeds, insects, and diseases; and better moisture content and crop yields with spring-tined cultivators than with traditional excessive shallow cultivation (Khan et al. 1986; Khan et al. 1990). Table 7.3 shows the effect of primary and secondary tillage on the grain yield of barani wheat.

Deep primary tillage with the mouldboard plough gave significantly better performance than the other primary and secondary tillage practices.

Table 7.3 Effect of primary and secondary tillage on the grain yield of barani wheat in 1982–83 at National Agricultural Research Centre (NARC), Islamabad

		Grain yield (t/ha) by secondary tillage method				
Primary tillage	Depth (cm)	MB	CU	SW	Disc	Mean
Mouldboard	30	4.50	3.98	4.30	4.46	4.30a
Subsoiler	45	3.90	3.78	3.70	3..82	3.80b
Chisel	25	3.92	3.18	3.60	3.48	3.54b
Cultivator	10	3.70	3.78	3.90	3.50	3.72b
Mean		4.00a	3.68a	3.78a	3.82a	3.84

MB = Mouldboard plough; CU = Cultivator; SW = Sweeps; Disc = Disc harrow. Values followed by the same letter do not differ significantly using a Duncan's multiple range test at the $p<0.05$ level.
Source: Adapted from Khan et al. (1986:143).

Several factors could be responsible for the increased yields with the mouldboard plough. The most obvious would be higher moisture content and better rooting.

Similar results were obtained from primary deep tillage with mouldboard and chisel tillage implements on irrigated wheat yields following rice at Sadhoki, Punjab in 1982–83. Table 7.4 presents data on wheat yield response to ploughing with the deep mouldboard and chisel plough as compared with other tillage practices.

Table 7.4 Tillage effect on wheat yield following rice at Sadhoki during 1982–83

Tillage treatment	Wheat grain yield (t/ha)
Animal-drawn desi plough	4.1b*
Tractor-drawn spring-tined cultivator	4.1b
Spring-tined cultivator + rotavator	3.9b
MB plough + rotavator	4.6a
Chisel plough + rotavator	4.5a

* Values followed by the same letters do not differ significantly at $p<0.05$ level using Duncan's multiple range test.
Source: Adapted from Khan et al. (1986:143).