STUBBLE MULCHING
IN THE NORTHWEST

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Irregular and often steeply sloping topography and a climate dominated by winter precipitation that often falls on frozen or very wet soils combine to make soil erosion by water a very serious problem on wheatlands of the Pacific Northwest. In drier parts of the region, summer fallowing is commonly practiced, and unless vegetation or crop residues are maintained on the land, erosion from water runoff or from wind can be very serious.

As in many other wheat-producing areas, stubble mulching has been found by research and experience to be one of the simplest and most effective management practices to protect land from erosion. Residues from the last crop are used as a mulch, held to the land by standing stubble, to conserve moisture and to prevent the soil from washing or blowing away; thus the term "stubble mulching."

Stubble-mulch farming is a year-round way of managing plant residues on cropland. Harvesting, cultivating, seedbed preparation, and planting are all done so as to leave residues of the previous crop on top of or near the surface of the soil until after the next crop is seeded. Such residues reduce the impact of raindrops on the soil surface and impede the flow of water down slopes, both of which help to control water erosion. The presence of residues on or near the immediate soil surface increases the rate of infiltration of water, and thereby reduces the quantity of water that runs off. Residues on the surface also prevent close contact between wind and soil, and are therefore particularly effective in preventing wind erosion (fig. 1).

This bulletin describes the machinery, and the sequence and methods of operation that have been found best for stubble-mulch farming in the Pacific Northwest wheat areas. Although directed primarily toward solution of erosion problems in that area, the information is applicable, wholly or in part, to other areas in the West where similar problems are encountered.

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Figure 1.—This field is adequately protected from wind or water erosion by mulch and clods on the surface during the summer-fallow season.
FIGURE 2.—The topography of much of the wheat-producing area of the Pacific Northwest ranges from gentle slopes to steep, rolling, dunelike hills, with south and southwest slopes longer and less steep than north and northeast slopes. Steeper slopes are farmed to the operational limit of machinery; in some cases slopes of as much as 50 percent are tillable. Photo taken in the Sky Rocket hills of southeastern Washington.

FIGURE 3.—Severe water erosion on fall-seeded, summer-fallowed land north of Pendleton, Oreg.
**GENERAL AREA DESCRIPTION**

**Topography**

The topography of wheatlands in the Pacific Northwest is extremely varied. Valleys with little slope occur between broken, relatively parallel ridges with long, moderate slopes to the southwest and short, steep slopes—up to extremes of 50 percent—to the northeast (fig. 2). These steep slopes produce the highest crop yields because of a combination of deeper soil, more favorable soil moisture, and less exposure to wind and sun. In many cases, slopes of 50 percent, or to the operational limit of machinery, are farmed. Therefore, when runoff occurs, movement of the water down the slope is relatively rapid, resulting in severe erosion (fig. 3). Channeling of runoff is also common because of the irregular, rolling topography (fig. 4).

Figure 4.—Runoff water following drill wheel tracks made when the field was seeded to fall wheat has caused serious gully erosion (estimated at 50 tons per acre).

Irregularities in topography often make application of certain erosion-control practices difficult. However, cross-slope tillage, stripcropping (figs. 5 and 6), diversion-type terraces (fig. 7), and stabilized waterways (figs. 8 and 9) have been used successfully under a wide variety of conditions. Although more difficult to apply in the Pacific Northwest than in other areas, these practices have generally produced a marked reduction in soil erosion and gully formation.

Figure 5.—Alternate strips of crop and summer-fallow land near Condon, Oreg., break up long slopes, and slow down runoff water, giving it time to soak into the soil and strain out the silt.

Figure 6.—Successful application of stripcropping in a wheat-fallow sequence near Heppner, Oreg.

Figure 7.—Heavy rains falling on frozen or very wet soil can be diverted from long slopes by terraces, and discharged into stabilized channels.
Figure 8.—A grass stand, established in this waterway and maintained by clipping and fertilizing, affords year-round protection from erosion.

Figure 9.—A series of economically constructed, wire-bound, loose rock dams, similar to this one near Walla Walla, Wash., can be used to safely step down heavy runoff on steep gradients.

Figure 10.—Heavy rains falling on frozen soil followed drill marks, severely washing this long slope near Umatilla, Oreg.

Figure 11.—Gully washed to bedrock on frozen soil on a 3-percent slope during a single spring storm.

Climate

The climate of the region is of the Pacific type with winter precipitation predominating. Rains generally begin in October and continue into early June. Precipitation in July, August, and September is usually very low. In eastern Washington and northern and southeastern Idaho, much of the precipitation normally occurs as snow.

During the summer months, daily maximum temperatures usually average in the high 80's or 90's, accompanied by low relative humidity. The diurnal temperature fluctuation is marked during the summer months, with daily minimum temperatures commonly in the 50's and sometimes in the 40's. Daily minimum temperatures during the winter months in east-central Washington and northeastern Oregon are commonly from 10° to 30° F., with frequent subzero readings. In eastern Washington and northern and southeastern Idaho, minimum temperatures are commonly lower, and sustained cold often causes soil freezing, sometimes to depths of 2 or 3 feet in the absence of snow cover. The occurrence of precipitation or melting snow on frozen or very wet soil often causes serious water erosion (figs. 10, 11, 12). Relative humidity during the rainy winter months is usually high.

Wind direction in the major wheat-producing areas is almost always southwesterly. Velocities are highest in the spring and early summer.

This combination of climatic conditions is conducive to a rapid buildup of soil moisture, with probable water erosion during the winter and early spring months, succeeded by rapid dissipation of soil moisture and, in drier areas where following is a common practice, wind erosion during the spring and summer months (figs. 13, 14, 15).
Figure 12.—Heavy spring rains falling on wet soil have washed this ditch in a wheatfield southeast of Walla Walla, Wash., to a depth of 4 to 6 feet.

Figure 13.—This crop of wheat seeded on Quincy sand near Stanfield, Oreg., was almost completely cut off by soil drifting. This means a crop failure as moisture levels are too low to reseed in April.
Figure 14.—This black cloud was first thought to be a rain cloud, but as it came closer it was found to be a cloud of dust that turned daylight into darkness. Such storms can impair not only the land but also the health of people and animals. These storms may occur in areas with light soil and precipitation of 10 inches or less per year, unless crop residues are kept on the soil surface, and the soil maintained in a rough and cloddy condition.

Cropping Practices

Winter wheat is the dominant cash crop in this geographic area. In drier parts, a straight wheat-fallow system is used. In wetter parts, a wheat-pea sequence is common, and legumes (alfalfa or sweetclover) and grasses are sometimes included in the cropping sequence. Inclusion of these crops greatly reduces runoff and soil erosion and materially aids in maintaining soil productivity.

Yields of wheat—both straw and grain—are very high (fig. 16) in the summer-fallow areas.

Figure 16.—In high moisture years with adequate fertilization, yields will sometimes average over 70 bushels per acre, resulting in total stubble and straw weights of 6,000 to 10,000 pounds per acre.

Yields of 15 to 50 bushels per acre are obtained, depending on climate and soil moisture. In areas where rainfall is higher, yields are seldom less than 40 bushels per acre, and 60- to 70-bushel yields are not uncommon. Straw production is usually in the range of 6,000 to 10,000 pounds per acre in the wetter areas, and 1,500 to 5,000 pounds in areas of lower rainfall. The use of nitrogen fertilizer has increased in recent years. Good yield responses to nitrogen in both straw and grain are common under favorable moisture conditions unless alfalfa or sweetclover is used in the crop sequence.
Experimental Work

Location

Most of the results and observations reported herein were obtained in the vicinity of Pendleton, Oreg.—an area that is somewhat representative of much of the wheat-producing area in Washington, Oregon, and Idaho. Much of the work was done at the Pendleton Branch Experiment Station, and most of the remainder at two leased pilot farms located approximately 15 miles north of Pendleton.

Type of Soil

Soil at the Pendleton Station is Walla Walla silt loam, 4 to 6 feet in depth, with slopes varying from 0 to 3 percent. Soil at the two pilot farms is Walla Walla silt loam, light soil phase, 8 to 20 feet in depth, with slopes ranging from 2 to 40 percent.

Procedures

The general procedure was to test a wide array of implement types and methods of operation on field-scale plots. Machinery was obtained from numerous commercial companies, and many modifications were made in design, operational procedure, and sequence to fit the topographic, soil, and residue conditions encountered. Through this testing procedure, the basic implement characteristics, required sequence, and techniques of operation were gradually developed. Emphasis in this bulletin will be on practices in a fallow-management system, since it is in such a system that erosion problems are most acute, and particular care and management are required to effect a successful stubble-mulch farming operation.

Operations and Equipment

This section of the bulletin describes the various aspects of stubble-mulch farming that follow in sequence, beginning with the harvest of wheat from early July through August, and following through to seeding of the succeeding wheat crop on summer-fallowed land 12 to 15 months later. The discussion is limited to management of wheat or similar small grain residues.

Harvesting

Equipment and Practices

Practically all harvesting of small grains is now done with a combine harvester, chiefly of the self-propelled type. A notable modification of standard types is the incorporation of automatic hydraulic leveling controls on both the header and the drive wheels to accommodate harvesting of the steep slopes encountered in this geographic area.

Use of the Straw Spreader

One feature of harvest management essential to successful stubble-mulch farming is the use of a straw spreader on the combine (fig. 17). When straw yields are high, uniform spreading of combine tailings is a “must” to avoid difficulties in operation of tillage equipment. The use of a straw spreader is especially important where lodging of the crop has occurred and a major portion of the

Figure 17.—The first essential in a stubble-mulch program is a straw spreader, as pictured on this combine. The spreader, shown over the right rear wheel, has three rubber flails, which spread the straw more uniformly than the older, metal types.
straw is cut in the harvest operation (figs. 18 and 19). In drier parts of the area, where residues are lighter (1,500 to 3,000 pounds per acre), uniform distribution of residues aids materially in maintaining a uniform cover throughout the summer-fallow season.

**MULCHING**

Mulching begins at harvesttime. Under normal conditions, the top one-third of the straw is cut, leaving stubble 12 to 30 inches high to hold crop residues and catch drifting snow. Where straw yields are high (4,000 pounds per acre or more), some stubble reduction is usually necessary. Such conditions occur most often in low-lying, wet parts of a field, but occasionally over entire fields.

**Stubble Reduction Prior to Initial Tillage**

When stubble is so heavy, excessively long-stemmed, or bunched that it will cause plugging of tillage implements, stubble reduction may begin in the fall. Fall operations help to balance the workload, particularly on larger farms. Care must be taken not to overdo the operation. When the stubble is cut too short, or broken off just above ground level, not enough is left standing to hold drifting snow. The finely broken stubble itself will blow and pile in drifts, which presents a major tillage problem, while much of the soil surface is left unprotected.

Left over winter, the standing stubble has been observed to reduce runoff, and to store more moisture in the soil than any fall tillage operation, except subsoiling in areas where frozen soil predominates. After weathering all winter, it shatters more readily than fresh stubble immediately after harvest, and is dry enough to mulch easily by the time the soil surface has dried sufficiently to permit initial spring tillage.

When freezing of the soil is common, as in east-central Washington and northern Idaho at approximately 2,600 feet and southeastern Idaho at over 5,000 feet above sea level, fall tillage with a rotary subsoiler (figs. 20 and 21) or chisel-type implement has been successful. While aimed primarily at shattering the soil to reduce runoff and increase the storage of water, adequate stubble reduction may be accomplished during this operation.

Where such conditions do not occur, fall tillage has not been beneficial, and stubble reduction can be economically and successfully done in the spring.

**Rotobeaters or Stubble Busters**

Stubble can be reduced by use of any one of the several types of rotobeaters, known locally as “stubble busters.” Three representative types are illustrated in figures 22, 23, and 24.
FIGURE 20.—This rotary subsoiler has sharp steel spades that are forced into the soil by the weight of the machine plus 2,400 pounds of cast iron weights suspended on the axle between the spades. As the implement is pulled forward, the tips of the spades rotate to the rear, forming elongated basins approximately 6 x 20 inches in area and 11 inches deep. Water trapped in these pockets soaks into the subsoil for more efficient water storage.

FIGURE 22.—This rotary, vertical-arm-type stubble buster is one of the most popular used in northeastern Oregon. Short, light, steel-tipped beaters, mounted on a 14-foot hollow tube, revolve at 1400 r.p.m., driven by the tractor power takeoff. Since beaters strike stubble to the rear, power requirements are low, permitting the use of a two-plow wheel tractor in mulching a 14-foot swath.

FIGURE 21.—Four tractors pulling 12 rotary subsoilers totaling 108 feet in width east of Idaho Falls, Idaho. This 250-acre field of winter wheat is being rotary subsoiled after seeding to help prevent erosion from heavy snow melt or rain on frozen soil in the spring.
Other Equipment

Two other implements that can be used for residue reduction prior to initial tillage are the skew treader (fig. 25), and the conventional spike-tooth harrow (fig. 26).

The skew treader can be used either before or after an initial tillage operation to distribute and break up long straw. Widths, up to 80 feet or more, of the rigid type spike-tooth harrow have been found to provide satisfactory stubble reduction. Use of the harrow is limited to periods when the stubble is dry and brittle; otherwise the residue will roll up under the harrow and form bunches. The first swath may be made across the field in any direction. The return trip is made on the same swath in the reverse direction, going against the grain or stubble. After the field is covered in this manner, if a second mulching is necessary, it should be done in a different direction. In heavy stubble, 8,000 to 10,000 pounds per acre, a third mulching is usually required. An important thing to remember is that the final operation should be in the same direction the next tillage implement will be pulled. This practice prevents considerable plug-
ging because the follow-up implement will be traveling in the direction the stubble leans, instead of across or against the grain.

Some farmers have tried to shorten standing stubble by using either an extra cutter bar mounted under the header of their combine or an old-style header from which the drapers and bottom have been removed, as in figure 27. Although the standing stubble was shortened, it still gave difficulty in summer weeding with a rod weeder, because the unshattered, stiff straws bridged across implement shanks instead of bending and wending their way between the shanks. Also, when there was an excess of stubble, it was observed that more of the shattered stubble came in contact with the soil, and decomposed more rapidly. When the straws were shattered, the bacteria could work on both the inside and outside of the straws simultaneously, thereby effecting more rapid decomposition.

It should be emphasized that in either fall "stubble busting" for residue reduction or fall tillage, 8 to 12 inches, or a major portion of the stubble, should be left standing to catch drifting snow (fig. 28). Implements that flatten the residue should not be used.

Figure 25.—A skew treader on the Pendleton station doing a combined mulching and tillage job in one operation. Speeds of 5 miles or more per hour have given best results with this implement. The skew angle of the treader is adjustable by means of a chain at the right end.

Figure 26.—Stubble shown here averaged 24 inches high and 6,000 pounds per acre. Three round trips with a spike-tooth harrow gave sufficient mulching to prevent plugging of tillage tools. This was the cheapest stubble buster used, and it had the lowest power requirements. Normally, 20 or more 4-foot-wide sections, totaling 80 feet in width, are pulled with a light tractor in this operation.

Figure 27.—This stubble cutter, made from a discarded combine header, gave results similar to cutter bars attached to the underside of combine headers where the stubble was shortened but not shattered.

Figure 28.—From 8 to 12 inches of stubble should be left standing when mulching is done in the fall. This standing stubble holds the mulched stubble and catches drifting snow.
Fall Disking of Stubble

Fall diskng of stubble may be justified where weeds, volunteer grain, or cheatgrass are serious problems. In such cases, care should be taken to adjust the implement so that it buries as little as possible of the stubble (figs. 29 and 30). Depth of cut should be limited to not over 3 or 4 inches, and the angle of cut reduced to avoid severe stirring of the soil and burial of the residue. A one-way, or wheatland, disk was found to be superior to an offset disk for this weeding operation. The one-way disk inverted and covered the young weeds, while the offset disk inverted the weeds with the front gang of blades and then reset many of them as they passed through the rear gang.

Stubble reduction and spreading of bunched residues can be performed either before or after the initial tillage operation. Any of the equipment mentioned can be used successfully if the straw is in condition to permit operation without clogging. The skew treaded is especially useful in post-tillage operations. It not only spreads and breaks up long residues, but also kills small weeds, and reconsolidates the tilled soil layer.
PREPARATION OF SEEDBED

Initial Tillage Operations

The initial tillage operation after harvest can be performed either in the fall or in the following spring. In general, there are only two conditions under which fall tillage should be recommended. First is the situation involving frozen soils, mentioned in the previous section, in which a rotary subsoiler, chisel, or sweep operation may be beneficial in reducing runoff and increasing moisture intake. The second is excessive growth of cheatgrass (*Bromus tectorum*), broadleaf weeds, or volunteer grain occurring in the fall after harvest. A one-way disk or a wide-blade sweep operated at shallow depth can be used to halt this growth.

Most common weed problems are with Russian-thistle (*Salsola pestifer*), prickly lettuce (*Lactuca scariola*), tarweed (*Amsinckia intermedia*), and cheatgrass (*Bromus tectorum* L.). If the former two occur in the wheat crop, or germinate immediately after wheat harvest, they should be eradicated by either a tillage operation or a post-emergence chemical treatment in late fall. Individual plants of Russian-thistle may reach sufficient size (3 to 4 feet in diameter) to cause serious trouble by plugging tillage implements. In the event of a cheatgrass problem, till the field lightly after harvest with a skew treader, rotary hoe, or disk implement in order to plant the seed. Later in the fall, after emergence, eradicate the cheatgrass with a light disking or chemical treatment to prevent seed set prior to tillage operations in the spring (figs. 31 and 32).

![Figure 31](image-url)  
*Figure 31.*—When surface soil is moist at harvesttime, early fall tillage induces germination and growth of cheatgrass in time for eradication by light tillage before winter sets in. This picture shows a dense stand of young cheatgrass plants that have come up in the stubble after harvest.

![Figure 32](image-url)  
*Figure 32.*—Light fall disking gave good control of cheatgrass in the background of this field near Condon, Oreg. In the foreground, where no disking was done, cheatgrass went to seed before the soil had dried sufficiently to start spring tillage operations.
Aside from the previous situations, the initial tillage operation normally should be performed in the spring after weed and volunteer grain growth has started, and the soil has begun to dry out. If the soil is tilled when it is wet, weeds and volunteer grain are difficult to kill. In addition, compaction and other adverse effects on the soil will result.

Whether performed in the fall or spring, initial tillage should be shallow—in the range of 3 to 5 inches (fig. 33). At this depth the operation successfully kills weeds but does not cause drying of the soil to an appreciable depth. Uniformity in depth of initial tillage is important to assure control of weed seedlings, and to permit ease and uniformity in the operation of implements during subsequent tillage.

**Implements for Initial Tillage**

For the initial spring tillage operation, three general types of implements were found to be the most satisfactory: (1) The high-clearance stubble cultivators that may be equipped with duckfoot or chisel-type blades, (2) the medium-width (30-inch) or wide (5- to 8-foot) subsurface sweep-type implements, and (3) disk-type implements such as the one-way, or wheatland, disk.

![Figure 34](image) —This 19-foot-wide, high-clearance stubble cultivator, with 32 inches of clearance from blade to frame, has spring shanks that provide considerable chatter in operation. This chatter helps to prevent bridging of stubble between shanks, which often causes plugging. The frame will permit variable spacing of shanks, and will accommodate either chisel points or 17-inch duckfoot blades as shown here. A hydraulic cylinder operated from the tractor lifts the blades from the ground. Wings may be raised when traveling on highways. This cultivator has the capacity to operate in unmulched stubble up to 10,000 pounds per acre.

The stubble cultivators of the type shown in figures 34, 35, and 36, whether equipped with duckfoot blades (12 to 18 inches wide) or with narrower chisel-type points or blades 2 inches wide, give considerable surface tillage, and usually control small weeds without excessive burial of surface residues. Characteristics essential to successful operation of this implement are: (1) high clearance (no less than 24 to 32 inches from the tillage point to the frame); (2) staggered spacing of the shanks in at least three ranks on the frame to provide corridors for the stubble to pass through the machine; (3) provision for adjusting spacing of the shanks; and (4) rugged construction. The above characteristics make this machine a valuable asset in stubble-mulch farming, since its flexibility provides for operation under a wide variety of conditions. With proper construction features, various tillage points or blades, ranging from 2 inches to 30 inches wide, may be employed.

With vertical clearance of 32 inches from blade to frame, this equipment can be operated successfully in initial tillage operations, with no previous stubble reduction, in stubble weights up to 10,000 pounds per acre.
FIGURE 35.—This medium-clearance stubble cultivator has such features as hydraulic lift, three-bank arrangement of shanks, variable adjustment of shank spacing, center-hinged frame for use on uneven ground, 24-inch clearance from ground to frame, and provision for the addition of wings to give wider ground coverage. It has the capacity to operate in unmulched stubble up to approximately 5,000 pounds per acre, or properly mulched stubble up to 8,000 pounds per acre.

In cold, wet springs, stubble cultivators have been found to be quite effective in controlling volunteer wheat and wild oats (Avena fatua), the broadleaved weeds such as tarweed and Russian-thistle, as well as the grassy weeds such as cheatgrass. Depending on the weather, soil type, and other local conditions, one or two operations may be necessary to control vegetative growth. Where spring weather is cold and rainy, it may be necessary to use the stubble cultivator with chisel points at 4- to 6-inch depth for the first operation, followed approximately 1 week later by the cultivator with the 12- to 18-inch-wide duckfoot blades at an average depth of 3 to 5 inches, going across or at an angle to the first operation. The duckfoot blades are essential in preparing a uniform depth zone for the rod weeder, commonly used in the summer weeding program, during one or both of the above operations.

The second general type of implement is the subsurface sweep (figs. 37, 38). The sweep consists of V-shaped or straight blades mounted on a suitable frame. Again, as with the stubble cultivator and other types of tillage equipment, essential characteristics are adequate vertical and horizontal clearance to permit operation in heavy residues without clogging, and a shallow and uniform depth of operation.

Wide-blade sweeps (figs. 39, 40) with one to three V-blades from 5 to 8 feet in width, have given trouble-free operation in unmulched stubble up to 8,000 pounds per acre, and in mulched stubble up to 12,000 pounds per acre at the Pendleton station.

To operate this type of equipment successfully it is essential to have the blade in a flat position. Unless the blade is level, draft will be excessive, the toe of the V-blade will be worn away rapidly on the bottom, and an uneven subsurface tillage level will result. This latter condition can cause continued plugging of the rod weeder during summer weeding operations as a result of the revolving rod being forced out of the ground where it will gather surface mulch.

Level operation can be assured by preadjusting the blade on a level surface. This can be done by first setting the blade flat on a concrete or other level surface. Then by blocking up the wheels and drawbar to a height equal to the depth of tillage desired, the V-blade can be adjusted until it is flat on the floor. The adjustments are then tightened.

Rolling coulters approximately 24 inches in diameter are desirable on implements working through stubble mulch. When placed ahead of each Shank they cut residues and prevent bunch-
Stubble cultivators can be converted to subsurface sweep-type implements by installing medium-width (24 to 30 inches) V-blades mounted on stiff shanks.

Seven 30-inch sweep blades mounted on this stubble cultivator frame provided a working width of 14 feet. The implement is being used for initial spring tillage in unmulched stubble of approximately 5,000 pounds per acre on the King Pilot Farm. If the stubble was properly mulched before tillage, this implement operated satisfactorily in weights up to 8,000 pounds per acre.
FIGURE 39.—This wide-blade sweep features hydraulic lift, high clearance, and coulters 24 inches in diameter. It can be adjusted to operate parallel to the soil surface at depths of 2 to 14 inches.

FIGURE 40.—This sweep, with a blade 8 feet in width, rumples the soil under heavy stubble. Having only one shank, together with high clearance, it permits spring tillage without plugging in unmulched stubble up to approximately 10,000 pounds per acre.

FIGURE 41.—At the Pendleton station, wide-blade sweeps used for initial spring tillage left from 60 to 90 percent of the stubble standing or on the soil surface, approximating 8,000 pounds of stubble per acre.

The wide-blade sweeps leave from 60 to 90 percent (fig. 41) of the stubble standing or on the soil surface. Since this type of sweep merely rumples the soil as the blade passes underneath, there is very little surface tillage except in the vicinity of the shanks. Therefore, when weeds and cheatgrass sod are a problem during cold, wet springs, the stubble cultivator with chisel points or duckfoot blades with their multiple shanks give more surface agitation and better weed control.
Since introduction of the skew treader to the Pacific Northwest at the Pendleton station in 1949, its use has spread rapidly. It is a particularly important implement in a trashy fallow tillage program. When tongues are reversed from the position shown above, the skew treader can be used successfully for mulching stubble, spreading bunched residue, and killing weeds.

In extremely adverse weather, or when unmulched stubble is excessive, it has been found desirable to trail several sections of skew treader (figs. 42, 43) behind the stubble cultivator during one or both of the two initial spring tillage operations.

Disk-type implements can be used most successfully where residues are in excess of 3,000 to 4,000 pounds per acre (fig. 44). Implements with disks 22 to 26 inches in diameter and with low concavity are the most satisfactory. The disks should operate at slow speed and at a low angle with respect to direction of travel to avoid inversion of the soil and burial of the residues. Implements with disks 18 inches or less in diameter should not be used, particularly the tandem-disk type, since they are not effective weed killers and tend to pulverize the soil.

Three sections of skew treader are being pulled behind this stubble cultivator during initial spring tillage to secure a more effective weed kill following a cold wet spring. Aqua nitrogen fertilizer is being applied as a third process in this once-over operation.

The wheatland, or one-way, disk, when equipped with oversize 26-inch disk blades spaced at least 9 inches apart, was successfully used in mulching 30- to 50-bushel wheat stubble. When the blades are moderately angled and operated at a depth of 3 to 5 inches, a considerable amount of stubble was left for soil protection.
Figure 45.—Approximately 50 percent of the stubble was left on the surface after use of this disk plow in 10,000 pounds of stubble per acre. This rugged implement has large-diameter disk blades of high curvature and wide spacing, providing clearance for tillage in heavy stubble up to 12,000 pounds per acre.

Disk plows can be used in hard or stony ground and where residues are sufficient (fig. 45) to leave approximately 50 percent, or at least 4,000 pounds, of the stubble on the surface. Care should be taken not to confuse offset, squadron, and tandem disks with the true disk plows that have three to six 26-inch or larger diameter blades of high curvature, spaced 20 to 24 inches apart, on a common rigid axle. These specifications provide the clearance and ruggedness necessary for tillage in stony or hard ground and in unmulched stubble up to 12,000 pounds per acre.

The common moldboard plow has no place in the stubble-mulch farming system (fig. 46). It is an inversion-type implement, and if used in a manner satisfactory to control weeds and volunteer grain growth, it will bury most of the crop residue. It can be converted to do an acceptable job by replacing the moldboards with metal plates 4 inches wide (fig. 47).

This implement is then commonly referred to as a “stubby moldboard.” It can be used as a stepping stone in the conversion from moldboard plowing to stubby mulch tillage with very little expense. The type of work this implement does is shown in fig. 48.
Followup of Initial Spring Tillage

In contrast to moldboard-plowed, summer-fallowed land, stubble-mulched land often requires a tillage operation immediately after the initial spring tillage to kill weeds or to consolidate the surface soil layer. Timeliness of operations, choice of the right implement, and climatic conditions are three important factors to be considered in the followup operation.

When the weather is dry and warm immediately after the initial spring tillage, weeds and cheatgrass usually are not a problem, and the followup tillage can be aimed at settling the soil and eliminating air pockets to reduce evaporation and thereby conserve moisture. Under such conditions and when residues are heavy, or no pretillelge mulching has been done, a skew treader is a most satisfactory implement (fig. 42). This implement further breaks up and spreads residues, as well as firms the soil for moisture conservation. Where residues are less heavy and further reduction or distribution of residue is not essential, the rod weeder (fig. 49) and narrow sweep or duckfoot cultivator work satisfactorily.

Where residues are less than about 15,000 pounds per acre after the initial tillage, emphasis should be placed on residue preservation by using the rod weeder or medium sweep implement (blades 24 to 30 inches wide) for the followup, as well as other subsequent tillage operations.

FIGURE 49.—An end-drive rod weeder being used on the Hill Pilot Farm in stubble that averaged 4,500 pounds per acre. Followup tillage should be done as soon as possible after initial spring tillage to firm the soil and fill air pockets to conserve moisture that would otherwise be evaporated down to the depth of tillage by high winds and hot weather.

FIGURE 50.—High-clearance cultivator working in unmulched stubble following a wide-blade sweep near Walla Walla, Wash. This followup tillage operation was necessary to kill small weeds, volunteer grain, and cheatgrass.

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When the spring weather is cold and wet, and the soil and stubble are damp, the rod weeder is not a satisfactory followup implement, even in medium stubble of 3,000 to 4,000 pounds per acre, because of plugging.

In a cold, wet spring, the followup tillage operation is primarily aimed at completing the kill of weeds, particularly grassy weeds and volunteer grain, after the initial operation. Under such conditions, particularly with heavy residues, the high clearance, cultivator type of implement (fig. 50) is most satisfactory. Disk-type implements can also be used, but should be avoided if residues are less than about 4,000 pounds per acre. Under conditions of moist soil and unmulched stubble, major difficulty in the clogging of rod weeders (fig. 51) has been experienced, and neither the rod weeder nor the skew treader or rotary hoe has given satisfactory weed kill.

**Summer Weeding Operations**

Summer weeding operations should be done only often enough to control weeds and volunteer grain. During the dry summer months, wind and sun dry out the soil, even under mulch, to the depth at which it is maintained in a loosened condition. Therefore, summer weeding operations should be performed at a uniformly shallow depth—no more than 3 or 4 inches. If residues have been incorporated during initial tillage operations, it is usually necessary to perform the first summer weeding at a depth sufficient to pass under most of these incorporated residues; otherwise, clogging of the tillage implement will result. From two to four summer weeding operations are required, depending on the frequency and amount of rainfall following the first tillage in the spring. In all tillage operations as much residue as possible should be left on or in the soil surface.

**Weeding Implements**

The two most satisfactory implements for summer weeding are the rod weeder and the stubble cultivator. If residues are light (3,000 pounds or less), the rod weeder or the cultivator with medium sweep blades (up to 30 inches) should be used. In heavier residues, the stubble cultivator with narrower duckfoot shovels or blades works satisfactorily and will reduce the quantity of residue approximately 15 percent with each operation.

If unmulched residue levels do not exceed 3,000 pounds per acre (fig. 52), the end-drive type of rod weeder works satisfactorily in most cases. With higher residue levels, the center-drive type has given less trouble from plugging, and, under favorable conditions, has been used successfully in unmulched stubble up to 8,000 pounds per acre in the summer weeding program (fig. 53). How-
FIGURE 54.—Spirals, as shown here, mounted on the rod of a conventional rod weeder gave a lateral stirring of the soil. These spirals were more effective than the plain rod in shaking moist soil from the roots of small weeds and cheatgrass plants, exposing them to the drying action of wind and sun, which resulted in more complete kills.

FIGURE 55.—The rod tiller consists of 6-inch-wide duckfoot shovels bolted to a stiff bar behind the revolving rod of the rod weeder. The duckfoot shovels extend out in front of the revolving rod, and permit normal operation of the rod weeder in areas where the soil is hard, or where subsurface ridges tend to lift the rod out of the ground.

However, the end-drive type has worked satisfactorily in residues up to 8,000 pounds where stubble has been properly mulched prior to initial tillage.

Where cheatgrass is a severe problem, additional stirring of the soil, and therefore better control, can be achieved with the rod weeder if a metal rod is placed in spiral fashion around the rod weeder bar (fig. 54). A second method for accomplishing greater stirring action is to attach curved metal rods to a metal bar behind the rod weeder rod. These long curved fingers tend to stir the tilled layer, and therefore improve the kill of grassy weeds. Some farmers have reported like benefits from using the new tine harrows.

If the soil is very compact or hard, narrow duckfoot shovels, 6 inches wide, can be attached to a bar and operated ahead of the rod weeder rod in order to break up the hard layers and permit passage of the rod (fig. 55).
Seeding wheat in stubble-mulched land remains one of the major problems of stubble-mulch farming. Placing the seed in moist soil without covering or bunching residues, or permitting residues to fall back into the seeded row, is the main problem.

Investigations have indicated that the length and stiffness of the straw in the mulch at seeding time is more important than the actual quantity of mulch on or in the immediate soil surface. More difficulty has been experienced with 1,650 pounds of long-stemmed, partially buried residue than with 4,400 pounds of short-stemmed, randomly placed stubble (figs. 56 and 57). These residue weights were reduced about 45 percent from the original stubble weights of approximately 3,000 and 8,000 pounds per acre, respectively, by the various tillage and summer weeding operations.

**Seeding Equipment**

In general, semi-deep-furrow, single-disk drills (fig. 58) or deep-furrow drills with shovel-, shoe-, or hoe-type openers (figs. 59 and 60) have proved most satisfactory for drilling in stubble-mulch fields. Double-disk types have proved less satisfactory because of difficulties in penetrating the mulch.

_Figure 58._—This semi-deep-furrow, single-disk drill is equipped with special furrow openers. The V-notch in these openers is designed to permit moist soil to flow into the furrow cut by the disk and cover the seed. The rest of the landside is shaped to hold back dry soil and mulch until the seed is covered. Large rubber-tired wheels provide lighter draft, help prevent side slippage on steep slopes, and cause less ridging than old style, steel wheels.

_Figure 59._—Deep-furrow drills with full-castered, rubber-tired wheels gave flotation and maneuverability on multiple hookups. The elevated grain hopper gave positive feeding to the staggered openers spaced at 14 inches. The enclosed packer wheels and hydraulic hitch helped control side slippage on steep slopes. Chrome plating on shovels gave lighter draft, better scouring, and better clearing of mulch, and also prevented rusting.
FIGURE 60.—This modified shoe drill was developed and manufactured by a farmer at Pendleton, Oreg. The spring steel shoe supports provided chatter, which aided in clearing mulch. Cast iron weights on these supports gave variable pressure on the shoes. The 2-inch-pipe sections trailing the shoes held dry soil aside until the seed was covered and packed with moist soil. These adjustable pipes also provided weight, which aided in depth control.

With the single-disk type, care must be taken to operate the drill at a speed slow enough to prevent soil and residue from being thrown into the furrow behind the adjacent disk, thereby covering the seed too deeply, which will delay germination and emergence. With the deep-furrow, shovel, shoe-, or hoe-type openers, the same principle that governs tillage implements applies; namely, there should be high clearance between the shovels and the drill framework, and adequate clearance between openers to avoid clogging. Added clearance can be effected by staggering the openers in two or more ranks, and by increasing the row spacing to 8, 12, or even 14 inches in drier areas.

Regardless of the type of drill used, it is essential to place the seed in moist soil and cover it uniformly. Press wheels or other compacting devices should be used following each drill opener. Where soil is dry and residues are appreciable at seeding time, the closed type of press wheel will cause less disturbance of the mulch and soil between the rows than the open type (fig. 61).

FIGURE 61.—Solid packer wheels did not disturb soil and mulch in the ridges, but gave uniform coverage to the seeded wheat in the furrows. This modern deep-furrow drill is seeding satisfactorily in a misty rain through wet soil and in approximately 6,600 pounds of mulch (originally 12,000 pounds per acre).
Also, both round and wedge-shaped packer wheels tend to anchor loose mulch at the side of the furrow, helping to hold both soil and mulch in place in drier areas subject to wind erosion. On steep slopes, open-type press wheels push considerable dry soil and mulch over the seed, throw soil and mulch down on the adjoining furrow, and sift fine soil over the furrow surface. Where the quantity of protective mulch is limited, the fine-dust-covered furrows are subject to wind erosion.

A special problem in seeding, as well as in tillage, is encountered on steeply sloping lands. When seeding across the slope, the drill tends to slip downhill, and to operate at an angle to the direction of travel (fig. 62). This causes excessive depth of covering and irregular spacing between drill rows and drill widths.

In both tillage and seeding operations, this difficulty can be largely eliminated by the installation of hydraulic hitches that permit application of differential pull by moving the hitch point up the slope (fig. 63). These hitches have proved very satisfactory in keeping the equipment in line behind the tractor, and are rapidly becoming standard equipment when operating on side slopes above approximately 15 percent.
Summary

The essentials for successful stubble-mulch farming in a wheat-fallow system, based on results of experiments and observations over the past 10 years, are:

1. A straw spreader on the combine promotes uniform straw distribution, which greatly facilitates mulch tillage and seeding in mulches, especially when straw yields are high.

2. Pretillage mulching (stubble reduction) is usually necessary if straw is not uniformly distributed, or if yields are 4,000 pounds or more per acre. Stubble busters, skew treadsers, or spike-toothed harrows are used for this operation.

3. Mulching can be performed in the fall after harvest, or in the spring before or after initial tillage. Fall work is recommended only to distribute the workload, to avoid difficulties in a wet spring, or to assure a satisfactory job when stubble and soil are dry.

4. Initial tillage normally should be done in the spring after weed and volunteer grain growth has begun and the immediate surface soil has dried out. Stubble cultivators, subsurface sweeps, or one-way disks are the most satisfactory implements. Moldboard plows should not be used unless modified by replacing the moldboard with a narrow metal plate. Disk plows equipped with large, widespread disks can be used in stony ground, or in excessively heavy stubble if properly operated to avoid burying too much of the residue. Depth of operation should not exceed 4 to 6 inches.

5. The initial tillage operation can be performed in the fall following harvest. However, fall tillage is recommended only where soil freezing is common, or where a severe weed or volunteer-grain problem exists.

6. Essential features for the successful operation of tillage equipment are adequate vertical and horizontal clearance to avoid clogging, and a shallow and uniform depth of operation.

7. A followup tillage, as soon as possible after initial spring tillage, is needed to complete the weed kill, to pack the soil, or both. The skew treader, rod weeder, or stubble cultivator are recommended, depending on the amount of residue, climatic conditions, and growth of weeds and volunteer grain.

8. Summer weeding operations can be accomplished with the rod weeder, stubble cultivator, or medium-width sweeps (24 to 30 inches wide). Tillage should be performed only often enough to control weeds, and should not exceed 3 to 4 inches in depth. If residues after initial tillage are less than 3,000 pounds per acre, care should be taken during subsequent tillages to leave as much residue on or near the soil surface as possible.

9. Every tillage operation should fulfill a specific need. Any tillage in excess of this need not only costs extra money, but reduces protective residues, and adversely affects soil condition.

10. Drilling is best accomplished with deep- or semi-deep-furrow drills with wide row spacing (8 to 14 inches). Closed packer wheels cause less disturbance of residue and soil between rows than open wheels. Seed must be placed in firm moist soil, and uniformly covered and packed.

With an effective program of stubble mulching, sustained high yields can be obtained, and soil losses by wind and water erosion can be materially reduced.