Implements for Wind Erosion Control

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IN his efforts to derive a livelihood from the soil, man has destroyed much of the natural vegetation and brought more and more land under cultivation. Periodic crop failures, particularly in the central and southern Great Plains regions of the United States, have produced a vegetative cover too sparse to protect the soil against high winds. Also, in many instances improper tillage practices have tended to leave the soil bare and highly pulverized.

However, progress in wind-erosion prevention and control is being made continually. Of particular importance in this connection are the development, improvement, and application of tillage implements in wind erosion control.

There are two principal groups of factors that must be considered in evaluating the requirements of tillage equipment for wind erosion control. These are *(a)* the conditions of operation with respect to climate, diversity of crops, soils, purposes of tillage, and size and method of farm operation and *(b)* the major factors influencing erodibility of field surfaces including residues, soil cloddiness, and surface roughness. Once these factors have been considered, it is possible to enumerate the various requirements of the equipment and to draw conclusions with regard to the effectiveness of present day equipment.

The Conditions of Operation

Climate. The annual precipitation on the Great Plains regions of the United States not only is low but also is extremely variable. Wind velocities are generally high and the peak velocities usually occur in years with low precipitation. The influence of the tremendous climatic variability on the conditions of operation of tillage machinery is exerted in many ways. It means that, in a year when precipitation is high, the problem will be one of handling heavy residues on wet soil, often a soil covered with small playa lakes because of poor drainage. On the other hand, during dry years the chief function of the tillage tool may be as an emergency control measure to bring up clods and roughen the surface on a soil that is extremely dry and compacted.

Diversity of Crops. Tillage machinery or a "line" of equipment must be highly versatile to meet the requirements of the various crops grown in the Plains area. These crops usually consist of wheat and sorghums; however, other crops such as cotton, beets, alfalfa, and potatoes are often grown. While wheat and sorghums can generally utilize the same implement, often a planter that places the seed in wider rows provides a better environment for sorghum crops. Cotton, alfalfa, beets, and potatoes necessarily require completely different equipment.

Soils. The chestnut and brown aridic soil groups (10)* are the principal soils of the Great Plains area. They are generally low in organic matter and usually have carbonates near the surface. The texture of the soils varies from sand to clay. It is apparent that insofar as soil conditions are concerned, tillage equipment used for wind-erosion control can be expected to operate in anything from light sands where traction is a problem to heavy clays where power becomes a major factor.

Purposes of Tillage. Major purposes of tillage in the Plains region are: *(a)* to produce a suitable seedbed, (b) to destroy weeds and conserve soil moisture, and *(c)* to maintain soil and surface conditions resistant to erosion. It is possible to obtain effective weed control by repeated cultivation. Unfortunately frequent cultivation of the soil increases the hazard of wind erosion. On the other hand, weeds must be destroyed if moisture is to be conserved. Obviously the soil requires careful treatment under these conditions if erosion is to be avoided, weeds controlled, and moisture conserved. To achieve these objectives proper choice of implement and method and timeliness of operation are imperative. Implements must bury or preserve crop residues on the surface, increase or decrease soil cloddiness, roughen or smooth the surface, if and when required.

Size and Method of Operation of Farms. The size of individual farm units in the Great Plains has increased steadily during the past 25 years. As an example, statistics (11, 12) show that the average size of a wheat farm in Ford and Greeley counties of Kansas in 1925 was 249 acres. The average for 1950 was 372 acres. In addition, the number of farms in the two counties having 1,000 acres or more has increased from 104 in 1925 to 251 in 1950. All this means that 25 years ago many small machines were doing a job now done by a few large machines. The advent of this type of farming has required that machines be so designed and of such size as to permit coverage of large acreages in a manner which gives adequate erosion control under the direction of one man.

Major Factors Controlling Wind Erosion

Many factors influence the amount of erosion in a given agricultural area. Factors over which man has little control are the climatic conditions and the topographic features of the land. Of the group over which he exerts some influence the three most important are the soil cloddiness, surface roughness, and crop residues. Studies (7) have shown that as much as 75 percent of the variability in amount of erosion can be attributed to these three factors. Tillage machinery exerts an exceedingly important influence on the state of all these factors. It would therefore seem that the job expected of tillage equipment should be evaluated in terms of these three factors. A prerequisite to this evaluation is an understanding of the nature of the effect of the factors.

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Residues. The amount of protection afforded the soil by crop residue is dependent upon type, quantity, evenness of distribution, anchorage, and vertical orientation of residue. A standing crop or crop residue is more effective than a flattened one because it is more capable of reducing the force of the wind on the ground surface.

Soil Cloddiness. Studies (5) have shown that soil erodibility varies inversely with the percentage of clods greater than 0.84 mm in diameter. The proportion of these non-erodible fractions depends on the physical and chemical characteristics of the soil, the factors of weather and climate, and tillage and cropping practices.

Surface Roughness. The rougher the surface, the greater is its tendency to lower the surface velocity of the wind and to reduce the movement of soil. Surface roughness is difficult to measure and divorce from crop residues and cloddiness. Any obstruction, whether it is a ridge, a depression, a large clod, or a piece of residue standing above the soil surface will serve as a roughness element. Since linear measurements of such a group of dissimilar objects would mean very little, it has been necessary to provide an alternate measurement. Zingg (13) has proposed a roughness equivalent which evaluates the roughness in terms of a height-spacing ratio of 1 to 4 of gravel ridges constructed in a wind tunnel. Thus, if a surface has a roughness of 4 in, it will resist the wind to the same degree as gravel ridges 4 in high and 16 in apart when placed at right angles to the wind.

The interrelationship of these three variables has been found to fit the exponential equation (6, 7):

$$E = a\frac{I}{(RK)^b}$$

where E is amount of erosion in tons per acre, I is a dimensionless index based on percentage of clods greater than 0.84 mm in diameter, R is amount of residue in pounds per acre, K is ridge-roughness equivalent in inches, and a and b are constants whose value depends on the condition of the surface crust and the immediate past history of erosion on the field. This equation correlates the results of many different soils and field surfaces tested during the last five years with a wind tunnel.

Functional Requirements of Tillage Equipment

The foregoing portion of this paper indicates in a general way the requirements of tillage tools for wind-erosion control; i.e., they should leave a rough and cloddy surface, a residue-covered surface with residues well anchored and standing if possible. Suffice to say that any one of these conditions considered individually would indicate several different functional requirements for a given implement. From a practical standpoint, the best conditions for wind-erosion control cannot be the only standard by which the requirements of tillage equipment are determined. For example, there is the requirement of a good seedbed; this usually means a smooth, bare, mellow-surface condition. Since these requirements are opposed to those for wind-erosion control, a compromise must be made between the two. In view of these considerations some of the more important general requirements of tillage equipment are:

1. *A variety of adaptable equipment must be available.* Since no single tillage implement that meets all the requirements for tillage is available at the present time, a selection or "line" of tools must be available. For the initial tillage operation, one-way disks, plows, or sweeps must be capable of cutting through heavy wheat or sorghum residues, leaving them well anchored and standing if possible. At the same time either a minimum pulverization of the soil or a maximum cloddy condition should be created. Rod weeders, disks, spring-tooth harrows, or skew treaders are often needed for the subsequent cultivation and seedbed preparation. These tools should pack the seedbed, kill the weeds, leave the residue on the surface, and not clog or drag the trash. Planters and drills with adequate coulter, knife, or jointer action to cut through residues and to place the seed well into the ground must be available. Often yields are increased when wheat is planted with a deep-furrow drill, not only because the seed is placed in a better moisture environment, but also because the rough surface reduces wind action and traps water. Crops such as sorghum often require planters with wider spacing than those on drills. This type of machine is, therefore, a necessity where such crops are grown. The emergency tillage operation, of course, requires still a different type of implement. Chisels and listers are most commonly used. The chisels do very well on hard lands but on sands listers are almost a necessity.

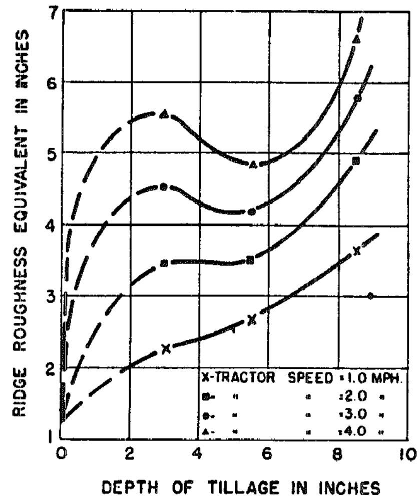

Fig. 1 The effect of depth and speed of tillage on surface roughness. The land, a silty clay loam having 16.3 percent moisture in the tillage layer, was tilled with a chisel of the type commonly used in emergency tillage operations

2. *The tillage implement should provide adequate facilities for adjustment and variation of the depth of tillage.* Depth of tillage is an important factor with reference to roughness and soil cloddiness. It is not so important as far as preservation of residues is concerned. Studies (6) have shown that the stability of clods increases with depth below the surface of the ground. Since stability is a very important secondary factor governing the length of time a cloddy surface will stay resistant to wind erosion, it is apparent that adequate depth adjustment is essential to obtain these stable clods.

Adjustment of depth of tillage is important in operations using subsurface tillage sweeps. Studies of stubble-mulch farming practices (9) indicate that better weed control and seedbed conditions can be obtained by deep tillage on the initial cultivation followed by less depth with each successive cultivation.

The effect of depth of tillage on roughness is an important factor in emergency tillage operations (Fig. 1). It is noted that for conditions of this test, depth of tillage had

Fig. 2 An example of the pulverization of the soil surface by the wide tracks of a heavy tractor

a variable effect on roughness and a greater roughness was created by tillage at a 3.0-in depth than a 5.5-in depth for the faster speeds. This was caused by greater upheaval of clods at the 3.0-in depth than at the 5.5-in depth. At the 8.5-in depth, however, a "mole effect" was obtained, leaving an undulating surface giving a greater roughness equivalent as measured by the wind tunnel. The surface created by tillage at this depth may not necessarily be the most resistant to wind erosion because of insufficient upheaval to give a uniformly cloddy surface.

3. *Sufficient power, traction, and speed should be available.* Adequate power is important where extensive acreages are farmed with large equipment. It must also be available for such operations as deep plowing, disruption of plow pans, and for tillage of extremely dry, compacted soils.

Traction is extremely important on sandy lands. If adequate wheel traction is not provided, it is nearly impossible to handle this land properly. Traction is also of some importance in its effect on compaction and pulverization of soils. The conflicting requirements of avoiding pulverization but at the same time providing adequate traction often create problems. A prime example of this is shown in Fig.2. Here a track-type tractor has provided ample traction, but the tracks have pulverized the soil to such an extent that these areas are vulnerable to erosion.

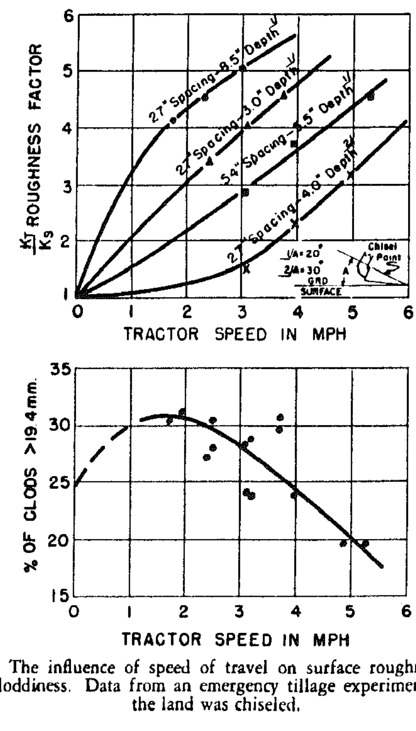

Fig. 3 The influence of speed of travel on surface roughness and soil cloddiness. Data from an emergency tillage experiment where the land was chiseled.

Fig. 4 View of a chiseled plot which meets the requirements for effective emergency wind-erosion control. Surface roughness was 5.4 in; clod structure, 69 percent >0.84 mm; measured erodibility, 0.04 tons per acre. Plot was tilled at 3-in depth at the speed of 3.7 mph

Speed of operation of the tillage tool has a very significant effect on how well a given tool meets the requirements for effective wind-erosion control. In the type of agriculture practiced in the Great Plains today, speed is a necessity in many cases in order to cover the land. This is particularly true in the emergency tillage operation. It is, therefore, difficult to prescribe a speed which will permit completion of the operation in the allowed time and still do an adequate job. The speed of travel affects all three of the major variables, *i.e.*, roughness, residues, and cloddiness. Both the degree of burial and anchorage of residues can be regulated by speed of travel. Too much speed tends either to bury most of the residue or to throw it on the surface in an unanchored condition. The effect of speed of travel on cloddiness and surface roughness is indicated in Fig. 3. Roughness is plotted as the ratio of K_t, roughness of tilled surface, to K_s, roughness of untilled surface. Cloddiness is in terms of the largest size clods as measured by a rotary sieve (4). It is noted that excessive speed breaks down clods but increases roughness. Since it is necessary to have a balance of these two variables, a compromise must be made. In this particular set of tests it was found that a speed of approximately 3.7 mph most nearly met the requirements for good tillage (Fig. 4).

4. *The tillage machine should have proper tool head designs for the particular job.* The size, shape, and design of a given tool head, whether it is a plowshare, a disk, or a chisel or cultivation point has considerable influence on the kind of tillage the machine will do. On plows the shape of the moldboard affects the amount of inversion of the soil layer which in turn affects the roughness, the cloddiness, and the burial of residues. On disks the concavity of the disk creates the vertical forces (1) which also affects residues, roughness, and cloddiness. On subsurface tillage tools, sweep blades that are convex upward give more suction and greater pulverization than flat blades (8). High-lift blades give a higher degree of pulverization but tend to

furrow and ridge the soil when it is loose (2). On chisels and subsoilers the shape of the points affects both roughness and cloddiness. The effect of a slight change in the shape of a chisel point is shown in Fig. 5.

5. *Tillage equipment should have adequate vertical clearance.* This feature is very important in all initial and cultivation operations on land covered with heavy wheat or weed residues where clogging and dragging become a problem.

6. *All equipment should have sufficient effective coulter, knife, or jointer action ahead of principal tool carrier.* This requirement is important in moldboard plows, subsurface sweeps, and in some types of drills and planters working on land covered with heavy residues.

7. *Disk-type tools should be provided with adequate gang-angle adjustment.* This is an important feature because of the influence on burial of residue, pulverization of the soil, and soil surface roughness.

The foregoing list of seven requirements does not cover all the features needed in tillage implements for farming in the Great Plains. It merely points out those that seem to be of the greatest importance with reference to creating the desired conditions for residues, roughness, and cloddiness for wind erosion control.

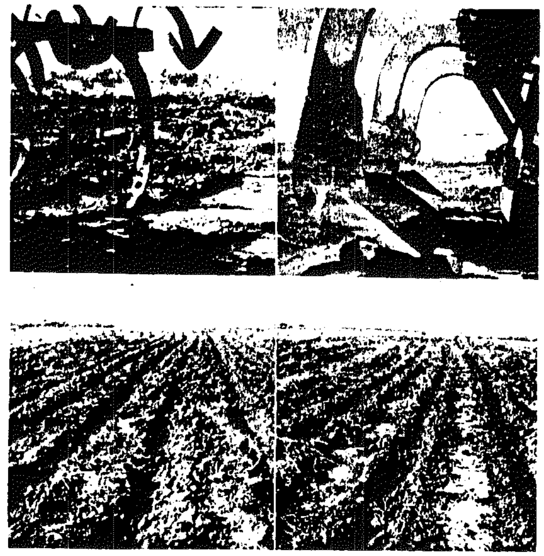

Fig. 5 An example of the difference in tillage caused by changing tool head designs. Two different chisel points (Upper views) and the type of tillage accomplished by each (Lower views). Both tools were operated at same speed and depth

Conclusions as to Effectiveness of Equipment

Present-day equipment, if operated properly, seems to meet most requirements for effective wind-erosion control. Studies of methods of controlling wind erosion (3) indicate that certain tools more nearly meet specific wind-erosion control requirements than others. Residues, for example, are usually best handled with the sweep-type implement because it cuts under the material leaving it in an erect position most effective against wind. The next best implement would be a properly angled one-way disk which leaves the material in a partial standing position. The moldboard plow does not meet the requirements for preserving residues on the surface. However, if residues are meager or absent, the plow under some soil moisture conditions is a good implement for creating a rough, cloddy surface resistant to wind erosion. Disk-type tools, such as the vertical disk or one-way, are usually not satisfactory for creating cloddiness Subsurface sweeps are even poorer for this purpose. The greatest surface roughness can be created by a lister; hence it is particularly useful where residue covers are poor. Deep-furrow drills for wheat planting and furrow-opener-type planters commonly used in sorghum planting are very good for creating a rough surface and for placement of seeds where they germinate readily.

While present-day equipment can do a reasonably good job of wind erosion control, it needs to be improved. Better methods of operating the available equipment are needed also. More information is required on the effect of speed on all phases of tillage to establish criteria for improved operation. The problem of "plow pans" believed to be associated with certain methods of tillage needs to be alleviated. Weed problems, such as control of "cheat" in wheat in some areas of Oklahoma, sometimes are associated with methods of tillage. Such problems may be solved by improved tillage techniques.

Probably one of the greatest needs for wind-erosion control is an implement that will do a better job of creating a cloddy soil surface and at the same time avoid burying the crop residue. Transport and traction of tillage machinery could be improved, particularly for tillage in sands and other soils that pulverize easily. Equipment used in secondary cultivation operation could be improved to do a better job of killing weeds without dragging or being clogged by the residues.

Finally, there is a need for a versatile tool that can accomplish more jobs. This would reduce the need for a "line" of equipment and would be desirable from the farmer's standpoint insofar as his investment in machinery is concerned.

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