Fig. 1 Hydroseeder sprays seeds and fertilizer mixed with water. This bantam seeder sprays 500 gallons of mixture covering one acre in about 15 minutes

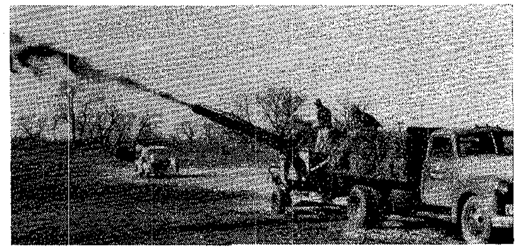

Fig. 2 Shredding-blowing type mulch spreader in operation. Liquid asphalt is sprayed directly into the mulch stream for complete mixing

Anchoring Vegetative Mulches

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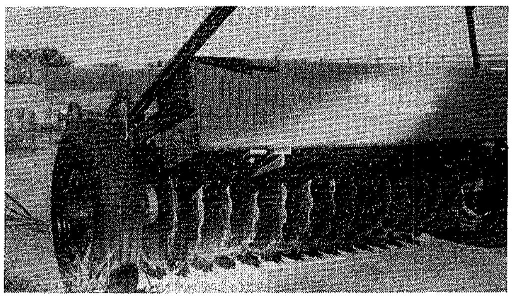
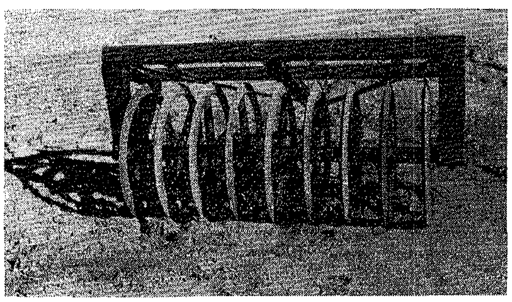
Five Implements Were Tested





THE Army, Navy, Air Force, highway departments, and other agencies continually encounter the problem of wind erosion of freshly tilled, bare ground. Mulching with crop residues before or after seeding to grass has become a common practice to stabilize soil.

In many cases Navy installations are built along coastlines and on sandblown islands where immediate sand stabilization during construction periods is necessary. Under such conditions immediate stabilization such as by mulching is essential before or instead of a grass cover.* Informa-

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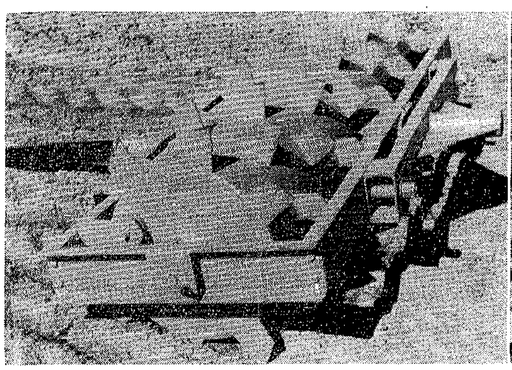
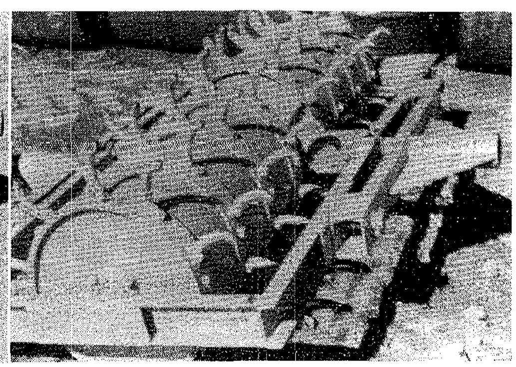
*Jones, Gordon H. Problems on airfield pavement shoulders in arid and semiarid regions. Paper presented at American Society of Agronomy meeting, Lafayette, Ind., August 1958.





Figs. 3-7 Five types of mechanical packers were tested. Shown above are *(top)* cutaway rolling disk packer with ¼-in. thick disks spaced 4 in. apart; *(center)* smooth rolling disk packer with disks spaced 8 in. apart; *(bottom)* V-tread rolling wheel packer with 1-in. thick wheels spaced 5 in., apart. Shown at right are *(left)* plate punch packer with ⅜-in. plates, 5 in. maximum length welded to a rolling drum 21 in. in diameter. The drum can be filled with water for required depth of penetration; and *(right)* L-rod punch packer with rods ⅞-in. diameter and 5 in. overall length, bent 90 deg., 1⅝ in. from the loose end

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tion is needed as to whether the same methods of anchoring mulch are applicable for extremely sandy areas as for finer textured soils.

A project was conducted to obtain information on the most effective methods and equipment to anchor vegetative mulches to stabilize soils against wind erosion. A plot of land was seeded to grass and fertilized. Various quantities, of mulch in the form of hauled-in prairie hay and wheat straw were applied uniformly on the surface using a blower type mulch spreader. Five different types of mechanical packers and various quantities of asphalt emulsion and cutback were used to anchor the mulch (Figs. 3-7).

Detailed description of test procedures and discussion of results are given in Appendix A.

During the tests the best implement for anchoring mulch was a disk packer, preferably with cutaway disks spaced not more than 4 in. apart if penetration and clogging are not a problem, as on dune sand. Where penetration or clogging is a problem, disks have to be spaced about 8 in. apart for packing once, or 12 in. apart for packing once in one direction and then once in the direction perpendicular to the first packing to form a grid system of rows. The 8-in. spacing of disks does not produce a grid system because virtually all the mulch is pulled into the rows and punched into the ground and the first time over. To improve the effectiveness of packing, two possible courses remain: *(a)* space the disks as close together as possible but not so close as to prevent proper penetration or to cause clogging of the disks, and *(b)* space the disks at least 12 in. apart, pack, then pack again at right angles to the direction of the first packing. A choice of two packers with about 4 and 12-in. disk spacings is desirable. However, if only a single packer is available and soil texture and hardness of ground are variable, compromising by spacing the disks about 8 in. apart is probably the best alternative. Changing the spacing of the disks to suit different conditions is a tedious task.

The disks should penetrate at least 2 in. but not more than 3 in. for proper anchorage and effectiveness. If ground is too hard for disks to penetrate to proper depth, it should be loosened by tillage to the depth of desired disk penetration.

The average quantity of well anchored (packed) mulch required for adequate protection against equivalent 85-mph wind appears to be as follows:

6000 lb per acre of wheat straw on most erodible dune sand.

5000 lb per acre of prairie hay on most erodible dune sand.

5000 lb per acre wheat straw on less erodible soils.

4000 lb per acre of prairie hay on less erodible soils.

Where a packer cannot be used, such as on steep dunes or construction slopes, liquid asphalt mixed with the mulch can be applied. For mulch anchored with asphalt on smooth ground and any degree of soil erodibility, including dune sand, the following treatment appears to be fully effective against strong winds: a uniform cover of 4000 lb per acre of prairie hay or 5000 to 6000 lb per acre of wheat straw mixed thoroughly with a fine spray of at least 300 gal per ton (600 gal per acre) of rapid-curing-asphalt cutback (RC) or emulsion for hay or with at least 400-gal per ton (900 to 1000 gal per acre) of rapid-curing-asphalt cutback or emulsion for straw.

For mulch anchored with asphalt on moderately rough ground of any degree of erodibility, the same quantity of mulch as for smooth ground can be used but the quantity of asphalt can be reduced to 200 gal per ton (400 gal per acre) for hay and 300 gal per ton (700 to 900 gal per acre) for straw.

Complete effectiveness of mulching and anchoring the mulch without packing apparently consists of *(a)* complete cover of the ground with the mulch, and *(b)* adequate anchorage of the individual pieces of the mulch to the ground or to each other. On loose sand, little anchorage of the mulch to the ground occurs so that the stability of the mulch cover depends on the roughness of the ground and on the strength with which the individual pieces of the mulch are

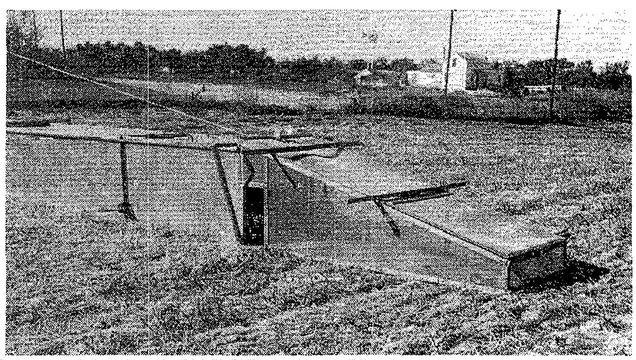

Fig. 8 *(Right)* Leeward end of wind tunnel was used as mulch catcher. A soil catcher (not shown) fits the mouth of the mulch catcher • Fig. 9 *(Lower left)* 4000 lb per acre of wheat straw anchored with disk packer with 8-in. spacing of disks. Dune sand was completely protected with 85 mph wind blowing at right angles to rows • Fig. 10 *(Lower right)* 4000 lb per acre of wheat straw with 400 gal per acre of rapid-curing-asphalt emulsion gave almost complete protection from strong winds on dune sand, as shown in the foreground. The background was not treated

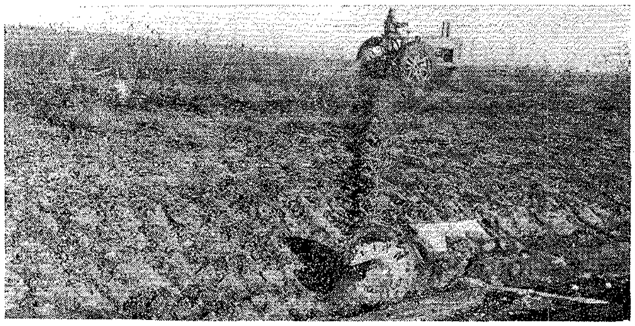

Fig. 11 A slope harrow composed of rotating chain to which 15-in. rods are welded is used for leveling small rills on 1:3 slope. Rotating weight at the bottom keeps harrow from pulling up slope

held together by the cementing agent. The ground roughness should not exceed 4 in. in height.

Ground too rough appears to be as bad as too smooth. On ground too rough, mulch falls too much on one side of the roughness so that when wind is reversed, mulch may roll into the depressions and consequent soil loss may occur. Land should be just rough enough to give good mulch anchorage but the roughnesses should be small enough so that the mulch will produce a continuous cover.

Small weeds or other plants, dead or alive, are important in holding down the mulch. It is better to let some weeds stand, especially on sand, than destroy them by tillage prior to mulching.

Whether the soil is highly erodible or not, the quantity of mulch and asphalt required for complete protection against wind appears to be about the same. The objective should be for complete cover of the surface no matter how erodible it is. Of course greater care must be exercised on sand than on less erodible soil to see that no weak spots exist in the mulch cover.

It is important that the mulch be spread uniformly as with a blower type spreader. It is impossible to hand-spread as uniformly or, in America, as cheaply as with a suitable mechanical spreader.

It is important that the liquid asphalt be spread uniformly with the mulch. Intermittent injections of asphalt into a stream of mulch when the blower is used are not entirely satisfactory. Rather than control the quantity of asphalt that way, it is preferable to reduce the size of the asphalt nozzle and apply the asphalt continuously into the stream of mulch. The asphalt spray should be as fine as possible.

Appendix A — Detailed Description of Test Procedures and Discussion of Results for Anchoring Vegetative Mulches.

PROCEDURE

The land was first seeded to grass and fertilized, using a hydroseeder for seeding and fertilizing simultaneously. Various quantities of hauled-in prairie hay and wheat straw, generally referred to as mulch, were then applied uniformly on the surface using a blower type mulch spreader. The mulches were anchored with five different types of mechanical packers and with various quantities of asphalt emulsion and cutback.

The packers used were *(a)* a cutaway rolling disk (Fig. 3), *(b)* a smooth rolling disk (Fig. 4), *(c)* a V-tread rolling wheel (Fig. 5), *(d)* a plate punch (Fig. 6), and *(e)* an L-rod (Fig. 7). The asphalt-in-water emulsion was a fast-curing material suitable for spraying and containing no petroleum solvents known to be toxic to plants. Both medium curing (MC) and rapid curing (RC) cutback asphalt liquids suitable for spraying were used.

Spacings of 4, 8, and 12 in. between the disks of the cutaway disk packer were tested on dune sand and sandy loam. Disk penetration of 2, 3, and 4 in. deep was tested on dune sand. The intention was to test the same depths of penetration on sandy loam soil, but the ground was so hard that disk penetration was only ¾, 1, and 1½ in.

A modified, portable wind tunnel used regularly at Manhattan, Kans., was used to test the anchorage of mulch and to determine soil loss from the different treatments. Several wind velocities were applied to a limited number of treatments and one velocity to all the treatments. This velocity had a mean surface drag of 42.5 dynes per square centimeter (3,850 lb per acre). It is associated with a mean wind velocity of approximately 85 mph at 50-ft height—a velocity occurring only occasionally in nature.

The quantity of soil moved by wind was determined with a modified Bagnold catcher, and the degree of mulch anchorage with a special mulch catcher (Fig. 8). The percentage of mulch trapped in the catcher subtracted from 100 gave the percentage of mulch anchored under the equivalent wind velocity of 85 mph at 50-ft height.

Emergence and growth of grass seedlings were observed at periodic intervals after treatment.

RESULTS

From general observations on the performance of the blower-type mulch spreader under windy conditions, it is apparent that, if mulch must be applied dry, the soil surface should be left rough so the mulch will not be blown away by the wind. Disking or chiseling generally leaves the soil rough enough for this purpose. Mixing water at the rate of 300 to 400 gal per acre with the mulch greatly aided in tacking the mulch down but only for a short time. The mulch had to be packed immediately after it was applied.

Straw or hay applied without any anchoring agent was completely ineffective against the equivalent 85-mph wind. All except a few short blades among the clods blew away. Mulch had to be anchored to be effective.

Anchoring Mulch with Packers

Percentage anchored with any packer was higher for hay than for straw. The rougher, tougher, and finer stemmed hay apparently was anchored better than the smoother, more fragile, and coarser straw. Long hay showed greater degree of anchorage than short hay. Therefore, it is better to use a mulch spreader that tears and shreds the baled mulch than one which cuts and thereby shortens the mulch.

The disk packers (both with cutaway and smooth edge) generally anchored the straw and the hay significantly better than the other packers used. Next in order of effectiveness was the V packer, the plate packer, and the L packer. Average anchorage for disk, V, plate, and L packers was 96, 72, 62, and 52 percent, respectively. No differences in degree of mulch anchorage were obtained with cutaway and smooth disk edges on uniformly spread mulch not exceding 4,000 lb per acre. The cutaway disks will likely have an advantage where mulch is bunched up and where it exceeds 4,000 lb per acre.

An additional advantage of disk packers was that they left the mulch erect, a position that is more effective in protecting the soil from erosion by wind. Previous experiments have indicated that standing wheat or sorghum straw or stubble with rows running at right angles to the wind is approximately twice as effective in reducing wind erosion as equal quantity of flattened stubble. On this basis alone, the disk packers seem to have an advantage for wind erosion control over packers that leave the mulch essentially flat.

The V packer failed to punch the mulch firmly into the soil. The very narrow V wheels (1-in. wide at the base) were more effective than the wider (3-in.) V wheels. On dune sand the narrow wheels spaced 5 in. apart anchored the mulch almost as well as the disks. The V packer had to be weighted as much as possible, but even then and even on soft ground the broader V wheels penetrated only about 2½ in. — not sufficient for maximum anchorage.

The plate packer failed to anchor the mulch very well. The strong wind pulled some mulch out of the slots.

The L packer had little ability to punch the mulch into the ground but did bring some soil clods to the surface. The packer threw some clods on top of the mulch and anchored it somewhat that way.

The basic idea behind the plate and L packers is to anchor the mulch but leave most of it flat, a position suited to control erosion by water but not by wind. The idea is plausible too because it eliminates rows running parallel with the direction of wind or running water. However, these packers did not anchor the mulch sufficiently against strong winds.

Disk Spacing and Depth of Penetration

The narrower the spacing between the rows produced by the disk packer, the lower was the soil loss when wind blew parallel with the rows, provided the mulch was well anchored. Soil loss when wind blew parallel to the rows of prairie hay was only from one-sixth to one-tenth as great for 4-in. as for the 12-in. spacing, provided the hay was fully anchored. On the other hand, soil loss was from 20 to 300 times as great when wind blew parallel to mulch rows as when it blew at right angles to the rows.

Moist loam soil clogged between disks spaced 4 in. apart. No such difficulty was encountered on dry or wet dune sand.

Prairie hay or wheat straw spread uniformly at 4,000 lb per acre and anchored with a disk packer with any disk spacing up to 12 in. reasonably stabilized even the most erodible dune sand, if the direction of an equivalent 85-mph wind was at right angles to the packer rows (Fig. 9). If the wind was parallel with the rows, the 4,000-lb per acre rate was almost sufficient on dune sand with row spacing 4 in. and mulch well anchored; 5,000 lb per acre on dune sand and 4,000 lb per acre on less erodible soil should be ample with 4-in. row spacing of well-anchored hay even if the wind hit parallel with the rows. Probably about 1,000 lb per acre more straw than hay should be used.

No problem was encountered on dune sand in properly anchoring the mulch with disk packers. On loam some difficulty was encountered. Here the ground was generally hard and the disks, especially with 4-in. spacing, would not penetrate the soil sufficiently to anchor the mulch. Under such conditions the disks, instead of penetrating the intended 3 in., penetrated only ¾ in. with 4-in. spacing, 1 in. with 8-in. spacing, and 1½ in. with 12-in. spacing of a heavily weighted packer. Only the 1½-in. depth of penetration was sufficient to anchor the mulch on sandy loam soil. However, the 1½-in. depth of penetration may not have been sufficient on loose dune sand; the 2-in. depth was sufficient. Penetration down to 3 in. also appeared to be satisfactory, but 4-in. penetration buried the mulch to a point where it caused a slight increase in soil loss under an equivalent 85-mph wind.

On soft ground, such as sand, the disk packer without depth gage wheels penetrated the ground deeper than necessary (6 in.) even with no weights. The depth gage wheels were then installed to regulate depth of disk penetration.

Operating the disk packer with 8-in. disk spacing the second time over did more harm than good. Little loose mulch was left to anchor after the first operation so that the second operation merely tended to bury more of the anchored mulch. Crosspacking with 12-in. disk spacing appears to hold some promise. It was not tried in these experiments.

Mulch Anchored with Asphalt

The purpose of using adhesives, such as asphalt, is to anchor the mulch where a packer cannot be used. Using the packer where asphalt was applied with the mulch generally did little good. The disks cut through the mulch-asphalt mixtures much more than through mulch alone, generally tended to ball up the mulch, and usually did more harm than good. The use of asphalt alone indicated that at least 1,000 gal per acre are needed to give anywhere near the protection afforded by 4,000 lb per acre of properly anchored hay.

No difficulty of mulch stabilization was experienced under moderately windy conditions (up to 50 mph) when mulch and rapidly curing liquid asphalt were blown as a mixture.

Only treatments that had a minimum of 4,000 lb per acre of hay with 600 gal per acre of rapid-curing asphalt cutback or emulsion or 6,000 lb per acre of hay with 400 gal per acre of asphalt emulsion gave complete stability against an equivalent 85-mph wind on smooth, bare ground. However, when the ground was moderately roughened such as by tandem disking before applying the mulch-asphalt mixture, 4,000 lb per acre of hay mixed with at least 400 gal per acre of rapid-curing asphalt cutback or emulsion was completely stable, even on the most erodible dune sand (Fig. 10).

Wheat straw with or without asphalt was less stable against wind than prairie hay with an equal quantity of asphalt, even when the hay was much shorter than the straw.

The rapid-curing asphalt emulsion served as a slightly stronger cementing agent than the rapid-curing cutback (RC). The medium-curing cutback (MC) was a considerably weaker cementing agent.

Anchoring Mulch on Construction Slopes

No wind tunnel tests were possible on the 1:3 slope on which these experiments were conducted, but strong natural winds gave some idea of the stability of the three treatments that were initiated. Treatments were as shown below. The land was hydroseeded before treatment.

(a) 4,000 lb per acre prairie hay plus 400 gal per acre asphalt emulsion mixed with the hay was applied uniformly, using shredder-blower type spreader.

(b) 4,000 lb per acre prairie hay applied with blower-type spreader followed by slope harrow (Fig. 11) pulled five times over the ground to roughen the surface and anchor the mulch.

(c) Pulled slope harrow over the ground five times, then spread uniformly with blower 4,000 lb per acre prairie hay, and finally applied 2,000 gal of water per acre to anchor the mulch, jetting the water with a hydroseeder into the slope to bury part of the mulch with the soil.

Treatment *(c)* indicated slight removal (not over 5 percent) of the mulch by strong winds, and treatments *(a)* and *(b)* were virtually completely stable. The choice of one or the other of the treatments appears to depend on equipment, materials, and time available. Treatment *(a)* is the quickest and most convenient.

Effects of Mulch Cover on Grass Emergence and Stands

Where no packer was used, no smothering of grass seedlings occurred with 2,000 lb per acre of hay mixed with up to 200 gal per acre of asphalt emulsion or cutback so that grass emerged uniformly and ultimately produced a 100 percent stand (ground surface covered). Where mulch and mulch-asphalt mixtures with 4,000 lb per acre of hay or straw were applied and where no removal of mulch by erosion occurred, slight smothering of seedlings and reduced grass stands occurred. Considerable smothering and markedly reduced grass stand (65 percent four weeks after seeding and 75 percent seven weeks after seeding) occurred with 8,000 lb per acre of hay plus 200 gal per acre of asphalt emulsion.

However, the poorest stands (21 percent four weeks after seeding and 36 percent seven weeks after seeding) were obtained where the land was bare and no mulch was applied. Here failures resulted due to removal of seeds or destruction of seedlings by either wind or running water, or by both.