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STRAW AS AN EROSION CONTROL MULCH

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# STRAW AS AN EROSION CONTROL MULCH

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Abstract

Straw was shown to be the most cost-effective mulch practice to retain soil in artificial rainfall tests. Straw was superior to hydraulic mulches and compared favorably with the expensive fabric products. Some fabrics were inferior to straw. Jute, applied over 3,000 lbs/acre straw, was the most effective. Straw practices are discussed.

## INTRODUCTION

The addition of mulch products to the surface of disturbed soils is the most practical way to obtain an immediate degree of protection from surface erosion and to encourage the establishment of plants for additional protection. Similar plant establishment effects on rock-free gentle slopes are created by cultivation and seed coverage, practices not possible on many erosion control sites. Even on cultivated soils the addition of surface applied mulches will sometimes offer worthwhile protection and increase the rate or amount of plant establishment.

Mulches control erosion directly by absorbing the impact of raindrops which would otherwise dislodge soil particles. They may also trap soil particles, retain water, and improve infiltration. Plant establishment is encouraged by limiting temperature extremes and retaining moisture.

The cost and effectiveness of mulching practices vary greatly. Therefore, it is important that their relative values be known. Straw was compared in this study to other commonly applied mulching practices for effectiveness in retaining soil under artificial rainfall conditions.

## PROCEDURES

Surface applied mulches were tested on 2 ft x 4 ft soil surfaces inclined at 5:1 and/or 2:1 (horizontal to vertical measurement). Artificial rainfall of 0.12 inch diameter drops falling 15 ft at the total amount of 6 inches/hr was applied to duplicate samples of the surfaces for periods of two to six hours. The boxes containing the soil were designed to allow rapid drainage if water moved through the 6 inch profile. Soil washed from the slope surface was collected, dried, and weighed.

Mulch treatments include hydraulically applied virgin wood fiber mulch (Silvafiber[R]) at rates of 1,500 and 3,000 lb/acre; barley straw at rates of 1,000, 2,000, 3,000 lbs (tacked to the surface with asphalt emulsion at 200 gpa) and 8,000 lb punched into the soil with a shovel. Fabrics stapled to the soil were jute, excelsior, and paper (Hold/-Gro$^R$); and jute stapled over 3,000 lb of straw. These were compared to no surface protection. The percent of the surface covered with the various straw and fabric treatments was measured with a point frame (100 points/replication), and are listed with weight/acre of various products (Table 1).

Table 1. Percent of surface covered and weight of mulch product.

| | lb/acre | Percent cover |
|---|---|---|
| Hydraulic mulch | 1,500 | 95 |
| Hydraulic mulch | 3,000 | 100 |
| Straw | 1,000 | 48 |
| Straw | 2,000 | 66 |
| Straw | 3,000 | 78 |
| Straw | 8,000 | 86 |
| Jute | 5,050 | 58 |
| Excelsior | 3,300 | 72 |
| Hold/Gro | 850 | 95 |
| Jute + straw | 8,050 | 96 |

The eight "soils" used in the tests were often subsoils or mixtures of profiles taken from construction sites. The Arnold fine sand was from a road cut near Prunedale, decomposed granite a road cut near Carson Pass, Cieneba gravelly sandy loam from a motorcycle park near Hollister, Dibble sandy clay loam from a brush area in Yolo Co., Los Osos loam from a construction site near Hercules, Yolo loam from Davis farmland, Auburn-Sobrante loam from the surface in the foothills of the Sacramento Valley near Browns Valley, and Altamont clay loam from a motorcycle park near Livermore. Soils were not compacted into the boxes other than by repeated waterings. Bulk density was measured periodically, at or near field capacity to be sure all treatments were comparable. Texture and particle size are shown in table 2.

Table 2. Texture, series name, and particle size of soils tested (percent).

| Texture | Name | Clay | Silt | Sand | Gravel |
|---|---|---|---|---|---|
| Uncemented fine sand | Arnold | 2 | 3 | 95 | 0 |
| Very gravelly coarse sand | Decomposed granite | 3 | 4 | 41 | 52 |
| Gravelly sandy loam | Cieneba | 9 | 9 | 49 | 33 |
| Sandy clay loam | Dibble | 21 | 18 | 61 | 0 |
| Loam | Los Osos | 17 | 48 | 35 | 0 |
| Loam | Yolo | 22 | 45 | 33 | 0 |
| Loam | Auburn-Sobrante | 21 | 43 | 36 | 0 |
| Clay loam | Altamont | 29 | 45 | 26 | 0 |

RESULTS

## Erodability of Soils

The unprotected soil surfaces varied considerably in the amount of soil lost (Figure 1). Loss was greater from all soil types when inclined at 2:1 than at 5:1. Least erodable were the soils containing gravel and the soil with the highest clay content. Much of the water flows through the gravelly soil draining out of the bottom of the boxes. Also the surface gravel particles absorb much of the energy from the water drops without being dislodged. By contrast the montmorillonite clay particles of the Altamont soil are firmly bonded together, and while they don't allow water to readily drain through, they are able to withstand considerable impact energy of the drop sizes used here.

Most erodable were the soils with high percentages of fine sand and silt. The Arnold fine sand allowed some infiltration but soon saturated and liquified. Steepness of the slope then became important in determining how fast the liquified soil flowed from the slope. Also highly erodable are the loams which are particularly important because they commonly occur on coastal sub-division sites.

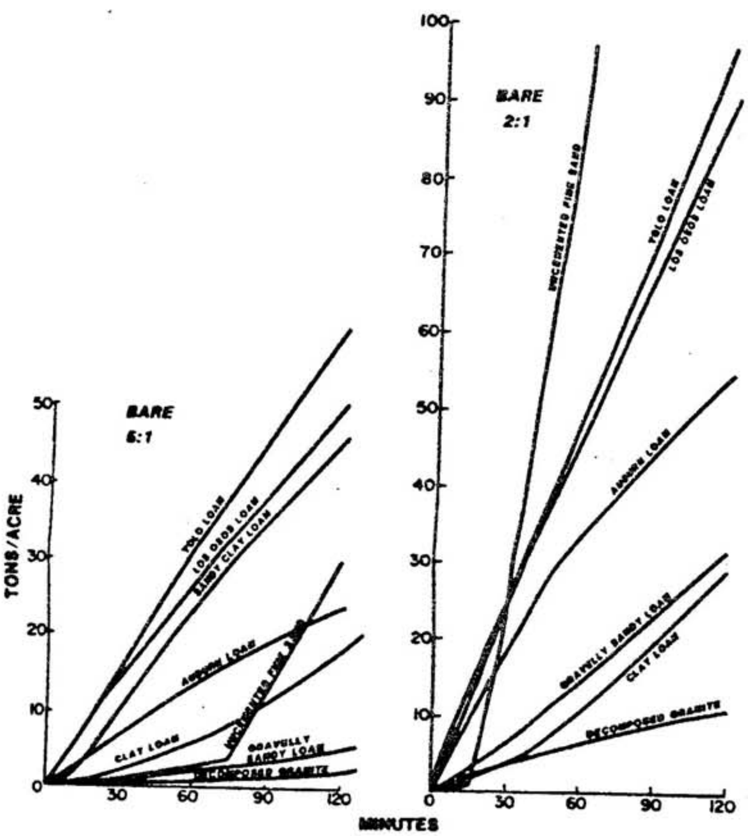


Figure 1. Erosion rates (tons/acre) of unprotected soil surfaces inclined at 5:1 and 2:1.

## Straw vs. Hydraulic Mulch

The hydraulic mulch rates were compared to 3,000 lbs of straw on seven soils at both 5:1 and 2:1. The effect on soil loss is shown in figure 2.

Straw provided much greater protection than wood fiber on all soils, but was most dramatic on DG, uncemented fine sand, and clay. The protection was so complete that the regular two-hour test was increased to as much as six hours. The excellent performance of straw on uncemented fine sand was particularly impressive because this soil liquifies and flows if not protected by a mulch. Wood fiber, though inferior to straw, offered some protection. Increasing the commonly used rate of 1,500 lb to 3,000 lb provided additional protection only on a fine sand at 5:1 and DG at 2:1.

Straw increased the infiltration rate of water on both DG and uncemented fine sand compared to bare soil as indicated by reduced volume of runoff. Wood fiber, by contrast, increased the volume of runoff on both soils.

Loam and sandy clay loam soils were much more erodable than either coarse textured or clay soils but the same mulch relationships existed. Straw was superior to hydraulic mulch (1,500 lb) on both slopes. Increasing the rate of hydraulic mulch to 3,000 lbs increased its effectiveness. On Yolo loam at 2:1, 3000 lbs of fiber compared favorably to straw.

Auburn loam was less erodable than other loams. The 3,000 lb of hydraulic mulch was superior to the 1,500 lb rate at 5:1 and comparable to 3,000 lb of straw. However, when the slope was increased to 2:1 straw was much better than the high rate of hydraulic mulch which was still better than the low rate of hydraulic mulch.

## Rates of Straw

Because straw is so effective it is important to choose the correct rate. In addition to the 3,000 lb tested above, lesser rates of 1,000 and 2,000 lb were compared on a sandy clay loam soil at 5:1. Also tested was straw punched into the slope at 8,000 lb/acre, a commonly used fill-slope treatment in California.

All treatments were very successful, allowing us to extend the test to six hours, even though this is a very erodable soil. Each increase in the amount of straw reduced the amount of soil lost (figure 3).

## Straw vs. Fabrics

The most commonly available fabrics are jute, excelsior, and a paper strip-synthetic yarn product (Hold/Gro). These were compared to straw at 3,000 lb/acre, also on a sandy clay loam at 5:1 for six hours.

Straw and jute were the most effective treatments and not significantly different from each other. Excelsior was less effective but better than the paper product (Figure 4).

Jute is sometimes used on top of straw for added effectiveness. This treatment was therefore compared to the other most effective treatments--

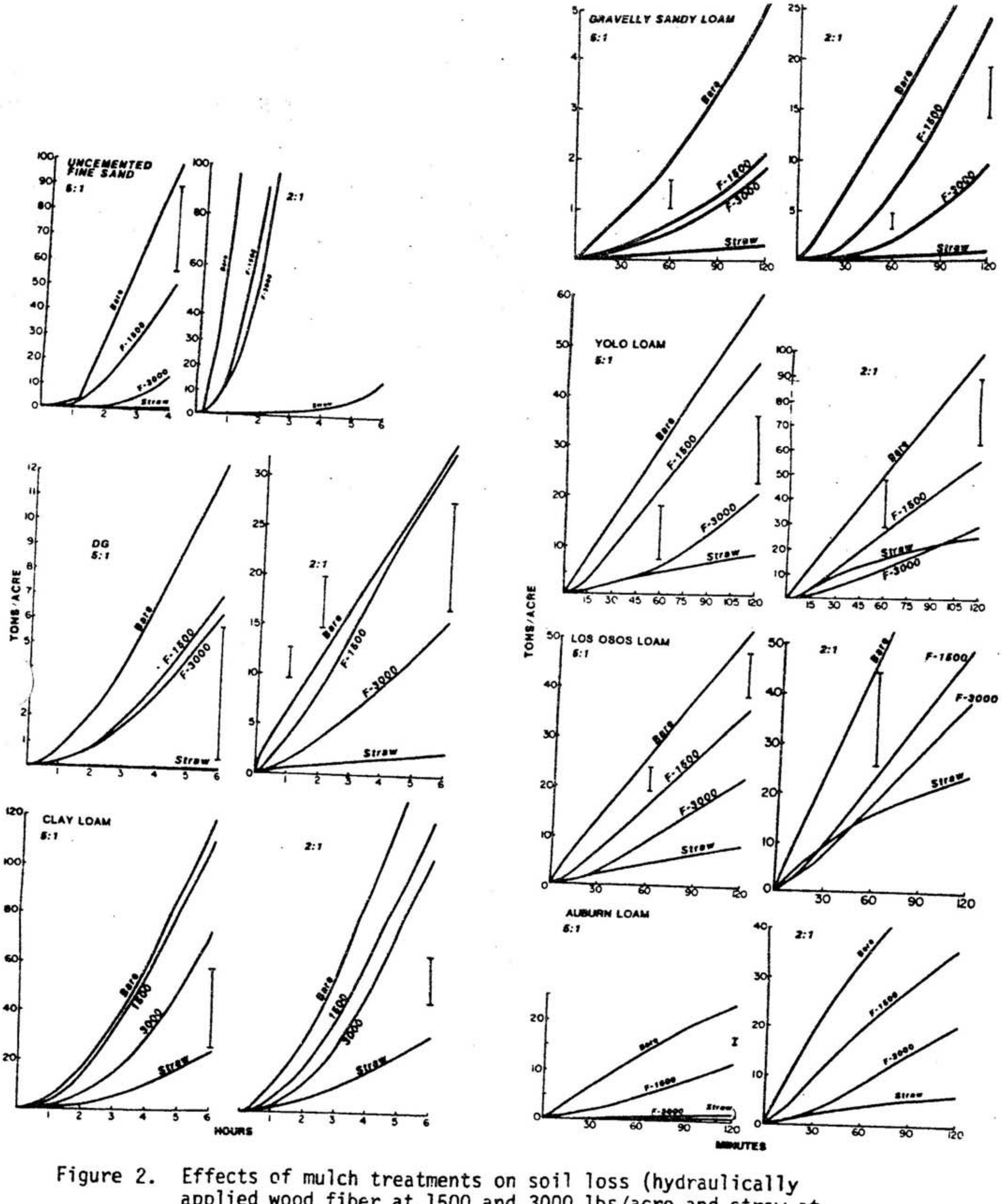


Figure 2. Effects of mulch treatments on soil loss (hydraulically applied wood fiber at 1500 and 3000 lbs/acre and straw at 3000 lbs/acre compared to bare soil) on seven soils at 5:1 and 2:1 slopes. Vertical insets indicate size of significant differences at .05 level.

straw punched at 8,000 lbs, straw tacked at 3,000 lbs, and jute alone. Because we expected these treatments to be very effective the slope was increased to 2:1.

Jute plus straw was the most effective and better than 8,000 lb of straw which was better than 3,000 lb of straw (Figure 5). Although jute alone was very effective at 5:1 in the previous test, it grew progressively worse during this test. It was as effective as 8,000 lb of straw for over two hours, but then performance deteriorated as soil washed from beneath the fabric.

## DISCUSSION OF RESULTS

These tests illustrate the importance of soil texture in erodability and the large differences in the effectiveness of mulch treatments for retaining soil. Also different are the costs of these treatments. Straw, though consistently the most effective treatment, is not expensive. At the rate of 3,000 lb/acre it is comparable in cost to hydraulic mulches at 1500 lb/acre and only 25% of the cost of installed fabrics (Kay, 1978).

Straw has been largely replaced in California by the currently popular hydroseeding techniques (hydraulic slurry applications of seed, fertilizer, mulch fibers, and possibly chemicals). Field and laboratory tests, such as reported here, consistently illustrate that straw is superior not only to retain soil but also to increase the establishment of plants.

The mulch effect of straw can be expected to increase plant numbers. Meyer et al. (1971) obtained fescue-bluegrass establishment of 3, 28, and 42% with respective surface straw mulch treatments of 0, 1, and 2 tons/-acre. Straw has been shown to increase plant establishment in decomposed granite (Kay, 1974). Seeding the annual grass Blanco brome (Bromus mollis) resulted in 7, 6, 26, 35, and 131 seedlings/ft$^2$ respectively on the untreated, fiber mulch at 1,000, 2,000, and 3,000 lb/acre, and straw at 2,000 lb/acre on a 2:1 slope. On 1.5:1 the number of plants were 1, 13, 29, 35, and 131, and at 1:1 slopes 0, 10, 27, 20, and 155. Seed coverage with soil produces superior stands when compared to hydraulic applications (Kay, 1979, Packer and Aldon, 1978). Fertilizer or legume seeding must be applied to compensate for the nitrogen tied up in decomposing the straw.

Size of mulch particles is important because of the mass required to absorb the energy in the water drops. Even though the hydraulic mulches provided the most complete ground cover (Table 1) they were too small to be effective.

Straw length may be important, particularly if it is to be punched into the soil, in which case longer straw is desirable. New agricultural practices are resulting in shorter lengths. The flails used in straw blowers will further shorten straw. The barley straw used in these tests was about 10 inches, ranging from 1-23 inches.

Soil contact is particularly a problem with the fabrics. They frequently allow erosion to occur from beneath them. A layer of straw under the fabric will improve this contact (Figure 4).

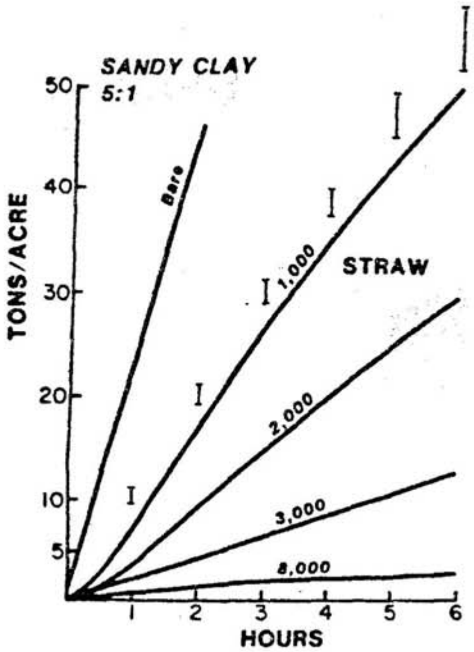


Figure 3. Effect of straw mulch rates on soil loss on 5:1 slopes, sandy clay loam soil. Vertical insets indicate a significant difference at .05 level.

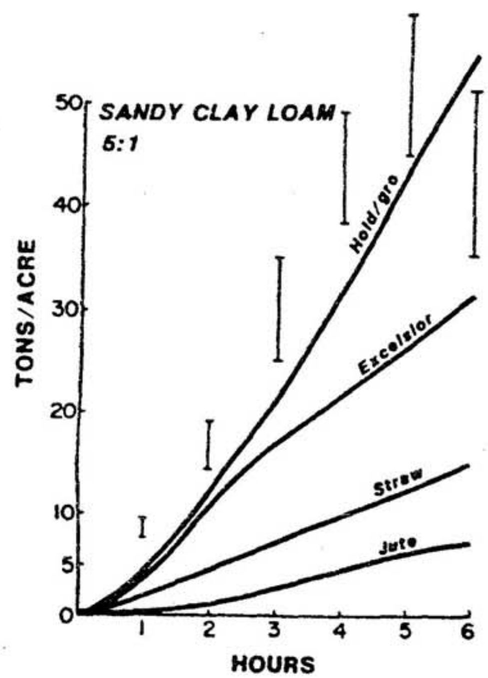


Figure 4. Effect of erosion control fabrics and straw on soil loss on 5:1 slopes, sandy clay loam soil. Vertical insets indicate significant difference at .05 level.

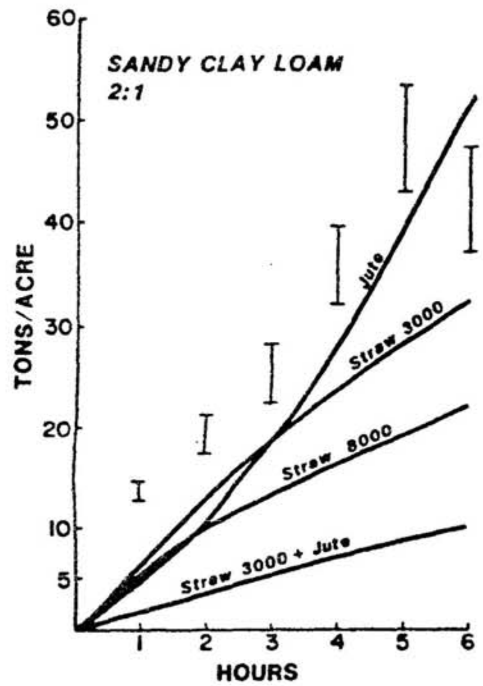


Figure 5. Effect of erosion fabrics or straw on soil loss on 2:1 slopes, sandy clay loam soil. Vertical insets indicate significant difference at .05 level.

Missing from these tests are the glue products, some of which may be expected to be very effective. Among the effective glues are the plastic types PVA and SBR. Organic glues are of questionable value (Kay, 1978). Properly applied, plastics may be as effective as the best treatments tested here. However, they are expensive and are not as versatile as straw in that they are not self-healing, having curing problems, and may inhibit seedling establishment.

## DISCUSSION OF STRAW PRACTICES

Cereals are a major crop in dry regions of the United States, and straw left on the site of production is often considered a liability because its decomposition ties up nitrogen needed for the next crop. Straw availability should be increased by current restrictions on removing this crop residue by burning in place. Clean grain straw, free of noxious weeds, is preferred for mulching. The straw can be expected to contain 0.5 to 5.0% cereal seed by weight, which may result in considerable plant cover in the first year. This provides additional erosion protection but may also be prohibitively competitive with the planted erosion-control or beautification mixture. Rice straw is sometimes used because neither the rice nor associated weeds can be expected to grow on most unirrigated disturbed lands. In areas where cereal crops are not common, hay is sometimes used but is normally more expensive than straw. Wild-grass hay may be a valuable source of native plant material if cut when the seeds are ripe but not shattered.

Straw can be applied with specially designed straw blowers or spread by hand. Commercial mulch spreaders or straw blowers advertise a capability of up to 15 US tons/hour and distances to 85 ft. The length of the applied straw may be important and can be controlled in most blowers by adjusting or removing the flail chains. Baled straw may also be relatively long or short, depending on agricultural practices. Straw to be crimped or punched should be relatively long to be incorporated into the soil effectively and still leave tufts or whisker dams. Rice straw is wiry, dirty, does not shatter readily, and consequently does not blow as well as straw of wheat, barley, or oats. It may come out of the blower in 'bird nests'. Blown straw (other than rice) lies down in closer contact with the soil than hand-spread straw and is anchored more successfully with a tackifier (substance sprayed on straw to hold it in place). Wind is a serious limiting factor in applying straw, though it can be an asset in making applications downwind. Dust, a problem in urban areas, can be overcome by injecting water into the airstream used to blow the straw.

The amount of straw to be used will depend on the erodability of the site (soil type, rainfall, length and steepness of slope), kind of straw (Grib, 1967), and whether plant growth is to be encouraged. Increasing rates of straw give increasing protection. Meyer et al. (1970) show that as little as 1,000 lb/acre reduced soil losses by two-thirds, while 4 tons/acre reduced losses by 95%. Straw to be crimped is commonly used at 2 tons/acre, while straw punched into fill slopes in California is at 4 US tons/acre in a split application and rolling operation (2 tons/acre each). Straw to be held down with a net should be limited to 1.5-2 tons/acre if plant growth is important. Too much straw may smother seedlings by intercepting all light or forming a physical barrier. Also, some grass straw (notably annual ryegrass, Lolium multiflorum) may contain inhibitors that have a toxic effect if used in excess. A good rule of thumb is that some soil should be visible if plant growth is wanted. Higher rates of straw may of course still satisfy these requirements if the straws are vertically oriented (like tufts) by crimping or punching. Excessive straw on the surface may be a fire hazard.

Straw or hay usually need to be held in place until growth starts. The problem is wind, not water. Water puddles the soil around the straw and helps hold it in place. Also, wet straw "mats down" and is not easily moved. If the straw covered area can be irrigated, or if rainfall is imminent, it will not be necessary to anchor the straw.

Common methods of holding straw in place are crimping, disking, or rolling into the soil; covering with a net or wire; or spraying with a chemical tackifier. Swanson et al. (1967) found similar protection from prairie hay applied as a loose mulch or anchored with a disk packer (crimper).

Crimping is accomplished with commercial machines which utilize blunt notched disks which are forced into the soil by a weighted tractor-drawn carriage. They will not penetrate hard soils and cannot be pulled on steep slopes.

Rolling or "punching" is done with a specifically designed roller. Not satisfactory for incorporating straw is a sheepsfoot roller, commonly used in soil compaction. Specifications of the California Department of Transportation contain the following provisions (State of Calif., 1975): "Roller shall be equipped with straight studs, made of approximately 7/8 inch steel plate, placed approximately 8 inches apart, and staggered. The studs shall not be less than 6 inches long nor more than 6 inches wide and shall be rounded to prevent withdrawing the straw from the soil. The roller shall be of such weight as to incorporate the straw sufficiently into the soil so that the straw will not support combustion, and will have a uniform surface."

The roller may be tractor-drawn on flat areas or gentle slopes, whereas on steeper slopes the roller may be lowered by gravity and raised by a winch in yo-yo fashion, commonly from a flat-bed truck. Requirements are soil soft enough for the roller teeth to penetrate, and access to the top of the slope. This is a common treatment on highway fill slopes in California. It can be used on much steeper slopes than a crimper. Punched straw may not be as effective as contour crimped straw, because of the staggered arrangement of tucked straw instead of the "whisker dams" made by crimping (Barnett et al., 1967).

A variety of nets have been used to hold straw in place: twisted-woven kraft paper, plastic fabric, poultry netting, concrete reinforcing wire, and even jute. Price and the length of service required should determine the product used. These should be anchored at enough points to prevent the net from whipping in the wind, which rearranges the straw.

Perhaps the most common method of holding straw, particularly in the eastern U.S., is the use of a tackifier. This method may be used on relatively steep slopes which have limited access and soil too hard for crimping or punching. Asphalt emulsion, the tackifier used most commonly, is applied at 200-500 gal/acre--either over the top of the straw or applied simultaneously with the straw blowing operation. Recent tests (Kay, 1978) have shown that 600 gal is superior to 400 gal. and that 200 gal/acre is not satisfactory. Wood fiber, or new products used in combination with wood fiber, have been demonstrated to be equally effective, similar in cost, and environmentally more acceptable (Table 3). Though wood fiber alone is effective as a short-term tackifier, glue must be added to give protection beyond a few weeks. Terratack I is a gum derived from guar (*Cyamopsis Tetragonoloba*). Ecology Controls M Binder is a gum from plantain (*Plantago insularis*). The remaining products are emulsions used in making adhesives, paints, and other products. Increasing the rate/acre of any of the materials will increase their effectiveness.

Table 3.--Effects of tackifier products on wind stability of barley straw broadcast at 2,000 lb/acre.

| Product | Chemical | Fiber lb | Water gal | Wind speed (mph at which 50% of straw was blown away) |
|---|---|---|---|---|
| None | | | | 9 |
| SS-1 asphalt | 200 gal | | | 40 |
| SS-1 asphalt | 400 gal | | | 80 |
| SS-1 asphalt | 600 gal | | | 84 |
| Fiber only | | 484 | | 47 |
| Fiber only | | 736 | | 84 |
| Terratack I | 45 gal | 150 | 750 | 68 |
| Ecology Control M-Binder | 100 lb | 150 | 700 | 84 |
| Styrene butadiene copolymer emulsion (SBR) | 60 gal | 75 | 400 | 84 |
| Polyvinyl acetate (PVA) | 100 gal | 250 | 1000 | 54 |
| Copolymer of methacrylates & acrylates | 100 gal | 250 | 1000 | 76 |

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