Mulches for Steep Cut Slopes

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•IT IS NECESSARY to obtain a quick cover of grass or other vegetation for soil and water control along highways and approaches or interchanges to interstate highways. Steep 1:1 slopes are not generally recommended for grass stabilization, but such slopes in Virginia are often unavoidable because of the tremendous cost of earth removal due to topography or the lack of adequate right-of-way for establishing flatter slopes. This paper gives results of experiments on steep 1:1 sloping cuts that have been carried on since 1962 to study mulching materials including nets, straw mulch, asphalt, glass fiber, woodfiber cellulose, and combinations of these materials in view of establishing a sod quickly.

Published results show that certain mulches improve the soil environment and seedling establishment. Barkley (1) found that straw mulch and woodfiber cellulose (Turfiber) gave faster germination, better seedling stands, and greater seedling growth than no mulch, sawdust, or certain plastic type mulch treatments. Straw and woodfiber cellulose both moderated soil temperatures and improved soil moisture as compared with no mulch and certain other mulch treatments. Button and Porharst (5) found that wood cellulose fiber was equal to hay as a mulch material. Blaser (2) noted that sod development with straw mulch was somewhat faster than with wood cellulose fiber, but both materials were very satisfactory. Richardson and Diseker (6) found that a crop of Abruzzi rye, that later served as a mulch, was superior for establishing crown vetch as compared to net type materials such as jute, glass fiber, paper, and no mulch. On the other hand, seedling competition from fast-growing seedlings, such as small grains and ryegrass, usually retard slow-developing desirable seedlings (3). Brant (4) pointed out that grassing results with some of the newer mulching materials were inconclusive or unavailable for comparison.

GENERAL PROCEDURE

All experiments were designed to make the individual and combination mulch treatments the only variable; seed, lime, and fertilizers were uniformly applied. Randomized block designs, where all the treatments were randomized within a block, were used. There were three or more such replicated randomized blocks at each location. When possible, experimental sites were selected so that mulch treatments could be studied on each side of the road with shaded and sunny slopes. The mulch treatments were laid out on adjacent plots up and down the entire length of slopes ranging from 12 to 50 ft in length for the different experiments. All mulch treatments for a given site or for a replication were planned to apply all treatments on the same day so as to have valid comparisons.

Straw was applied by hand, after which the asphalt application was made to hold the straw in place. On the stakes-straw-asphalt treatments, wooden stakes were driven on 18-in. centers after which the other materials were applied. Glass fiber was applied by means of compressed air, and the equipment recommended by the manufacturer. The various nets were held in position with metal staples supplied by the manufacturer or with small wooden stakes. When used with nets or glass fiber, wood cellulose fiber

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was applied last. The methods of applying wood cellulose fiber are discussed with specific experiments.

The various mulch materials and manufacturers were as follows: Soil Saver (heavy jute netting) by Ludlow Corporation; Erosionet (a closely woven twisted, about ¼-in., paper mesh material; Mulchnet (a lightweight paper fabric about 2-in. mesh); and jute (heavy matting of jute yarns) made by Bemis Bros. Bag Co.; Strandex (a knit wood pulp fiber net, about ¼-in. mesh) by Strandex Inc.; Turfiber (a wood cellulose fiber) by International Paper Co.; Silvacel by Weyerhauser Co.; Soil-Set or Soil Gard (an elastomeric polymer emulsion which forms a water insoluble film when dry) by Alcoa Chemical Co.; Glassroot (glass fiber) by Pittsburgh Plate Glass Co.; Troyturf.

Experiments I, II, and III

The lime, fertilizer, and seed were applied uniformly across all plots; the mulch treatments were applied last. About 100 lb per acre of Turfiber were applied with a fertilizer-seed slurry because the slopes were so steep that the materials would not otherwise adhere to the soil. There was a slight spotted downward movement of lime, fertilizer, and seed due to tramping when applying the nets; thus, more seed and fertilizer were added to all plots after the mulch treatment had been applied.

Experiment IV

The methods were similar to those just mentioned, except that the four replicated plots of each mulch treatment were sprayed with a slurry of seed-fertilizer-lime. These materials were applied before applying mulch treatments or combinations other than for Silvacel and Turfiber. A very light application of Turfiber, 100 lb per acre, was included with each mulch treatment to make the material adhere to the steep slopes. Turfiber or Silvacel was applied in one application (mulch-seed-fertilizer-lime), except for some treatments with Turfiber (indicated in Table 2). When Turfiber was used with Glassroot or nets, it was applied last (alone in a slurry). The area for the four replicated plots was carefully computed and a small hydro-seeder was loaded so that the rates per acre of lime, seed and fertilizer were alike for all treatments.

EXPERIMENTS AND RESULTS

Experiment I—Approach to Interstate 81 Near Salem, Virginia

The reddish subsoil (1:1 northern and southern slopes, 15 to 40 ft in length) was an acid, colluvial shale, low in fertility. Because of the 1:1 slope, topsoil was not applied. This was a very difficult environment for seedling establishment due to the drought, steepness, and the crumbling and loosening surface, which occurs soon after rain. Mulches were thus essential to stabilize the soil, moderate temperatures, and improve moisture.

The following mulch treatments were applied in August 1962: (a) straw with asphalt; (b) straw with Soil-Set; (c) straw held in place with Mulchnet; (d) straw; (e) asphalt; (f) jute net (Soil Saver); (g) Erosionet; (h) Turfiber (woodfiber cellulose); (i) horizontal scarification before seeding, then Turfiber; (j) Erosionet topdressed with Turfiber; and (k) Turfiber with a light application of Soil-Set. The mulch treatments were randomized on a cool slope (northern exposure) and repeated in two randomized blocks on a warm southern slope exposure. All plots received 2 tons of lime; 1,500 lb of 10-20-10 fertilizer; and a seeding mixture of 60 lb of Kentucky 31 fescue and 1 lb of redtop per acre.

TABLE 1

EFFECT OF VARIOUS MULCHES ON SOIL MOISTURE AND SURFACE TEMPERATURE ON A COOL SLOPE HIT BY AFTERNOON SUN, SEPTEMBER 18, 1962

Treatment	% Moisture in Soil	Soil Surface Temperature
No mulch	14.0	84
Asphalt	13.9	83
Turfiber + Soil-Set	14.1	81
Jute net	16.5	79
Turfiber	-	77
Straw + asphalt	15.2	75

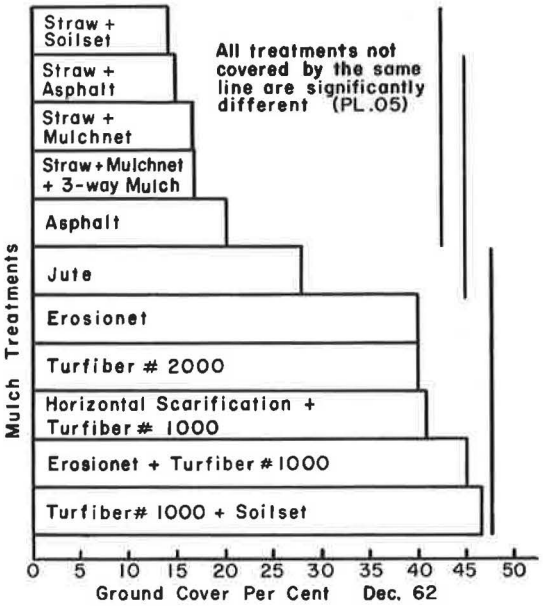

Figure 1. Soil covered with sod for various mulch treatments near Salem on an interchange to I-81. Experiment established in August 1962, and data obtained in December 1962. Treatments not intersected by same line are significantly different.

The moisture contents and temperatures for some of the treatments on September 18 are given in Table 1. Although no great differences are shown, the mulches which maintained the lower soil surface temperatures also had higher soil moisture contents. This is expected as higher temperatures stimulate evaporation of soil moisture. Figure 1 shows a decided improvement in sod cover by certain mulches $3\frac{1}{2}$ months after seeding. Any treatment combination with straw gave rather poor ground cover apparently because the straw was applied too heavily or lost due to erosion. The best sod cover was obtained with various nets, Turfiber, and combinations of Turfiber with nets or Soil-Set.

Although good sod establishment was obtained with certain mulches, the seedlings failed to develop deep root systems because of the impervious soil and inferior aeration. Growth was also retarded by low rainfall. The winter season was critically cold and alternate freezing and thawing was deeper than the roots. There was much slipping of sod on all plots, but sod retention was best on slopes with jute net or combinations of net-straw mulch treatments.

Experiment II—State Highway 614 Near Pilot Mt.

This experiment was established on September 14, 1962 on old slopes where all grass and woody vegetation had degenerated. The slopes were 1:1 and steeper with variable exposures due to the curving mountainous highway. The subsoil on cut slopes, sandstone in origin influenced by the presence of some limestone, was very acid and especially low in organic matter, nitrogen, phosphorus, and calcium. The mulch treatments were similar to those for Experiment I, except that Troyturf was included. Lime at 2 tons per acre; 1,200 lb of 10-20-10; and a mixture of 60 lb of Kentucky 31 fescue, 1 lb of redtop, and 5 lb of ryegrass were applied with all mulches.

The soil moisture under different mulches approximately one month after establishing the experiment is shown in Figure 2. All mulches tended to retain moisture better than no mulch. Certain combinations of Turfiber with other materials and Troyturf tended to have the most favorable moisture; however, moisture with straw or certain nets was about as good. (Other data are not given for Troyturf, because of a fertilizer and seed differential for this mulch.) The data help substantiate the earlier results which showed the beneficial effects of mulches in retaining moisture. Soil temperatures were not taken.

It is very important to obtain quick germination, dense stands and large plants for establishing a sod quickly. Mulches had a decided effect on seedling stands, there being about $2\frac{1}{2}$ times as many seedlings per unit area with Erosionet as with no mulch (Fig. 3). Asphalt used liberally by itself actually retarded germination and seedling stands. Seedling populations for straw-asphalt and Turfiber mulches were similar and not significantly different. Figures 2 and 3 show some relationships between the moisture level and population of grass plants. This relationship does not hold exactly

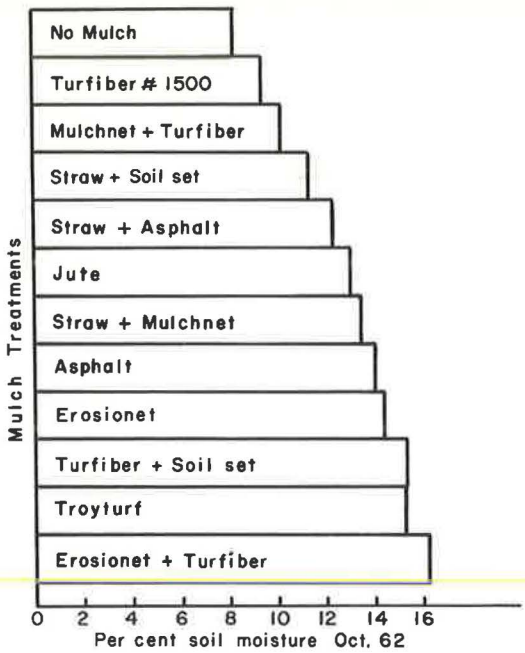

Figure 2. Influence of various mulches on total soil moisture for an experiment established along State Road 615 near Pilot Mountain; established in September, data taken in October 1962.

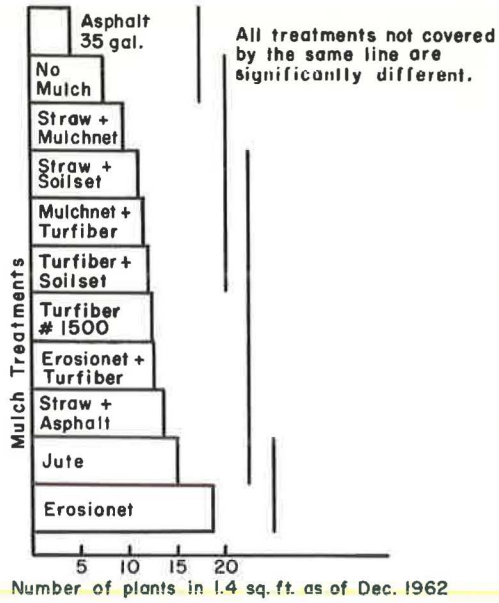

Figure 3. Grass seedling stands with various mulch treatments along State Road 615 near Pilot Mountain; established in September and plant counts made in October 1962. Turfiber was applied at 1,000 lb/a except as indicated. Treatments not intersected by same line are significantly different.

true because other factors besides moisture influence germination and growth. The variable environment, even with repeated treatments, also hindered a better association between stands and soil moisture.

Mulches should improve microclimate to encourage fast seedling growth to stabilize the soil with many roots and also to shade the soil to reduce temperatures and conserve moisture. The largest fescue seedlings occurred on Turfiber-Erosionet and Turfiber-Soil-Set mulch combinations (Fig. 4). The seedlings were smallest with no mulch and straw-Soil-Set mulches. The small seedlings with straw mulch treatments are attributed to applying the straw too liberally which caused excessive shading and retarded seedlings. Seedlings with some of the nets used for mulch were also small as compared with other treatments; the nets did not stay in contact with the soil, thus, seedlings under the nets were apparently shaded.

Seedling sizes tend to correlate with the moisture levels of the soil (compare Figs. 2 and 4).

Experiment III—Access Road to Interstate 81 Near Salem

This experiment was established April 1, 1963 on steep 1:1 cuts. The subsoil, deep red and calcareous in origin, was moderately fertile. All plots received 1,500 lb of 10-20-10, 60 lb of Kentucky 31 fescue, 4 lb of redtop, and 48 lb of Lespedeza sericea per acre. The mulch treatments were replicated twice on slopes with a cool northern exposure and once with warm southern exposure.

Data taken 6 months after seeding show poor sod cover during the first summer (Fig. 5). This is attributed to extremely dry soil during the spring and summer as there was a deficiency of 15 in. of rainfall. The area staked for stabilizing the straw

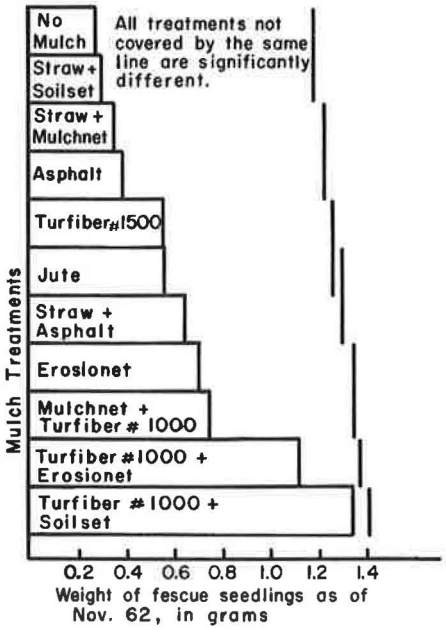

Figure 4. Growth of Kentucky 31 fescue seedling plants with different mulch treatments along State Road 615 near Pilot Mountain. Experiment on this steep cut slope was established in September, and plant weights were obtained in November 1962. Treatments not intersected by same line are significantly different.

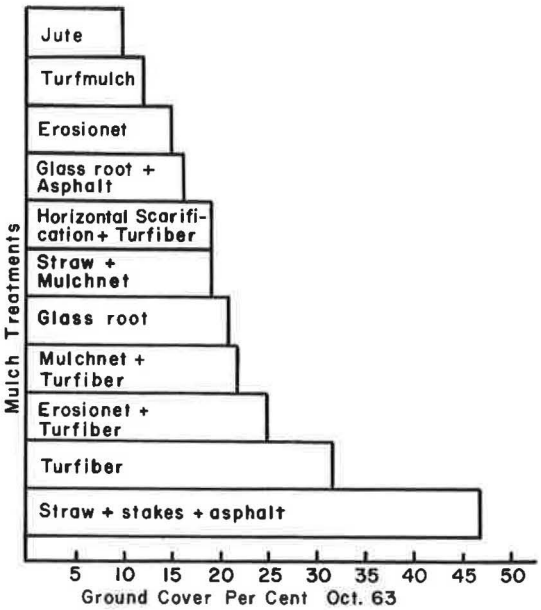

Figure 5. Effect of mulch treatments on percent ground covered with sod for cool slopes during fall of 1963. Experiment established April 1963, on access road to I-81 near Salem, Virginia.

mulch-asphalt treatment gave the best sod, yet straw with Mulchnet was inferior to Turfiber or two Turfiber-net combinations. The shading of the soil by the stakes with the straw mulch treatments may have improved soil moisture and sod development. Sod cover was very poor where various nets alone served as mulches. Grasses failed where the nets were not in contact with the soil. Turf mulch, an organic peat, no longer available, did not give a satisfactory sod cover. Glassroot mulch controlled erosion, but the sod was not as good as for some other mulches. The grasses failed to survive on all mulch treatments on slopes with a southern exposure due to drought.

Experiment IV—US 58 Near Martinsville

This experiment, with various mulch materials in different combinations, was established in September 1963, in the Piedmont region. The residual reddish subsoil, of crystalline rock origin, was acid, very low in calcium, phosphorus, and nitrogen, and high in exchangeable aluminum. The 1:1 slopes on each side of the newly constructed east-west highway (US 58) were from 10 to 50 ft in length. All mulch treatments received 1 ton of lime, 1,000 lb of a 10-20-5 fertilizer, 60 lb of Ky. 31 fescue, and 1 lb of redtop per acre. Crown vetch was seeded on the cool slopes, and Lespedeza sericea was sown on the warm slopes. There were two replications on each of the two slope exposures.

Twenty days after applying fertilizer and seed with various mulch treatments, there was an average of 42 percent sod cover on cool slopes with a northern exposure as compared with only 12 percent sod cover on warm slopes with southern exposures (Table 2). There was more rapid germination and growth of turf plants on the semi-shaded slopes with a northern exposure because cool soil temperatures per se favored

TABLE 2

EFFECT OF MULCH TREATMENTS ON GRASS SOD ESTABLISHMENT FOR STEEP 1:1 CUT SLOPES WITH NORTHERN AND SOUTHERN EXPOSURE, US 58, MARTINSVILLE, ESTABLISHED SEPTEMBER 10, 1963

Treatment	Soil Covered with Sod[1] (%)					
	September 30			December 11		
	Southern Slope	Northern Slope	Average	Southern Slope	Northern Slope	Average
No mulch	8	29	14e	19	39	29c
Straw + asphalt	13	70	41ab	33	70	51ab
Stakes + straw + asphalt	15	75	45a	33	73	52ab
Mulchnet over straw	20	40	29abcde	40	63	51ab
Turfiber, 1,000 lb	16	50	33abcd	25	45	35bc
Turfiber, 1,500 lb	14	40	27abcd	35	50	42abc
Turfiber, 2,000 lb	11	35	22cde	22	60	41abc
500 lb Turfiber with seed, 1,000 lb after	16	58	37abc	33	65	46abc
Turfiber, 1,500 lb, patched 30 days later	7	50	28abcde	53	60	56a
Turfiber, 1,500 lb + Sea Magic	12	31	21cde	25	40	32bc
Turfiber + Mulchnet	18	40	29abcde	43	63	53ab
Silvacel, 1,000 lb	5	30	17de	18	50	34bc
Silvacel, 2,000 lb	10	48	29abcde	24	55	39abc
Silvacel, 750 lb—Turfiber, 750 lb	15	23	21cde	30	40	35bc
Glassroot	10	30	20cde	26	60	43abc
Glassroot + Turfiber	12	35	23bcde	33	43	40abc
Glassroot + asphalt	7	45	26abcde	20	60	40abc
Strandex	5	25	15de	25	63	44abc
Soil Saver	12	43	27abcde	45	43	47abc
Average	12	42	27	31	55	43

[1]All treatments not having same letter are significantly different.

germination and improved soil moisture. It is invariably more difficult to establish a sod and to maintain it on warm sunny slope sites than on cool slope sites. Mulches that improve the microclimate (reduce temperatures and increase moisture) are especially necessary on steep sunny slope sites.

When averaging the sod cover for cool and warm slopes, 20 days after seeding, the sod cover averaged 14 percent for no mulch as compared with significant increases ranging from 29 to 41 percent for the straw mulch treatments. Sod cover for Turfiber at various rates ranged from 22 to 33 percent. The values tend to be lower than those for straw, but variances were large so differences were not significantly different. The initial sod cover was 33, 27, and 22 percent when applying Turfiber at rates of 1,000, 1,500, and 2,000 lb per acre, respectively. Applying 500 lb of Turfiber per acre in a lime-fertilizer-seed slurry and then 1,000 lb of Turfiber as a mulch by itself was not significantly better than applying 1,500 lb of Turfiber in the seed-lime-fertilizer slurry.

Data on percent of soil covered with sod about three months after establishing the mulch treatments are also given in Table 2. It was very dry during late October and November; thus, all values for sod cover are low. The average sod cover for all treatments was 43 percent; in seasons with normal rainfall, values higher than 75 percent are usually obtainable. Sod cover was 80 percent better for cool as compared with the warm slope exposures.

Three months after seeding, the sod cover for straw mulch used in combination with stakes or held in place with a net averaged about 51 percent. A Turfiber-sod-fertilizer-lime slurry applied over Mulchnet gave an average sod cover of 53 percent. Silvacel applied at 1,000 and 2,000 lb per acre gave sod covers of 34 and 39 percent as compared to 35 and 41 percent for Turfiber at the same respective rates. Applying Turfiber at rates of 1,000 to 2,000 lb per acre did not improve sod cover significantly as the rate was increased. The differences in sod cover of the treatments mentioned in this paragraph were not large enough to be significant (Table 2).

The sod cover of Glassroot used alone or top sprayed with Turfiber or asphalt ranged from 40 to 43 percent. Glassroot controlled soil erosion very effectively. Strandex and Soil Saver gave sod cover values of 44 and 47 percent, respectively.

TABLE 3

EROSION AND APPEARANCE OF STAND 20 DAYS AFTER ESTABLISHMENT FOR MULCH TREATMENTS

Mulch	Soil Erosion[1]	Appearance[2]
Mulchnet over straw	0	1.3
Soil Saver	0	2.5
Glassroot-Turfiber	0	3
Straw-asphalt-stakes	0	2.5
Glassroot	0.3	2.6
Mulchnet-Turfiber	0.5	2.5
Straw-asphalt	0.8	2.5
Silvacel, 2,000 lb	0.6	2.5
Strandex	0.8	3.3
Turfiber (500 with seed, and fertilizer, then 1,000 lb)	1.0	2.1
Glassroot-asphalt	1.3	1.3
Turfiber, 2,000	1.3	2.4
Silvacel, 1,000 lb	1.3	2.7
Turfiber, 1,000 lb	1.5	2.6
Turfiber-Sea Magic	1.8	3.2
Turfiber, 750—Silvacel, 750 lb	1.9	2.8
No mulch	2.8	3.6

[1]0 is no erosion, 5 is very serious erosion.
[2]1 is very good germination and growth, 5 would be no germination and growth.

Sea Magic did not improve sod cover. When Turfiber mulch was used at seeding followed with a "patch-up" operation 30 days later, the sod cover was 56 percent. A very light application of a Turfiber-seed-fertilizer slurry was applied in spots where grass appeared thin in the "patch-up" operation.

Table 3 gives the effect of materials on erosion and appearance of the slope seedings 20 days after establishment. There was one heavy rain of approximately 1 in. between establishment and time of observation. Erosion was not serious; it was moderate without mulch; nil with Mulchnet over straw, straw-stakes-asphalt, Soil Saver and Glassroot-Turfiber; and mild with the remaining mulches. The sod appearance was best with Mulchnet over straw; the other mulch treatments did not differ significantly (Table 3).

Experiment V—Water Runoff with Mulches

Water runoff was studied with no mulch as compared with Silvacel and Turfiber, each applied at 1,000 and 2,000 lb per acre. The mulch treatments were applied on 3- by 3-ft plots with a 1:4 slope and an arrangement to catch surface runoff. The treatments were replicated three times. One inch of simulated rain applied in 30 min was used with each treatment. The runoff water was collected and measured (Fig. 6). An average of 43 percent of the water was lost as surface runoff without a mulch as compared with a water loss of only 28 percent from plots receiving 1,000 lb of the mulch materials. The 2,000-lb rate of mulch reduced the runoff to 25 and 18 for the Silvacel and Turfiber.

CONCLUSIONS

Rainfall and soil moisture were very deficient during the period when the reported mulching experiments were conducted. The data for evaluating the effectiveness of the mulches should not be considered conclusive. More research has been initiated. The results for establishing grass apply to adverse conditions, steep 1:1 slopes, drought, and subsoil materials that sluff easily due to alternate freezing and thawing or wetting and drying.

The following mulch materials tested gave satisfactory to excellent turf: various nets, Glassroot, straw with asphalt, Turfiber and Silvacel.

Net mulch materials must be applied to maintain firm contact with soils. It is necessary to prepare a

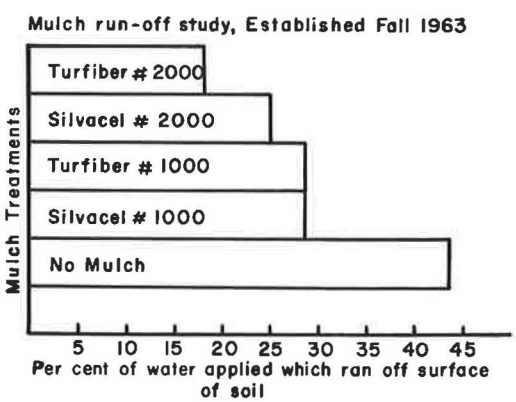

Figure 6. Effect of cellulose and woodfiber mulch on retention of rain water expressed as percent of water lost from 1 in. of water applied artificially.

uniform soil surface to maintain good soil-net contact. Considerable hand labor and time were required to apply net mulches to steep slope sites.

One of the best methods of obtaining good stands on adverse steep slope conditions is to use wooden stakes spaced on 18-in. centers followed with straw mulch topped liberally with asphalt. Without stakes, straw mulch topdressed liberally with asphalt is suitable if the soil under the straw does not become supersaturated to cause slipping of straw and soil. Stakes with straw mulch are required on long slope faces.

A practical method for large-scale steep slope seedings is where a woodfiber cellulose-fertilizer-seed slurry is applied hydraulically in one operation. It is recommended that second patch-up operations be specified in seeding contracts. Irrespective of what seeding method is used, there will invariably be spotted turf stands on slope sites such as those discussed in this paper, making a retreatment necessary.

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