# *Effectiveness of Selected Erosion Control Materials Under Simulated Rain and Sunlight*

by

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# INTRODUCTION

This report presents the results of an erosion control testing study performed by the Utah Water Research Laboratory (UWRL) for the Mountain-Plains Consortium (MPC), a University Transportation Centers Program for Transportation Research, Public Service and Education. The purpose of the study was to compare the performance of selected erosion control products under simulated rainfall and sunlight conditions in terms of soil loss reduction and vegetation growth.

The Mountain-Plains Consortium involves universities in the states of Colorado, North Dakota, Utah and Wyoming; therefore, input was requested from the Departments of Transportation of those four states as to which materials to test. A total of 19 materials — 11 mulches and 8 erosion control blankets were selected for this test program. The materials tested are listed in Table 1. A code has been given to each material, as indicated in Table 1, to facilitate the graphic representation of test results. Tests were performed in the UWRL rainfall simulator facility, in which the variables of soil, slope, and rainfall rate and duration can be controlled.

Protection of slopes and embankment against erosion during and after highway construction and other highway maintenance work, particularly in rural areas, is important in order to minimize the environmental and economic impact of those activities. While there are a variety of erosion control products currently available in the market there is a dearth of information on how effective they are in protecting slopes against the erosive effect of rain. The study presented here provides data and information that shows the relative effectiveness of the several products tested in controlling erosion under similar conditions of soil type, slope steepness, rainfall intensity, and rainfall duration. Such information can be used to select the most appropriate erosion control material for a particular situation.

The current research project involved the following tasks:

1. Selection of nineteen different erosion control materials from those most commonly used by Departments of Transportation from the states of Colorado, North Dakota, Utah and Wyoming.

2. Selection of standard slope, rainfall intensity and rainfall duration.

3. Testing of erosion control materials in two-feet wide plots under simulated rain and sunlight.

4. Writing and submitting this final report showing the erosion control effectiveness of the different erosion control materials.

The test set up and equipment used in determining the erosion control and plant growth effectiveness of the products chosen is described below.

## RAINFALL SIMULATOR FACILITY

The UWRL rainfall simulator facility consists of a rainfall simulator, a tilting flume, a sunlight simulator, and a wind generator. The rainfall simulator and the tilting flume allow for the measurement of erosion and water runoff rates. The sunlight simulator enables us to grow vegetation in the test plots, and the wind generator produces unidirectional wind up to about 60 mph. No wind was applied to the present tests, however, as wind tests are used mainly with straw mulches and none was tested in this program. The components of the Rainfall Simulator Facility are described below.

### Rainfall Simulator

The rainfall simulator is a drip-type device in which individual raindrops are formed by water emitting from the ends of small-diameter brass tubes. The simulator consists of 100 modules arranged and supported to form a square horizontal area containing 37.18 m2 (400 ft2). Each module has separate manually-operated controls. The rate of flow is controlled by admitting water into a manifold chamber through fixed orifice plates under constant hydraulic pressure. Five separate inlet orifices are used in each chamber or module. The ratios of the areas of these orifices are 1:2:4:8:16. By controlling the flow of water to the orifices with electrically operated solenoid valves, it is possible to vary flow in on-off increments with 31 equal steps up to a maximum rainfall rate of 787.4 mm/hr (31 in/hr). Outlet from the chambers or modules is through uniform equally-spaced brass tubes. Each module is 609.6 mm (2 ft) x

609.6 mm (2 ft) x 25.4 mm (1 in) deep enclosed box oriented so that the tubes or needles form a horizontal level plane from which the water drips. Each module contains 625 brass tubes spaced in a 25.4-mm (1 in) square pattern. A schematic of the rainfall simulator is shown in Figure 1.

Raindrops have diameters of approximately 4 mm (0.157 in), and their velocities of impact represent the energy of typical high-intensity storms. The spatial distribution of rainfall is essentially uniform and the control of application rates is within the accuracy requirements of most experiments. The simulator has been extensively tested and used in research since its construction in 1973. The original plexiglass modules were replaced with aluminum panels in 1992.

## Tilting Flume

The tilting flume is square and measures 6.10 m (20 ft) on each side. The flume is designed so that a vacuum can be maintained beneath the soil, when desired, to aid infiltration, and water sheet flow can be maintained over the top of the soil when this is necessary. The rainfall simulator is supported over the flume so that rain falls directly onto the soil.

Approximately 304.8 mm (1 ft) depth of soil is supported in the tilting flume by a metal grating covered with filter cloth through which water can drain. For the tests performed in this study the flume was divided into six test plots, each measuring approximately 1.22 m (4 ft) by 5.94 m (19.5 ft). Three blocks of two plots are separated from each other and form the side walls by 0.61-m (2-ft) wide walkways as presented schematically in Figure 2. Runoff from each plot is collected in a large plastic tub, then dried and weighed for determining the amount of soil and water runoff leaving the plot. The flume can be tilted hydraulically to any angle up to 43í from horizontal for simulating hill slopes.

## Sunlight Simulator

A balance of radiant energy needed for good plant growth is provided to the test plots by a sunlight simulator which utilizes several incandescent lamps as well as an array of florescent lamps. The

simulator is the same size as the tilting flume, square, measuring 6.10 m (20 ft) on each side. The sunlight simulator is rolled on and off the test plots on horizontal rails mounted on top of the side walls of the tilting flume. When in position, it is about 0.91 m (3 ft) above the test plot surfaces, and provides enough illumination to facilitate plant growth on seeded plots after the rainfall events.

The test procedure used in this research project is described below. The next section includes also the test parameters used.

## TEST PROCEDURE

### Test Parameters

In order to compare the performance of all the materials tested, a single set of test conditions were selected, as follows:

soil type: sandy - loam ( 56% sand, 29% silt, 15% clay)

soil slope: 2.5:1

rainfall intensity: 127 mm/hr (5 in/hr)

rainfall duration: 30 minutes (60 minutes in Test 10).

seed: barley

plant growth time: 6 days.

After reviewing the results of the tests it is obvious that the slope and rainfall intensity used are quite extreme for mulch covers. These results point out the need to select appropriate testing conditions for different types of erosion control materials when developing test standards. In this test program, however, we were limited by time constraints to use a single set of test parameters for all materials regardless of their nature.

## Plot Preparation

The selected soil was originally placed in the six plots to a depth of approximately 304.8 mm (1 ft), and cultivated with a garden tiller to a depth of approximately 152.4 mm (6 in). Each plot was then leveled, uniformly compacted with a lawn roller and raked to produce a rough surface. After every test run the top layer of soil, up to the maximum depth of erosion, was removed and discarded and new soil added. The soil in each plot was then spaded to the full 304.8 mm (1 ft) depth, and the entire process of tilling, leveling, compacting and raking repeated to prepare the plots for the next test run. After the plots were prepared, the erosion control material (mulch or erosion control blanket) was applied and the test flume was tilted to the desired slope in preparation for rain application.

## Mulch and Seed Application

Three replications of two mulches were applied in each mulch test at a rate of 2246 kg/ha (2000 lb/Ac), except for the two materials indicated in Table 1 that were applied at a different rate. Barley seed was applied at a rate of 225 kg/ha (200 lb/Ac). The mulch and seed were mixed together in a water slurry in a laboratory-sized hydromulcher and then applied under pressure through a hose to the plots while the test bed was in a horizontal position. Afterwards the plots were allowed to drain overnight before the rain was applied.

## Tests on Erosion Control Blankets

Three samples of two erosion control blankets were laid in the plots in each blanket test. Each sample was secured by rows of 152.4 mm- (6 in-) long, steel staples driven through the soil at both edges along the slope. Staples on these rows were separated by 0.91 m (3 ft). A third row of staples, with the same 0.91 m (3 ft) separation but staggered by 0.46 m (1.5 ft), was used along the centerline. In addition, rows of three staples were used to secure the both the upstream and downstream edges of the blankets. The staple pattern just described represents a staple density (number of staples per area) equal

to the minimum recommended by the blanket manufacturers. For tests on erosion control blankets, seed was applied by hand before laying the blanket on each plot. The application rate of seed in these tests was the same as in mulch applications.

### Rainfall Application

The test flume containing the selected erosion control materials was tilted to the prescribed slope and covered with a plastic sheet. The rainfall simulator was turned on at full capacity to purge the air from the system. During the purging the rain fell onto the plastic and into a drain without wetting the plots. When the purging was completed, the rain was adjusted to the desired rate and allowed to stabilize. The plastic cover was then quickly removed so the rain fell onto the plots and the time clock was started. Rain was applied for 30 minutes in all tests.

### Runoff Measurements

All of the runoff (water and sediment) leaving each plot during a test was collected in large plastic tubs. The runoff was subsequently filtered through fabric clothes that retained the solid materials for drying and weighing. The sediment-laden fiber clothes were then placed on top of metal grids and left to dry at air temperature for periods ranging from a few days up to two weeks.

### Sunlight Application

When rainfall ended in each test, the sunlight simulator was rolled into position over the plots, and the entire assembly was tilted to the prescribed slope. Sunlight was applied for six days, 24 hours a day, with the plots still in the tilted position, after which the vegetation was harvested. The barley seed used produced plants after two or three days that could grow up to approximately 200 mm (7.9 in).

### Harvesting of Plant Samples

When the predetermined time for the test had elapsed, the test bed was returned to a horizontal position and the sunlight simulator was removed. Using a template prepared for the purpose, six 0.092 m2 (1 ft2) sample areas were randomly selected on each plot, two at the lower end of the slope, two towards the center, and two other near the top. Samples were gathered from each plot and the plants counted, measured, dried, and weighed. Counts were made also of seeds that did not germinate.

## RESULTS

Results obtained from each test include water runoff rate, soil erosion rate, average plant height, dry weight of plants and percentages of lost and germinating seed. Water runoff and soil erosion rates for the nineteen materials tested are presented in Table 2 and Figures 3 and 4, while plant data is given in Table 3 and Figures 5 through 8.

It follows from the data of Table 2 and Figure 3 that, for the test conditions used, hydromulches, in general, allowed more soil loss than erosion control blankets. It should be pointed out that the slope and rainfall intensity used in these tests may have been too high for most of the hydromulches tested to effectively protect the soil against excessive erosion. The numbers from Table 3 and Figure 3 may give the impression that hydromulches are always at a disadvantage with respect to erosion control blankets. It may be the case, however, that for flatter hill slopes and lower rainfall intensities the performance of hydromulches and of the erosion control blankets is comparable. Additional testing is necessary, therefore, to determine the appropriate range of slopes and rainfall intensities for the controlled testing of hydromulches and erosion control blankets.

The hydromulches tested, with the exceptions of those identified as M10, M11 and M12, did not include tackifiers. The addition of a tackifier or other additives may in most cases improve the erosion control performance of a hydromulch, particularly under the extreme test conditions used in this

program. The effect of adding tackifiers to a hydromulch cover is evident when comparing the performance of mulch M6 with that of M10 or M11 in Figure 3, the two latter being essentially the same as M6, but with a tackifier added.

Data from Table 2 and Figures 3 and 4 suggest that, in general, blankets also retained more water than did hydromulch covers. This is a beneficial aspect of an erosion control product for it helps in the growth of a vegetative cover. The effects of water retention will be more apparent when plant data is discussed below.

The vegetative cover characteristics are related to the amount of soil and water retained by a given erosion control material. It is not surprising then to find from the data in Table 3 that, in general, the vegetation in plots with erosion control blankets performed better, in terms of plant characteristics and germinations rates, than the plants in most hydromulch plots.

While the data from Figure 5 indicates that the average plant height was about the same for all blankets and for mulch M12, there are differences in terms of the dry weight of plants for those materials as indicated in Figure 6. These differences can be attributed to the different seed germination rates (Figure 7) as well as to the amount of water retained by each material (Figure 4). (Plant weight may also be influenced by the chemical composition of the erosion control cover, although such parameters were not under scrutiny in these tests.) For hydromulches, both plant height and dry weight of plants show more variation than for erosion control blankets as depicted in Figures 5 and 6. Again, such variation is related to the amount of water and soil retained, which, in turn, affects the germination rates (see Figures 3, 4 and 7). Although the relationships between runoff and plant characteristics are not easily quantifiable, a good qualitative picture can be inferred from the data in Figures 4 through 7. Namely, that the more soil and water retained the better the germination rates and the taller the plants, which translate into larger plant weight.

Figures 7 and 8 present, for each material, the percentage of seed germinating and seed lost from the plots, respectively. The percentage of seed germinating (Figure 7) was calculated from the known seed application rates and the measured plant population. From the data shown in that Figure it follows that the blankets had the best germination rates (50 percent or more). The rates of seed lost in Figure 8 were estimated from the count of plants and of seeds left in the samples collected from each plot. The data from Figure 8 indicate that hydromulches, which allowed the largest amount of runoff, also allowed the largest percentage of seed lost. This result is not surprising as the seed was laid on top of the soil or of the hydromulch cover and was easily carried off the plots by the flowing water.

## SUMMARY

The present tests on hydromulches and erosion control blankets under controlled slope and rainfall conditions were of a exploratory nature and their results should not be taken as the definitive criteria in the selection of erosion control systems. Only a single set of soil type, soil slope, rainfall intensity and duration was used, therefore placing hydromulches at a disadvantage with respect to erosion control blankets as the soil slope (2.5:1) and the rainfall intensity (127 mm/hr or 5 in/hr) were relatively high. The results of these test point out, however, the need for a sustained program of testing on hydromulches, blankets and other erosion control systems, under a varied set of conditions, in order to determine not only their relative performance, but also the range of conditions (soil types, slopes and rainfall intensities and durations) for which each system is most appropriate.

Observations from this series of tests do point out the advantage of using hydromulches with tackifiers to better protect soil slopes from rainfall erosion.

**TABLE 1. LIST OF PRODUCTS TESTED**

| Hydromulches | | Erosion Control Blankets | |
|---|---|---|---|
| Code | Brand | Code | Brand |
| M1 | Climatizer Mulch (*) | B1 | High-velocity Curlex |
| M2 | Cellumulch (*) | B2 | Conwed Futerra |
| M3 | Verdyol Mulch (*) | B3 | North-American Green S-150 BN |
| M4 | Nature's Own Mulch (*) | B4 | North-American Green SC-150 BN |
| M5 | Silva Fiber Mulch (*) | B5 | Anti-Wash GeoJute |
| M6 | Conwed Mulch (*) | B6 | Dekowe 400 Coir |
| M7 | Re-Fiber Mulch (*) | B7 | Bonterra S-1 |
| M8 | Re-Fiber Mix Mulch (*) | B8 | Bonterra S-2 |
| M9 | Grass Fiber Mulch (*) | | |
| M10 | Conwed 2000 Mulch (*) | | |
| M11 | Conwed 2000 Mulch (**) | | |
| M12 | Soil Guard (‡) | | |

(*) Applied at 2246 kg/ha (2000 lb/Ac).
(**) Applied at 3370 kg/ha (3000 lb/Ac).
(‡) Applied at 3931 kg/ha (3500 lb/Ac).

**TABLE 2. WATER RUNOFF AND SOIL EROSION DATA**
**(Averages of Three Replications of Tests)**

| Material | | Water Runoff Rate | | Soil Erosion Rate | |
|---|---|---|---|---|---|
| Code | Brand Name | lt/hr | (gal/hr) | kg/hr | (lb/hr) |
| M1 | Climatizer Mulch (*) | 354.66 | (93.70) | 52.00 | (114.40) |
| M2 | Cellumulch (*) | 343.55 | (90.77) | 46.58 | (102.47) |
| M3 | Verdyol Mulch (*) | 295.78 | (78.15) | 32.67 | (71.87) |
| M4 | Nature's Own Mulch (*) | 321.26 | (84.88) | 48.97 | (107.73) |
| M5 | Silva Fiber Mulch (*) | 331.78 | (87.66) | 32.00 | (70.40) |
| M6 | Conwed Mulch (*) | 328.03 | (86.67) | 31.64 | (69.60) |
| M7 | Re-Fiber Mulch (*) | 323.86 | (85.57) | 46.18 | (101.60) |
| M8 | Re-Fiber Mix Mulch (*) | 306.55 | (80.99) | 51.30 | (112.87) |
| M9 | Grass Fiber Mulch (*) | 346.22 | (91.47) | 62.09 | (136.60) |
| M10 | Conwed 2000 Mulch (*) | 212.79 | (56.22) | 10.03 | (22.07) |
| M11 | Conwed 2000 Mulch (**) | 144.23 | (38.11) | 3.714 | (8.171) |
| M12 | Soil Guard (‡) | 34.68 | (9.15) | 0.054 | (0.119) |
| B1 | High-velocity Curlex | 37.01 | (9.78) | 0.412 | (0.939) |
| B2 | Conwed Futerra | 64.81 | (17.12) | 0.021 | (0.045) |
| B3 | NAG S-150 BN | 8.53 | (2.25) | 0.006 | (0.013) |
| B4 | NAG SC-150 BN | 4.30 | (1.14) | 0.004 | (0.008) |
| B5 | Anti-wash GeoJute | 180.68 | (47.74) | 5.030 | (11.067) |
| B6 | Dekowe 400 Coir | 287.97 | (76.08) | 9.879 | (21.733) |
| B7 | Bonterra S-1 | 70.11 | (18.52) | 1.183 | (2.603) |
| B8 | Bonterra S-2 | 25.46 | (6.73) | 0.077 | (0.170) |

(*) Applied at 2246 kg/ha (2000 lb/Ac).
(**) Applied at 3370 kg/ha (3000 lb/Ac).
(‡) Applied at 3931 kg/ha (3500 lb/Ac).

**TABLE 3. PLANT HEIGHT, WEIGHT AND GERMINATION DATA (Averages of Three Replications of Tests)**

| Material | | Plant Height | | Dry Weight | | Percentage of seed | | |
|---|---|---|---|---|---|---|---|---|
| Code | Brand Name | mm | (in) | kg/ha | (lb/Ac) | lost | germ. | Non-g. |
| M1 | Climatizer Mulch (*) | 87.3 | (3.44) | 11.73 | (10.44) | 71.01 | 14.95 | 14.04 |
| M2 | Cellumulch (*) | 110.7 | (4.36) | 22.16 | (19.73) | 71.01 | 20.00 | 8.99 |
| M3 | Verdyol Mulch (*) | 125.0 | (4.92) | 26.97 | (24.01) | 65.76 | 22.42 | 11.82 |
| M4 | Nature's Own Mulch (*) | 123.9 | (4.88) | 38.06 | (33.89) | 66.67 | 26.06 | 7.27 |
| M5 | Silva Fiber Mulch (*) | 132.7 | (5.22) | 58.18 | (51.80) | 44.65 | 40.61 | 14.74 |
| M6 | Conwed Mulch (*) | 135.5 | (5.33) | 61.69 | (54.92) | 42.02 | 43.84 | 14.14 |
| M7 | Re-Fiber Mulch (*) | 117.6 | (4.63) | 30.53 | (27.18) | 58.08 | 24.65 | 17.27 |
| M8 | Re-Fiber Mix Mulch (*) | 115.9 | (4.56) | 29.53 | (26.29) | 64.85 | 24.44 | 10.71 |
| M9 | Grass Fiber Mulch (*) | 129.2 | (5.09) | 26.03 | (23.17) | 63.94 | 18.69 | 17.37 |
| M10 | Conwed 2000 Mulch (*) | 134.5 | (5.30) | 44.38 | (39.51) | 49.29 | 33.44 | 17.27 |
| M11 | Conwed 2000 Mulch (**) | 169.9 | (6.69) | 104.91 | (93.41) | 34.04 | 49.19 | 16.77 |
| M12 | Soil Guard (‡) | 165.3 | (6.51) | 128.90 | (114.76) | 26.57 | 62.93 | 10.50 |
| B1 | High-velocity Curlex | 165.3 | (6.51) | 104.25 | (92.82) | 13.43 | 73.52 | 13.05 |
| B2 | Conwed Futerra | 167.2 | (6.58) | 120.92 | (107.66) | 12.02 | 84.51 | 3.47 |
| B3 | NAG S-150 BN | 166.5 | (6.56) | 147.72 | (131.52) | 11.92 | 68.59 | 19.49 |
| B4 | NAG SC-150 BN | 163.6 | (6.44) | 135.22 | (120.39) | 16.87 | 55.66 | 27.47 |
| B5 | Anti-wash GeoJute | 146.2 | (5.76) | 101.19 | (90.09) | 22.93 | 55.15 | 21.92 |
| B6 | Dekowe 400 Coir | 152.6 | (6.01) | 130.97 | (116.60) | 25.56 | 50.50 | 23.94 |
| B7 | Bonterra S-1 | 152.4 | (6.00) | 110.19 | (98.10) | 9.05 | 70.76 | 20.19 |
| B8 | Bonterra S-2 | 151.0 | (5.94) | 89.93 | (80.06) | 8.86 | 68.57 | 22.57 |

(*) Applied at 2246 kg/ha (2000 lb/Ac).
(**) Applied at 3370 kg/ha (3000 lb/Ac).
(‡) Applied at 3931 kg/ha (3500 lb/Ac).

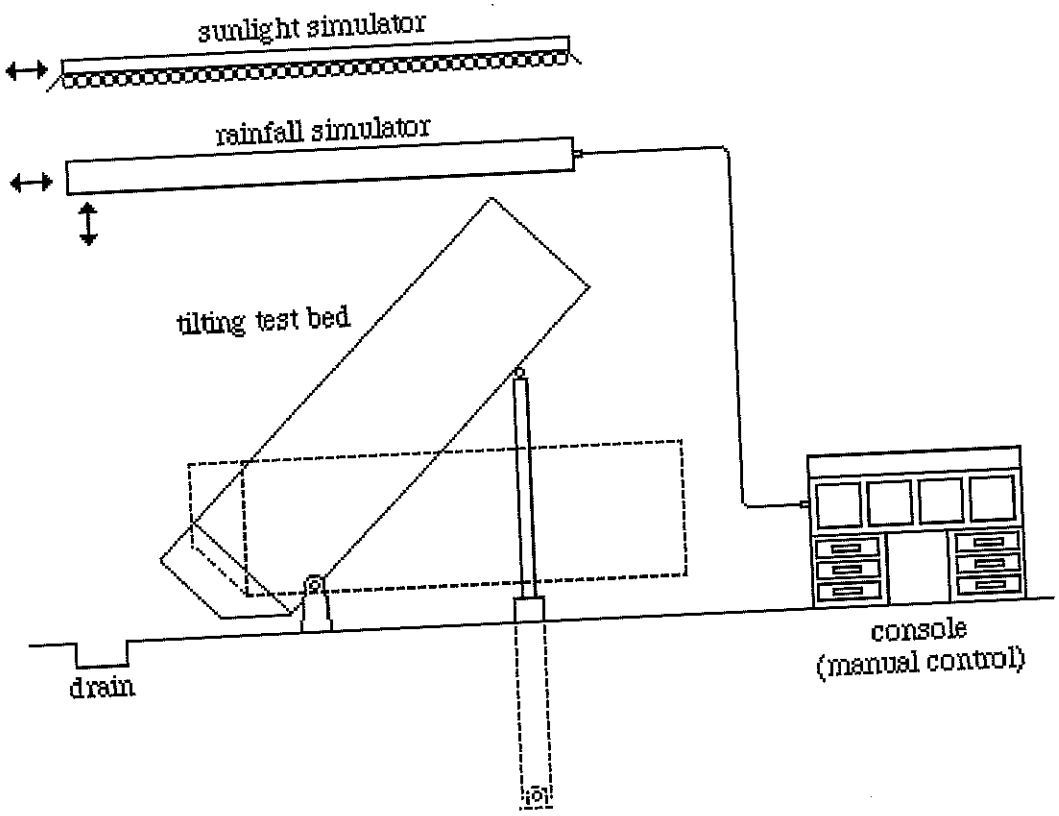


**Figure 1. Schematic of the UWRL Rainfall Simulator Facility.**

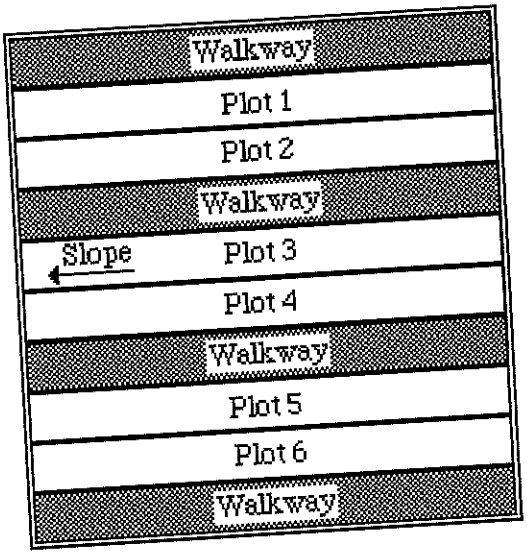


**Figure 2. Plot layout for simulated rain tests.**

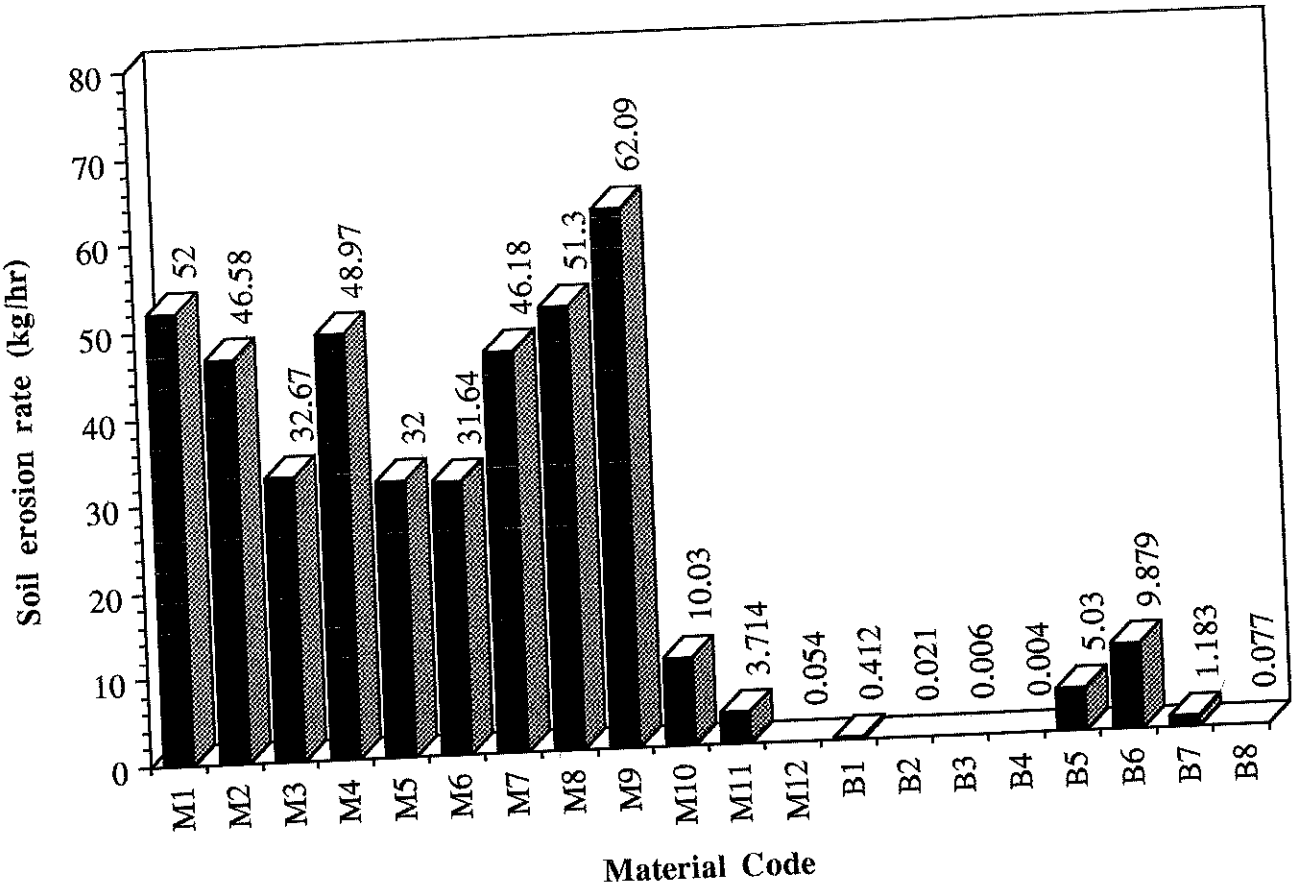


**Figure 3. Comparison of erosion rates for the twenty products tested.**

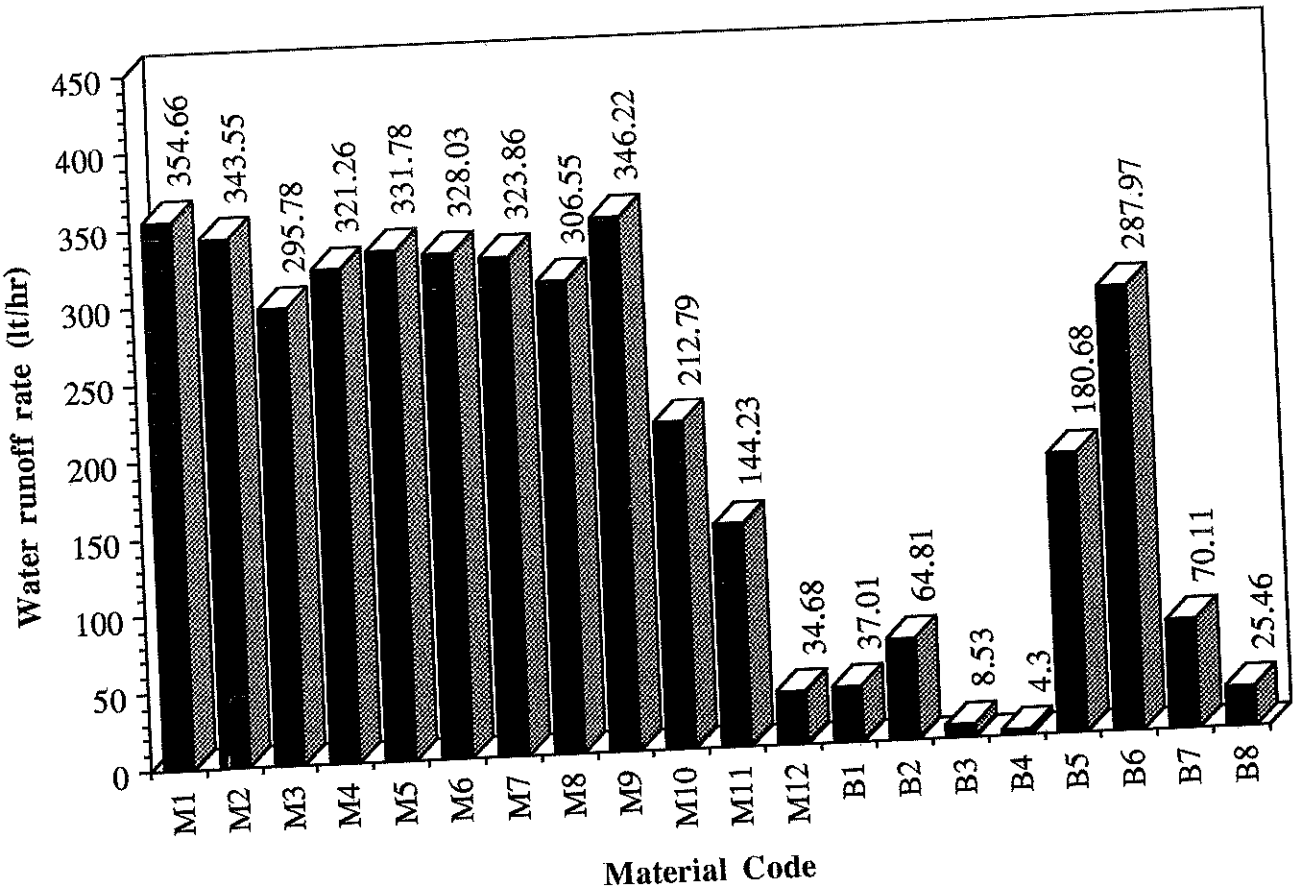


**Figure 4. Comparison of water runoff rates for the twenty products tested.**

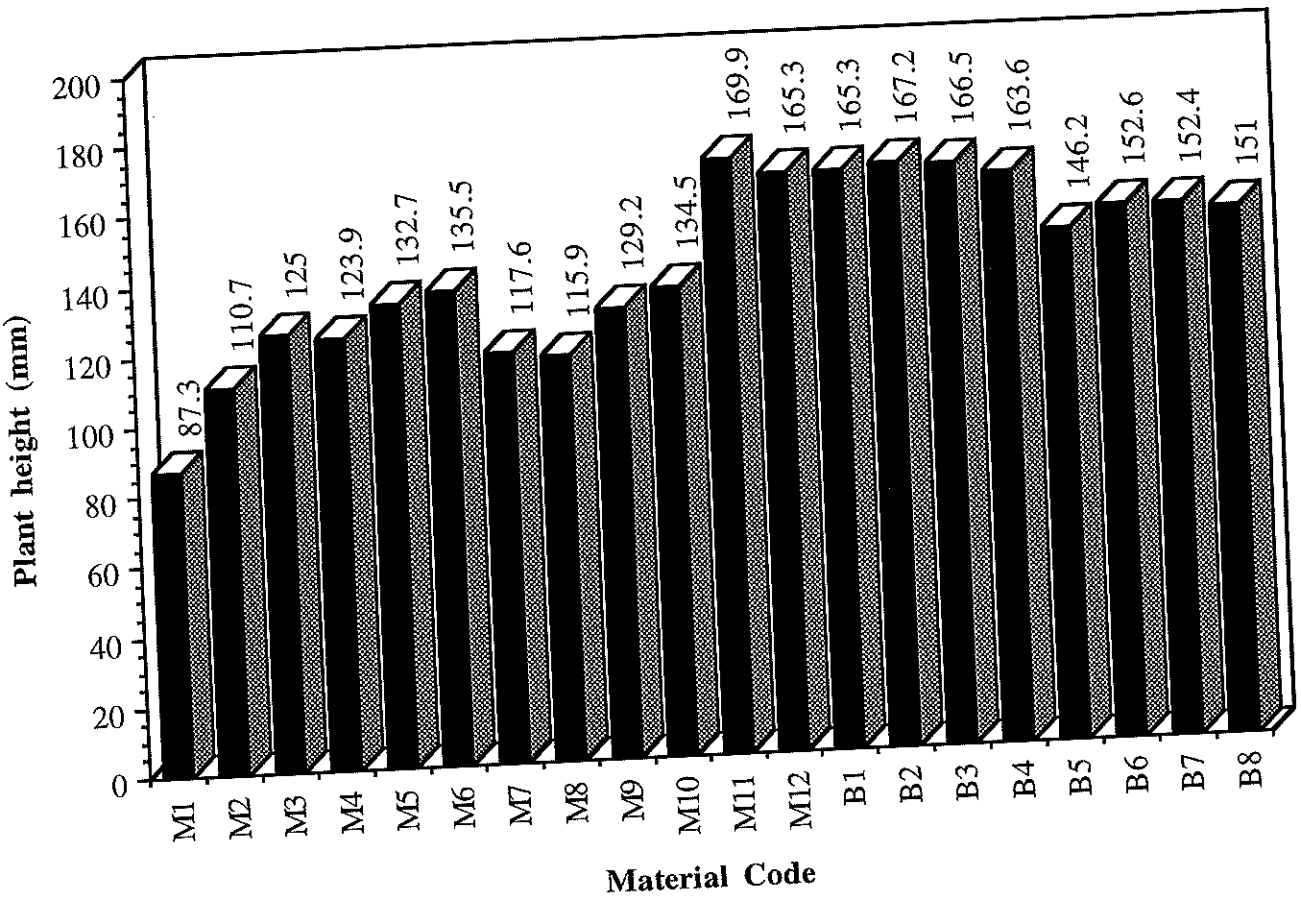


**Figure 5. Comparison of plant height for the twenty products tested.**

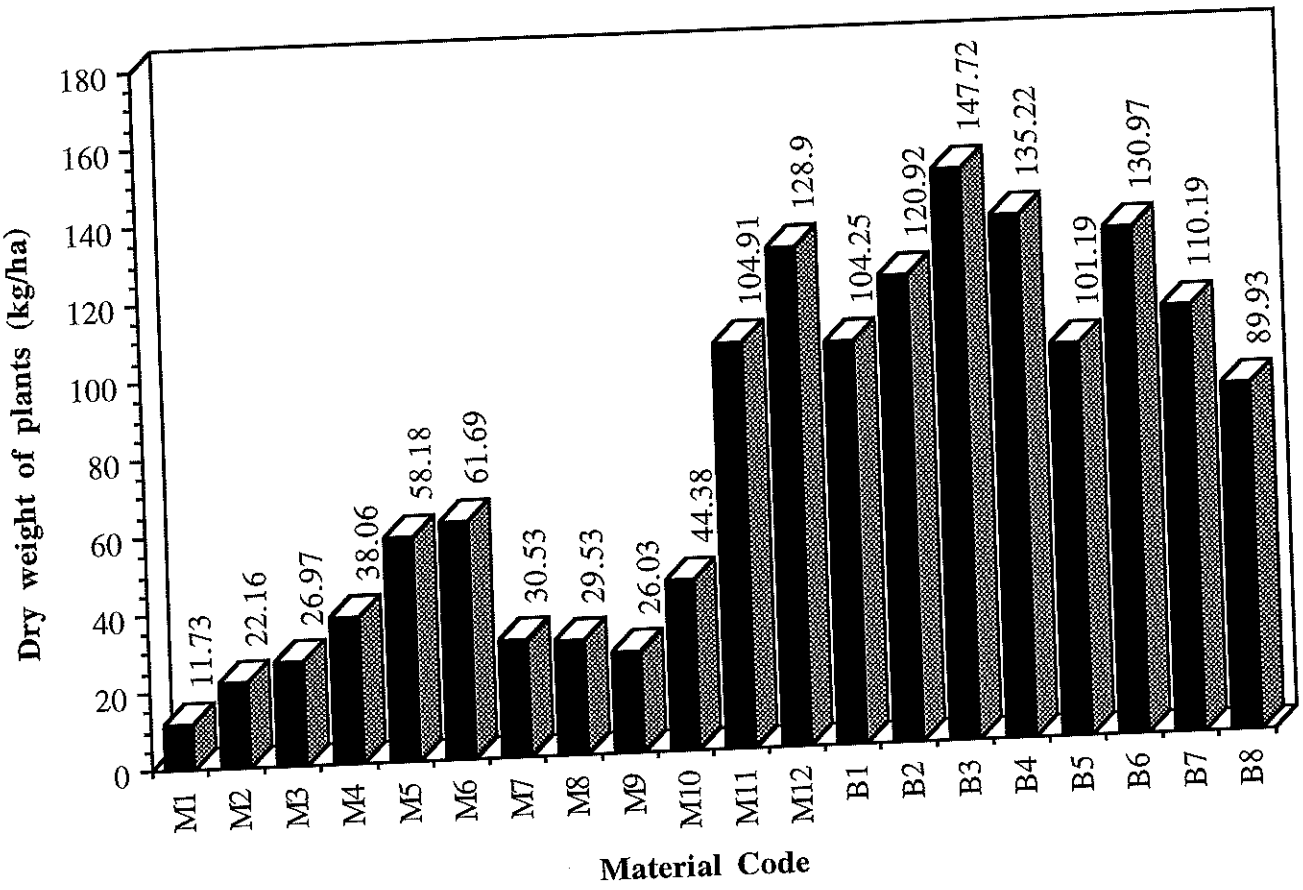


**Figure 6. Comparison of dry weight of plants for the twenty products tested.**

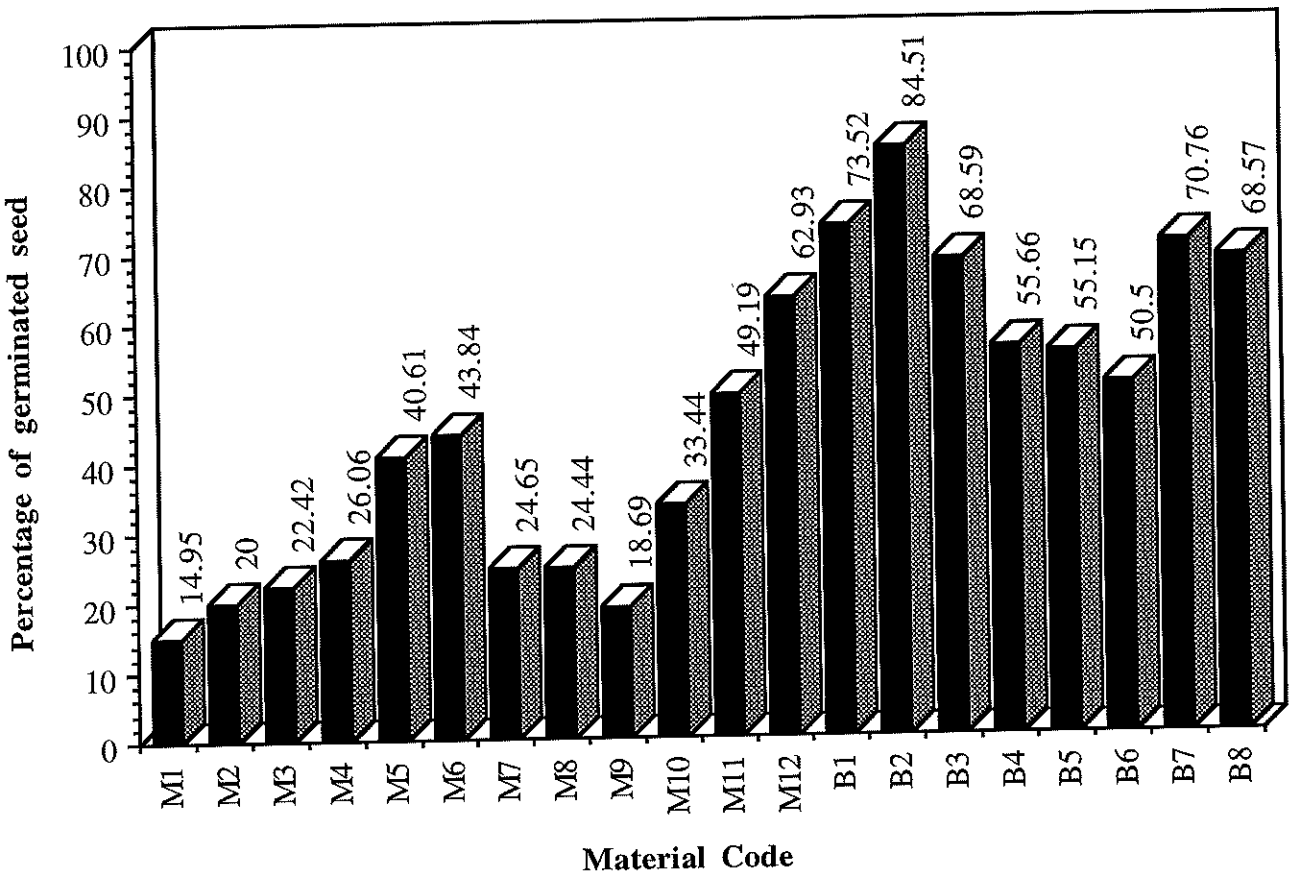


**Figure 7. Comparison of percentage of seed germinating for the twenty products tested.**

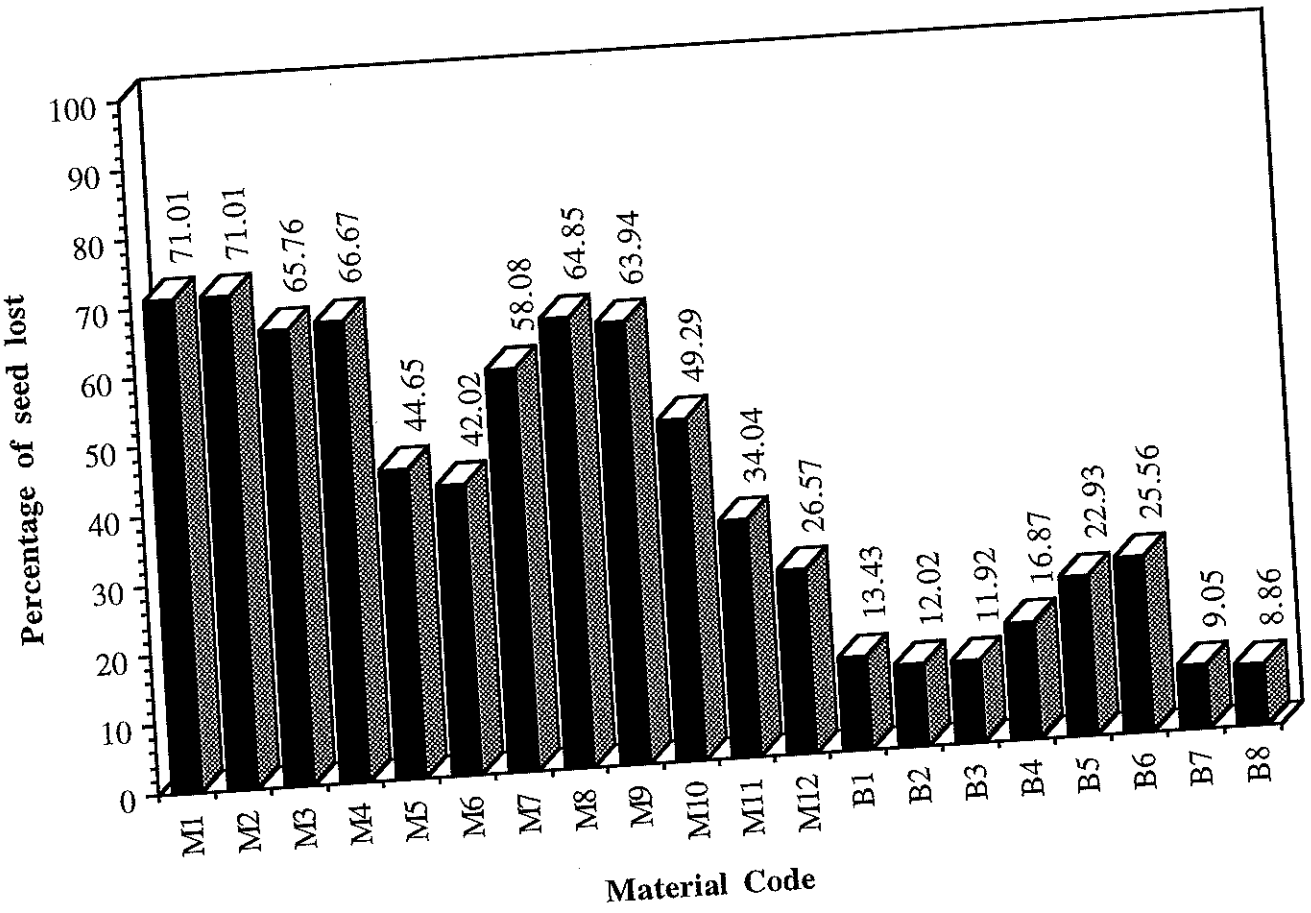


**Figure 8. Comparison of percentage of seed lost for the twenty products tested.**

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# APPENDIX A. Data from Individual Tests

Table A-1. Water runoff and soil erosion data for Tests 1 through 5.
Slope = 2.5:1. Rainfall = 5 in/hr. Collection time = 0.5 hour.

| Test | Plot | Material | water runoff rate, lt/hr | water runoff rate, gal/hr | soil erosion rate, kg/hr | soil erosion rate, lb/hr |
|---|---|---|---|---|---|---|
| 1 | 1 | High-velocity Curlex | 30.23 | (7.99) | 0.005 | (0.110) |
| 1 | 2 | Conwed Futerra | 67.35 | (17.79) | 0.020 | (0.044) |
| 1 | 3 | Conwed Futerra | 80.60 | (21.30) | 0.031 | (0.068) |
| 1 | 4 | High-velocity Curlex | 47.93 | (12.66) | 0.518 | (1.140) |
| 1 | 5 | Conwed Futerra | 46.47 | (12.28) | 0.011 | (0.024) |
| 1 | 6 | High-velocity Curlex | 32.86 | (8.68) | 0.713 | (1.569) |
| 2 | 1 | Climatizer mulch | 361.16 | (95.42) | 51.545 | (113.400) |
| 2 | 2 | Cellumulch | 330.57 | (87.34) | 46.727 | (102.800) |
| 2 | 3 | Climatizer mulch | 347.28 | (91.75) | 52.727 | (116.000) |
| 2 | 4 | Cellumulch | 355.54 | (93.94) | 51.727 | (113.800) |
| 2 | 5 | Climatizer mulch | 343.92 | (90.87) | 53.364 | (117.400) |
| 2 | 6 | Cellumulch | 344.55 | (91.03) | 41.273 | (90.800) |
| 3 | 1 | Verdyol mulch | 316.87 | (83.72) | 37.000 | (81.400) |
| 3 | 2 | Nature's Own mulch | 293.18 | (77.46) | 42.364 | (93.200) |
| 3 | 3 | Nature's Own mulch | 341.56 | (90.24) | 53.727 | (118.199) |
| 3 | 4 | Verdyol mulch | 290.27 | (76.69) | 31.273 | (68.800) |
| 3 | 5 | Verdyol mulch | 280.20 | (74.03) | 29.727 | (65.400) |
| 3 | 6 | Nature's Own mulch | 329.03 | (86.93) | 50.818 | (111.800) |
| 4 | 1 | Silva Fiber | 348.36 | (92.04) | 40.727 | (89.600) |
| 4 | 2 | Conwed mulch | 315.23 | (83.29) | 26.455 | (58.200) |
| 4 | 3 | Conwed mulch | 334.30 | (88.33) | 42.818 | (94.200) |
| 4 | 4 | Silva Fiber mulch | 338.92 | (89.55) | 26.182 | (57.600) |
| 4 | 5 | Silva Fiber mulch | 308.06 | (81.39) | 29.091 | (64.000) |
| 4 | 6 | Conwed mulch | 334.57 | (88.40) | 25.636 | (56.400) |
| 5 | 1 | Re-Fiber mulch | 345.55 | (91.30) | 40.818 | (89.800) |
| 5 | 2 | Re-Fiber Mix mulch | 297.99 | (78.73) | 47.636 | (104.800) |
| 5 | 3 | Re-Fiber mulch | 320.50 | (84.68) | 48.636 | (107.000) |
| 5 | 4 | Re-Fiber Mix mulch | 306.43 | (80.96) | 58.545 | (128.800) |
| 5 | 5 | Re-Fiber mulch | 305.52 | (80.72) | 49.091 | (108.000) |
| 5 | 6 | Re-Fiber Mix mulch | 315.23 | (83.29) | 47.727 | (105.000) |

Note: all hydromulches, except those in Test #10, were applied at a rate of 2000#Ac.

Table A-2. Water runoff and soil erosion data for Tests 1 through 5.

| Test | Plot | Material | water runoff rate, lt/hr | water runoff rate, gal/hr | soil erosion rate, kg/hr | soil erosion rate, lb/hr |
|---|---|---|---|---|---|---|
| Slope = 2.5:1. Rainfall = 5 in/hr. Collection time = 0.5 hour. | | | | | | |
| 6 | 1 | Grass Fiber mulch | 346.73 | (91.61) | 58.909 | (129.600) |
| 6 | 2 | Conwed 2000 mulch | 242.44 | (64.06) | 12.273 | (27.000) |
| 6 | 3 | Grass Fiber mulch | 357.08 | (94.34) | 63.818 | (140.400) |
| 6 | 4 | Conwed 2000 mulch | 210.67 | (55.66) | 10.091 | (22.200) |
| 6 | 5 | Grass Fiber mulch | 334.84 | (88.47) | 63.545 | (139.800) |
| 6 | 6 | Conwed 2000 mulch | 185.26 | (48.95) | 7.727 | (17.000) |
| 7 | 1 | NAG S-150 BN | 12.15 | (3.21) | 0.013 | (0.028) |
| 7 | 2 | NAG SC-150 BN | 2.20 | (0.58) | 0.005 | (0.012) |
| 7 | 3 | NAG S-150 BN | 2.20 | (0.58) | 0.002 | (0.004) |
| 7 | 4 | NAG SC-150 BN | 5.45 | (1.44) | 0.004 | (0.008) |
| 7 | 5 | NAG S-150 BN | 11.24 | (2.97) | 0.004 | (0.008) |
| 7 | 6 | NAG SC-150 BN | 5.26 | (1.39) | 0.002 | (0.004) |
| 8 | 1 | Anti-wash GeoJute | 165.55 | (43.74) | 0.545 | (1.200) |
| 8 | 2 | Dekowe 400 | 271.37 | (71.70) | 9.818 | (21.600) |
| 8 | 3 | Anti-wash GeoJute | 208.02 | (54.96) | 4.364 | (9.600) |
| 8 | 4 | Dekowe 400 | 305.78 | (80.79) | 11.000 | (24.200) |
| 8 | 5 | Anti-wash GeoJute | 168.46 | (44.51) | 10.182 | (22.400) |
| 8 | 6 | Dekowe 400 | 286.74 | (75.76) | 8.818 | (19.400) |
| 9 | 1 | Bonterra S-1 | 114.38 | (30.22) | 2.212 | (4.866) |
| 9 | 2 | Bonterra S-2 | 36.86 | (9.74) | 0.158 | (0.348) |
| 9 | 3 | Bonterra S-1 | 62.19 | (16.43) | 1.136 | (2.500) |
| 9 | 4 | Bonterra S-2 | 9.27 | (2.45) | 0.012 | (0.026) |
| 9 | 5 | Bonterra S-1 | 33.76 | (8.92) | 0.202 | (0.444) |
| 9 | 6 | Bonterra S-2 | 30.24 | (7.99) | 0.062 | (0.136) |
| Slope = 2.5:1. Rainfall = 5 in/hr. Collection time = 1.0 hour. | | | | | | |
| 10 | 1 | Soil Guard 3500#/Ac | 46.78 | (12.36) | 0.075 | (0.164) |
| 10 | 2 | Conwed 2000 3000#/Ac | 121.34 | (32.06) | 3.523 | (7.751) |
| 10 | 3 | Conwed 2000 3000#/Ac | 157.75 | (41.68) | 4.270 | (9.393) |
| 10 | 4 | Soil Guard 3500#/Ac | 30.09 | (7.95) | 0.029 | (0.063) |
| 10 | 5 | Soil Guard 3500#/Ac | 26.99 | (7.13) | 0.059 | (0.129) |
| 10 | 6 | Conwed 2000 3000#/Ac | 153.59 | (40.58) | 3.350 | (7.370) |

Note: all hydromulches, except those in Test #10, were applied at a rate of 2000#Ac.

Table A-3. Average number of plants and plant height data for Tests 1 through 5.
Slope = 2.5:1. Rainfall = 5 in/hr. Collection time = 0.5 hour.

| Test-Plot | Material | Number of Plants/sample | | | | Plant height (cm) | | | Average |
|---|---|---|---|---|---|---|---|---|---|
| | | Top | Middle | Bottom | Total | Top | Middle | Bottom | h (cm) |
| 1-1. | High-velocity Curlex | 69 | 58 | 121 | 248 | 17.36 | 16.50 | 14.21 | 15.62 |
| 1-2. | Conwed Futerra | 87 | 86 | 88 | 261 | 16.79 | 16.79 | 14.95 | 16.17 |
| 1-3. | Conwed Futerra | 90 | 124 | 124 | 338 | 17.14 | 16.98 | 14.60 | 16.15 |
| 1-4. | High-velocity Curlex | 113 | 87 | 88 | 288 | 19.58 | 15.68 | 17.62 | 17.80 |
| 1-5. | Conwed Futerra | 85 | 97 | 119 | 301 | 16.93 | 15.84 | 20.15 | 17.85 |
| 1-6. | High-velocity Curlex | 71 | 79 | 97 | 247 | 17.53 | 16.63 | 14.28 | 15.97 |
| 2-1. | Climatizer mulch | 20 | 29 | 26 | 75 | 10.44 | 8.53 | 7.92 | 8.83 |
| 2-2. | Cellumulch | 14 | 31 | 25 | 70 | 11.79 | 12.35 | 10.50 | 11.58 |
| 2-3. | Climatizer mulch | 16 | 5 | 10 | 31 | 8.80 | 10.92 | 9.14 | 9.25 |
| 2-4. | Cellumulch | 22 | 11 | 14 | 47 | 10.97 | 11.64 | 9.88 | 10.80 |
| 2-5. | Climatizer mulch | 12 | 16 | 14 | 42 | 9.03 | 9.03 | 6.40 | 8.15 |
| 2-6. | Cellumulch | 33 | 17 | 31 | 81 | 11.90 | 10.50 | 9.73 | 10.78 |
| 3-1. | Verdyol mulch | 34 | 29 | 9 | 72 | 13.65 | 13.50 | 11.76 | 13.35 |
| 3-2. | Nature's Own mulch | 32 | 34 | 36 | 102 | 12.87 | 13.41 | 12.23 | 12.82 |
| 3-3. | Nature's Own mulch | 28 | 26 | 23 | 77 | 12.91 | 13.54 | 11.50 | 12.70 |
| 3-4. | Verdyol mulch | 25 | 13 | 25 | 63 | 11.98 | 12.71 | 12.14 | 12.19 |
| 3-5. | Verdyol mulch | 36 | 14 | 37 | 87 | 13.66 | 12.97 | 10.05 | 12.01 |
| 3-6. | Nature's Own mulch | 25 | 16 | 38 | 79 | 13.88 | 13.84 | 9.00 | 11.52 |
| 4-1. | Silva Fiber | 57 | 40 | 40 | 137 | 13.84 | 13.88 | 12.25 | 13.39 |
| 4-2. | Conwed mulch | 47 | 27 | 42 | 116 | 13.97 | 13.01 | 14.52 | 13.95 |
| 4-3. | Conwed mulch | 69 | 48 | 46 | 163 | 13.84 | 12.54 | 12.54 | 13.09 |
| 4-4. | Silva Fiber mulch | 45 | 60 | 59 | 164 | 13.92 | 12.44 | 12.30 | 12.80 |
| 4-5. | Silva Fiber mulch | 39 | 34 | 28 | 101 | 13.71 | 14.16 | 13.83 | 13.89 |
| 4-6. | Conwed mulch | 67 | 28 | 60 | 155 | 14.79 | 14.34 | 12.26 | 13.73 |
| 5-1. | Re-Fiber mulch | 30 | 23 | 18 | 71 | 13.10 | 13.55 | 10.68 | 12.63 |
| 5-2.5 | Re-Fiber Mix mulch | 22 | 43 | 23 | 88 | 13.73 | 11.30 | 10.59 | 11.72 |
| 5-3. | Re-Fiber mulch | 19 | 31 | 35 | 85 | 12.04 | 12.40 | 10.30 | 11.45 |
| 5-4. | Re-Fiber Mix mulch | 38 | 18 | 19 | 75 | 12.77 | 11.89 | 10.97 | 12.10 |
| 5-5. | Re-Fiber mulch | 31 | 18 | 39 | 88 | 13.32 | 11.39 | 9.77 | 11.35 |
| 5-6. | Re-Fiber Mix mulch | 23 | 19 | 37 | 79 | 12.63 | 11.75 | 9.52 | 10.96 |

Table A-4. Average number of plants and plant height data for Tests 6 through 10.

Slope = 2.5:1. Rainfall = 5 in/hr. Collection time = 0.5 hour.

| Test-Plot | Material | Number of Plants/sample | | | | Plant height (cm) | | | Average |
|---|---|---|---|---|---|---|---|---|---|
| | | Top | Middle | Bottom | Total | Top | Middle | Bottom | h (cm) |
| 6-1. | Grass Fiber | 25 | 35 | 17 | 77 | 14.16 | 13.20 | 12.87 | 13.44 |
| 6-2. | Conwed 2000 | 31 | 35 | 51 | 117 | 12.91 | 14.29 | 13.48 | 13.57 |
| 6-3. | Grass Fiber | 14 | 21 | 7 | 42 | 11.09 | 13.36 | 11.85 | 12.35 |
| 6-4. | Conwed 2000 | 20 | 35 | 43 | 98 | 13.18 | 13.07 | 13.65 | 13.35 |
| 6-5. | Grass Fiber | 29 | 17 | 20 | 66 | 12.82 | 13.41 | 11.84 | 12.68 |
| 6-6. | Conwed 2000 | 34 | 51 | 31 | 116 | 13.74 | 12.91 | 13.90 | 13.42 |
| 7-1. | NAG S-150 BN | 57 | 55 | 100 | 212 | 17.12 | 16.43 | 16.06 | 16.44 |
| 7-2. | NAG SC-150 BN | 62 | 53 | 62 | 177 | 15.80 | 17.23 | 16.07 | 16.32 |
| 7-3. | NAG S-150 BN | 64 | 92 | 80 | 236 | 16.93 | 16.99 | 15.50 | 16.47 |
| 7-4. | NAG SC-150 BN | 43 | 74 | 69 | 186 | 16.79 | 16.49 | 16.12 | 16.42 |
| 7-5. | NAG S-150 BN | 86 | 61 | 84 | 231 | 17.48 | 17.38 | 16.28 | 17.02 |
| 7-6. | NAG SC-150 BN | 50 | 70 | 68 | 188 | 16.27 | 16.78 | 15.89 | 16.32 |
| 8-1. | Anti-wash GeoJute | 64 | 86 | 75 | 225 | 15.43 | 14.99 | 13.77 | 14.71 |
| 8-2. | Dekowe 400 | 46 | 52 | 90 | 188 | 13.65 | 16.54 | 15.21 | 15.20 |
| 8-3. | Anti-wash GeoJute | 42 | 62 | 42 | 146 | 12.33 | 14.66 | 15.00 | 14.09 |
| 8-4. | Dekowe 400 | 49 | 65 | 33 | 147 | 14.07 | 15.28 | 14.45 | 14.69 |
| 8-5. | Anti-wash GeoJute | 39 | 59 | 77 | 175 | 15.16 | 15.29 | 14.59 | 14.95 |
| 8-6. | Dekowe 400 | 47 | 48 | 70 | 165 | 16.51 | 15.98 | 15.30 | 15.84 |
| 9.-1 | Bonterra S-1 | 50 | 86 | 71 | 207 | 15.78 | 15.49 | 15.63 | 15.61 |
| 9.-2 | Bonterra S-2 | 85 | 95 | 82 | 262 | 15.44 | 15.34 | 15.44 | 15.40 |
| 9.-3 | Bonterra S-1 | 84 | 96 | 84 | 264 | 14.95 | 15.04 | 15.67 | 15.21 |
| 9.-4 | Bonterra S-2 | 71 | 78 | 87 | 236 | 14.91 | 14.28 | 13.78 | 14.29 |
| 9.-5 | Bonterra S-1 | 74 | 70 | 128 | 272 | 14.18 | 15.23 | 15.35 | 15.00 |
| 9.-6 | Bonterra S-2 | 43 | 104 | 75 | 222 | 15.20 | 16.04 | 15.26 | 15.61 |
| Slope = 2.5:1. Rainfall = 5 in/hr. Collection time = 1.0 hour. | | | | | | | | | |
| 10.-1 | Soil Guard (*) | 74 | 92 | 88 | 254 | 16.55 | 16.11 | 16.45 | 16.36 |
| 10.-2 | Conwed 2000 (**) | 48 | 63 | 79 | 190 | 16.66 | 16.12 | 17.55 | 16.85 |
| 10.-3 | Conwed 2000 (**) | 27 | 39 | 79 | 145 | 13.90 | 16.69 | 18.09 | 16.93 |
| 10.-4 | Soil Guard (*) | 44 | 54 | 74 | 172 | 15.37 | 17.51 | 15.81 | 16.23 |
| 10.-5 | Soil Guard (*) | 51 | 79 | 67 | 197 | 16.34 | 17.23 | 17.30 | 17.02 |
| 10.-6 | Conwed 2000 (**) | 34 | 50 | 68 | 152 | 16.52 | 17.05 | 17.68 | 17.21 |

(*) Applied at 3500 lb/Ac. (**) Applied at 3000 lb/Ac.

Table A-5. Dry weight of plants and germination data for Tests 1 through 5.

Slope = 2.5:1. Rainfall = 5 in/hr. Collection time = 0.5 hour

| Test-Plot | Material | Dry weight (gm/sample) Top | Middle | Bottom | Total | (gm/plot) | Percentage of seed lost | germi. | non-g. |
|---|---|---|---|---|---|---|---|---|---|
| 1-1. | High-velocity Curlex | 1.26 | 1.06 | 1.65 | 3.97 | 32.86 | 12.11 | 69.86 | 18.03 |
| 1-2. | Conwed Futerra | 1.57 | 1.65 | 1.28 | 4.50 | 37.24 | 20.28 | 73.52 | 6.20 |
| 1-3. | Conwed Futerra | 1.90 | 2.51 | 1.80 | 6.21 | 51.39 | 1.69 | 95.21 | 3.10 |
| 1-4. | High-velocity Curlex | 1.43 | 1.83 | 2.47 | 5.73 | 47.42 | 10.70 | 81.13 | 8.17 |
| 1-5. | Conwed Futerra | 1.66 | 1.75 | 1.76 | 5.17 | 42.79 | 14.08 | 84.79 | 1.13 |
| 1-6. | High-velocity Curlex | 1.28 | 1.45 | 1.26 | 3.99 | 33.02 | 17.46 | 69.58 | 12.96 |
| 2-1. | Climatizer | 0.19 | 0.24 | 0.21 | 0.64 | 5.30 | 58.18 | 22.73 | 19.09 |
| 2-2. | Cellumulch | 0.13 | 0.54 | 0.48 | 1.15 | 9.52 | 70.00 | 21.21 | 8.79 |
| 2-3. | Climatizer | 0.32 | 0.11 | 0.15 | 0.58 | 4.80 | 80.61 | 9.39 | 10.00 |
| 2-4. | Cellumulch | 0.35 | 0.20 | 0.26 | 0.81 | 6.70 | 77.88 | 14.24 | 7.88 |
| 2-5. | Climatizer | 0.10 | 0.12 | 0.10 | 0.32 | 2.65 | 74.24 | 12.73 | 13.03 |
| 2-6. | Cellumulch | 0.43 | 0.16 | 0.36 | 0.95 | 7.86 | 65.15 | 24.55 | 10.30 |
| 3-1. | Verdyol | 0.67 | 0.59 | 0.20 | 1.46 | 12.08 | 64.85 | 21.82 | 13.33 |
| 3-2. | Nature's Own | 0.87 | 0.76 | 0.72 | 2.35 | 19.45 | 64.55 | 30.91 | 4.55 |
| 3-3. | Nature's Own | 0.70 | 0.54 | 0.45 | 1.69 | 13.99 | 69.70 | 23.33 | 6.97 |
| 3-4. | Verdyol | 0.44 | 0.20 | 0.36 | 1.00 | 8.28 | 70.61 | 19.09 | 10.30 |
| 3-5. | Verdyol | 0.53 | 0.23 | 0.32 | 1.08 | 8.94 | 61.82 | 26.36 | 11.82 |
| 3-6. | Nature's Own | 0.41 | 0.24 | 0.31 | 0.96 | 7.94 | 65.76 | 23.94 | 10.30 |
| 4-1. | Silva Fiber | 1.23 | 0.74 | 0.65 | 2.62 | 21.68 | 47.27 | 41.52 | 11.21 |
| 4-2. | Conwed | 1.05 | 0.46 | 0.90 | 2.41 | 19.95 | 45.76 | 35.15 | 19.09 |
| 4-3. | Conwed | 1.16 | 1.01 | 0.69 | 2.86 | 23.67 | 35.45 | 49.39 | 15.15 |
| 4-4. | Silva Fiber | 0.70 | 1.25 | 1.12 | 3.07 | 25.41 | 35.76 | 49.70 | 14.55 |
| 4-5. | Silva Fiber | 0.64 | 0.74 | 0.57 | 1.95 | 16.14 | 50.91 | 30.61 | 18.48 |
| 4-6. | Conwed | 1.28 | 0.62 | 0.93 | 2.83 | 23.42 | 44.85 | 46.97 | 8.18 |
| 5-1. | Re-Fiber | 0.57 | 0.50 | 0.26 | 1.33 | 11.01 | 67.88 | 21.52 | 10.61 |
| 5-2. | Re-Fiber Mix | 0.35 | 0.87 | 0.37 | 1.59 | 13.16 | 60.91 | 26.67 | 12.42 |
| 5-3. | Re-Fiber | 0.31 | 0.59 | 0.50 | 1.40 | 11.59 | 50.30 | 25.76 | 23.94 |
| 5-4. | Re-Fiber Mix | 0.42 | 0.32 | 0.31 | 1.05 | 8.69 | 67.27 | 22.73 | 10.00 |
| 5-5. | Re-Fiber | 0.60 | 0.23 | 0.45 | 1.28 | 10.59 | 56.06 | 26.67 | 17.27 |
| 5-6. | Re-Fiber Mix | 0.38 | 0.47 | 0.39 | 1.24 | 10.26 | 66.36 | 23.94 | 9.70 |

Table A-5. Dry weight of plants and germination data for Tests 6 through 10.

| Test-Plot | Material | Dry weight (gm/sample) Top | Middle | Bottom | Total | (gm/plot) | Percentage of seed lost | germi. | non-g. |
|---|---|---|---|---|---|---|---|---|---|
| Slope = 2.5:1. Rainfall = 5 in/hr. Collection time = 0.5 hour | | | | | | | | | |
| 6-1. | Grass Fiber | 0.50 | 0.67 | 0.36 | 1.53 | 12.66 | 54.24 | 23.33 | 22.42 |
| 6-2. | Conwed 2000 | 0.45 | 0.58 | 0.86 | 1.89 | 15.64 | 50.91 | 35.45 | 13.64 |
| 6-3. | Grass Fiber | 0.25 | 0.49 | 0.14 | 0.88 | 7.28 | 75.15 | 12.73 | 12.12 |
| 6-4. | Conwed 2000 | 0.44 | 0.58 | 0.74 | 1.76 | 14.57 | 53.33 | 29.70 | 16.97 |
| 6-5. | Grass Fiber | 0.43 | 0.33 | 0.25 | 1.01 | 8.36 | 62.42 | 20.00 | 17.58 |
| 6-6. | Conwed 2000 | 0.77 | 0.67 | 0.74 | 2.18 | 18.04 | 43.64 | 35.15 | 21.21 |
| 7-1. | NAG S-150 BN | 1.31 | 1.85 | 2.16 | 5.32 | 44.03 | 10.00 | 64.24 | 25.76 |
| 7-2. | NAG SC-150 BN | 1.59 | 1.56 | 2.62 | 5.77 | 47.75 | 16.06 | 53.64 | 30.30 |
| 7-3. | NAG S-150 BN | 2.88 | 2.57 | 2.36 | 7.81 | 64.64 | 10.00 | 71.52 | 18.48 |
| 7-4. | NAG SC-150 BN | 1.22 | 2.74 | 2.46 | 6.42 | 53.13 | 16.67 | 56.36 | 26.97 |
| 7-5. | NAG S-150 BN | 2.42 | 1.33 | 2.52 | 6.27 | 51.89 | 15.76 | 70.00 | 14.24 |
| 7-6. | NAG SC-150 BN | 1.46 | 2.83 | 1.28 | 5.57 | 46.10 | 17.88 | 56.97 | 25.15 |
| 8-1. | Anti-wash GeoJute | 1.61 | 2.62 | 1.71 | 5.94 | 49.16 | 4.85 | 68.18 | 26.97 |
| 8-2. | Dekowe 400 | 1.71 | 1.40 | 3.20 | 6.31 | 52.22 | 25.15 | 56.97 | 17.88 |
| 8-3. | Anti-wash GeoJute | 0.82 | 1.62 | 0.78 | 3.22 | 26.65 | 32.42 | 44.24 | 23.33 |
| 8-4. | Dekowe 400 | 1.29 | 2.89 | 0.82 | 5.00 | 41.38 | 30.91 | 44.55 | 24.55 |
| 8-5. | Anti-wash GeoJute | 0.77 | 1.43 | 1.93 | 4.13 | 34.18 | 31.52 | 53.03 | 15.45 |
| 8-6. | Dekowe 400 | 2.68 | 1.20 | 2.01 | 5.89 | 48.75 | 20.61 | 50.00 | 29.39 |
| 9.-1 | Bonterra S-1 | 1.13 | 1.90 | 1.45 | 4.48 | 37.08 | 24.00 | 59.14 | 16.86 |
| 9.-2 | Bonterra S-2 | 1.80 | 1.52 | 1.33 | 4.65 | 38.48 | 6.57 | 74.86 | 18.57 |
| 9.-3 | Bonterra S-1 | 1.39 | 1.64 | 1.29 | 4.32 | 35.75 | 2.86 | 75.43 | 21.71 |
| 9.-4 | Bonterra S-2 | 1.11 | 1.10 | 1.52 | 3.73 | 30.87 | 1.71 | 67.43 | 30.86 |
| 9.-5 | Bonterra S-1 | 1.24 | 1.26 | 3.17 | 5.67 | 46.93 | 0.29 | 77.71 | 22.00 |
| 9.-6 | Bonterra S-2 | 0.68 | 1.74 | 1.01 | 3.43 | 28.39 | 18.29 | 63.43 | 18.29 |
| Slope = 2.5:1. Rainfall = 5 in/hr for 60 minutes | | | | | | | | | |
| 10.-1 | Soil Guard (*) | 2.11 | 2.32 | 2.22 | 6.65 | 55.04 | 17.58 | 76.97 | 5.45 |
| 10.-2 | Conwed 2000 (**) | 1.58 | 1.70 | 1.97 | 5.25 | 43.45 | 26.36 | 57.58 | 16.06 |
| 10.-3 | Conwed 2000 (**) | 0.56 | 0.89 | 2.29 | 3.74 | 30.95 | 30.91 | 43.94 | 25.15 |
| 10.-4 | Soil Guard (*) | 1.41 | 1.86 | 1.87 | 5.14 | 42.54 | 41.82 | 52.12 | 6.06 |
| 10.-5 | Soil Guard (*) | 1.36 | 2.17 | 1.61 | 5.14 | 42.54 | 20.30 | 59.70 | 20.00 |
| 10.-6 | Conwed 2000 (**) | 1.12 | 1.63 | 2.04 | 4.79 | 39.64 | 44.85 | 46.06 | 9.09 |

(*) Applied at 3500 lb/Ac. (**) Applied at 3000 lb/Ac.