January 1981

Evaluation of Particular Mulches for Fostering Plant Growth and Inhibiting Erosion (Phase 2)

C. Earl Israelsen

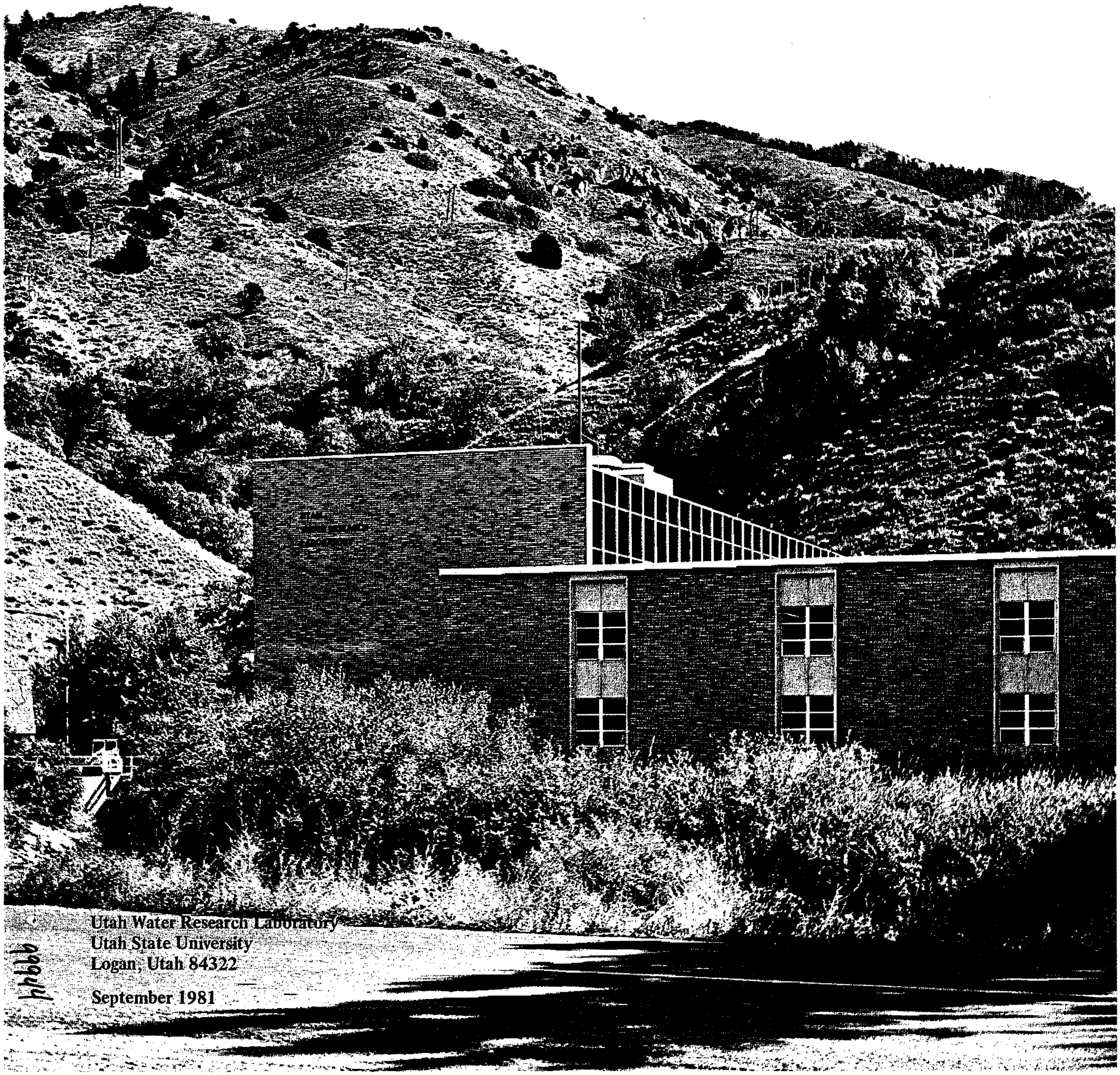
Eugene K. Israelsen

William N. McNeill

Evaluation Of Particular Mulches For Fostering Plant Growth And Inhibiting Erosion (Phase 2)

Final Report to CONWED Corporation

C. Earl Israelsen, Eugene K. Israelsen, William N. McNeill



Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

September 1981

CONWED CORPORATION

Final Report

EVALUATION OF PARTICULAR MULCHES FOR FOSTERING PLANT GROWTH AND INHIBITING EROSION

(PHASE 2)

Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

C. Earl Israelsen
Eugene K. Israelsen
William N. McNeill

September 1981

ACKNOWLEDGMENTS

The research reported herein was performed by the Utah Water Research Laboratory, Utah State University, Logan, Utah. Principal investigators were C. Earl Israselsen, Associate Professor of Civil and Environmental Engineering, Utah State University, and Hydrologist, Utah Water Research Laboratory; Eugene K. Israelsen, Senior Research Engineer, Utah Water Research Laboratory; and William N. McNeill, Research Meteorologist, Utah Water Research Laboratory.

Grateful acknowledgment is made to David Ianson, Graduate Research Assistant, Plant Science Department, Utah State University, who conducted the barley germination tests reported herein, and to Ronald V. Canfield, Associate Professor, Applied Statistics-Computer Science Department, Utah State University, who assisted with the interpretation and analysis of data.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Increasing public awareness of the desirability of protecting the environment from soil erosion caused by wind and water has centered attention on large construction projects such as highways and housing subdivisions, as well as on individual building sites and parking lots. If unattended, sediment produced from these areas pollutes surface water, restricts drainage, fills reservoirs, damages adjacent land, and upsets the natural ecology of lakes and streams.

The search continues for products and practices that will prevent or lessen the amount of sediment leaving construction sites. Products currently in use include chemical as well as organic materials, and they are applied with varying degrees of success. Many designed to stabilize the unprotected soil for a long enough period of time for vegetation to become established are in wide use and are quite effective (Clyde et al. 1978). Moreover, applying organic material to the soil surface around shallow-rooted crops has been a cultural practice for many years (Russell 1961). Janick (1963) summarized the effects of mulching as conservation of soil moisture, reduction of surface runoff and erosion, reduction of evaporation, and possible control of weeds. Others (Borst and Woodburn 1942; Duley 1939) have indicated the value of mulches in reducing runoff and erosion. Mulching has been reported as superior to other treatments for reducing soil and water losses and stabilizing bare slopes before grass is established (Swanson et al. 1965). Gilbert and Davis (1967) and Blaser (1962), in studies of highway slope stabilization, found mulches improved seed germination and seedling growth by conserving moisture and protecting highway slopes against erosion.

Many materials have been evaluated for use as a mulch, including bark, wood wastes, soybean residues, wheat straw, and seaweed (Bollen and Glennie 1961; Kidder et al. 1943; Latimer and Percival 1947). McKee et al. (1964) found wheat straw to be one of the best mulches, particularly when used to aid vegetation establishment on steep cut slopes of highways. Osborne and Gilbert (1978) also demonstrated that shredded hardwood bark mulch provided adequate erosion control on highway slopes.

A previous study conducted by the Utah Water Research Laboratory evaluated, using simulated rainfall and sunlight, the effectiveness of various fiber mulches for controlling erosion to facilitate the establishment and growth of barley on a 2:1 (50 percent) slope. The objective of the present study was to perform similar evaluations of additional mulches.

MATERIALS AND METHODS

Description of Testing Facility

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 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 simulator module. The ratios of the areas of the orifices are 1:2:4:8:16. By controlling the flow to the orifice with an electrically operated solenoid valve it is possible to vary flow in on-off increments with 31 steps. Outlet from the chambers or modules is through uniform equally spaced brass tubes. Each module is a 24 inch rectangular box about 1 inch deep and oriented so that the ends of the tubes or needles form a horizontal plane to let the water drip vertically toward the tilting flume. Each module has 672 needles spaced on a 1 inch triangular pattern.

The rainstorm simulator consists of 100 modules spaced and supported to make a continuous simulator 20 feet square. Each module has separate controls so that a spatially moving storm with time-changing intensities can be simulated. The 500 switches are manually operated, or can be controlled by a programmed computer if desired.

Raindrop sizes and velocities of impact have been designed to represent the energy of typical high intensity storms. The spatial distribution of the rain is essentially uniform and the control of application rates is within the accuracy requirement of most experiments. The simulator has been extensively tested and used in research since its construction in 1973.

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

Approximately 1-foot depth of soil is supported in the tilting flume by a metal grating covered with filter cloth through which water can drain. The flume is divided into three test plots, each measuring approximately 4 feet by 19.5 feet. These plots are separated from each other and from the side walls of the flume by 2-foot wide buffer strips. Runoff from each test plot is captured in a cone-shaped filter, then dried and weighed for determining the exact amount of mulch and soil leaving the plot.

The flume can be tilted hydraulically to any angle up to 43° from horizontal. Figure 1 shows the rainfall simulator in position over the tilting flume.

Sunlight simulator. A balance of radiant energy needed for good plant growth is provided to the test plots by a sunlight simulator which utilizes incandescent as well as fluorescent lamps. It is the same size as the tilting flume, square, measuring 20 feet on each side. It 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 3 feet above the test plot surfaces, and provides illumination at a photon flux density (400-700 nm) of 216 $\mu E \cdot m^{-2} \cdot sec^{-1}$ (measured with a Li-cor

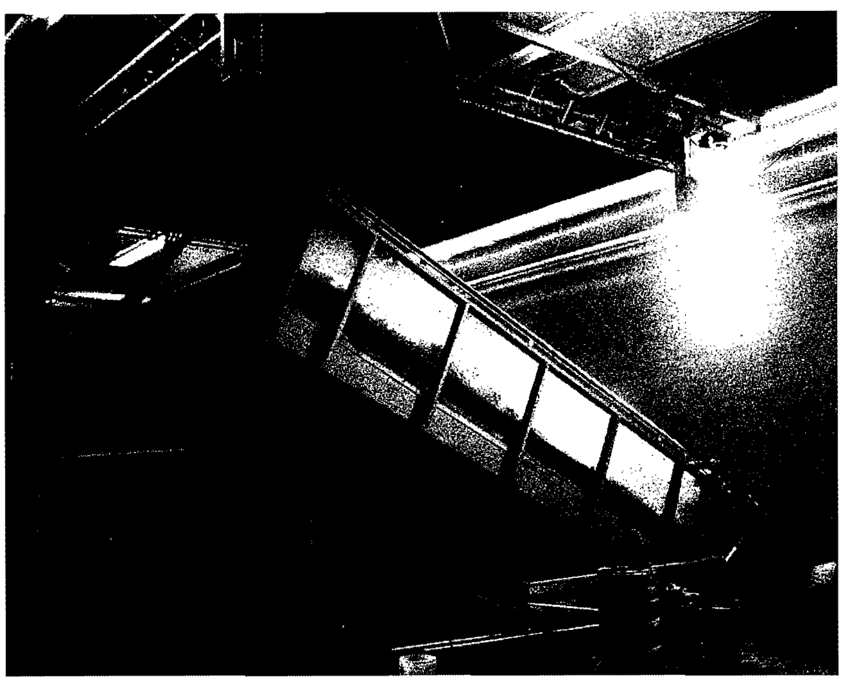


Figure 1. Erosion control testing facility.

190 S quantum sensor on a model LI-185 quantum radiometer/photometer). Figure 2 shows the sunlight simulator in position over the flume.

Products Included in Tests

Three different products were provided by CONWED Corporation in sufficient amounts to accomplish the desired testing. These products are manufactured by CONWED and, for purposes of the tests, were identified as follows:

1. Hydro Mulch 2000 Fiber - 1-A
2. Hydro Mulch 2000 Fiber - 2-A
3. Hydro Mulch 2000 Fiber - 3-A

Test Description and Procedures

Plot preparation. Each of the three test plots was filled with a loam soil having the following approximate composition: Total sand = 28 percent; total silt = 49 percent; total clay = 23 percent; total organic matter = 2.7 percent. After every test run the top layer of soil and mulch was removed and discarded from each plot to the depth that erosion had occurred. New soil was added to replace that removed, then each plot was cultivated with a garden tiller to a depth of approximately 6 inches. It was then raked smooth and uniformly compacted with a lawn roller filled with water.

Installation and use of psychrometers. After the plots were prepared and before the mulch was applied, three psychrometers were installed in each plot at preselected locations along the lengthwise axes (Figure 3). These were buried at a depth of 6 inches beneath the soil surface, and leads from them extended to the outside of the test bed for ease in reading. With the aid of these psychrometers, soil moisture and temperature readings were taken in each plot after the crop was planted but

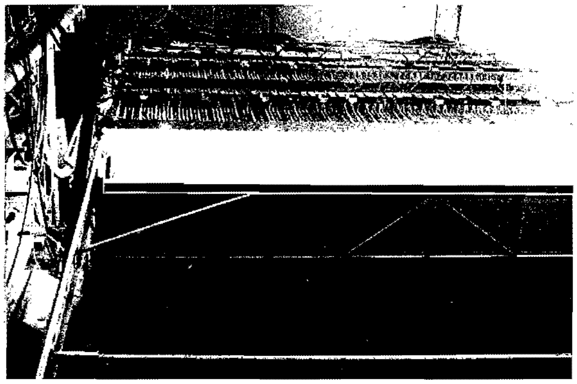


Figure 2. Sunlight simulator in position over testing flume.

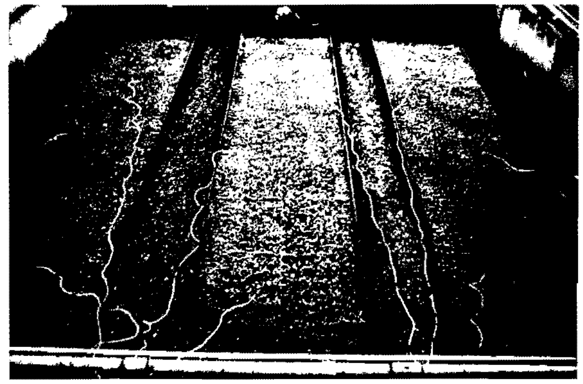


Figure 3. Mulched and seeded test plots after psychrometers are in place.

before the rain was applied, and then on a daily basis thereafter until the end of each test.

Rainfall application. The test bed containing the mulch-covered plots was tilted to a slope of 2:1 and covered with a sheet of plastic. The rainfall simulator was turned on at full capacity to purge the air from the system. (During this purging the rain fell onto the plastic and ran into the drain without wetting the plots.) When the purging was complete the rainfall rate was adjusted to 4 inches per hour and allowed to stabilize. Plastic covering the test beds was then quickly removed so the rain could fall directly onto the test plots, and the time clock was started. Total time was recorded from the instant that rain began falling onto the plots until failure of the mulch occurred. Failure was defined as the time at which the equivalent of approximately 2 tons per acre of soil had been washed from the plot. As each plot failed, rainfall to that plot was stopped so that no additional soil, seed or mulch would be lost.

Mulch and seed application. Three replications of each mulch were applied at the rate of 1600 pounds per acre. The mulch and seed were mixed thoroughly in a water slurry in a hydromulcher and then applied under pressure through a hose to the plots while the test bed was in a horizontal position (Figure 4). Afterwards the plots were allowed to drain overnight before rain was applied.

Sunlight application. When rainfall ceased, the sunlight simulator was rolled into position over the plots, and the entire assembly was tilted to a 2:1 slope (50 percent). Sunlight was applied to the plots for 12 hours and then removed for 12 hours, alternately, throughout the period of each test. Plants can be seen growing in the plots in Figures 5 and 6.

Harvesting the crop. When the predetermined time for the test had elapsed, the test bed was returned to a horizontal position and the sunlight simulator was removed from above the plots. Using the template shown in Figure 7, three 1-foot square sample areas were randomly selected on on each plot, one at the lower end of the slope, one towards the center, and another near the top. Within each of these areas a count was made of the total number of plants and also of the seeds that did not germinate. The height of each plant was measured, then all plants within each sample area were cut off at the soil surface, dried, and weighed. Psychrometers were removed from the plots, and preparations were begun for the next test.

RESULTS AND DISCUSSION

Vegetation

Barley growing in conjunction with mulch 1-a exhibited the greatest amount of growth as judged by plant height and dry weight (Table 1). Mulches labeled 2-a and 3-a appeared to cause a slight reduction in both

Figure 4. Applying mulch and seed with hydromulcher.

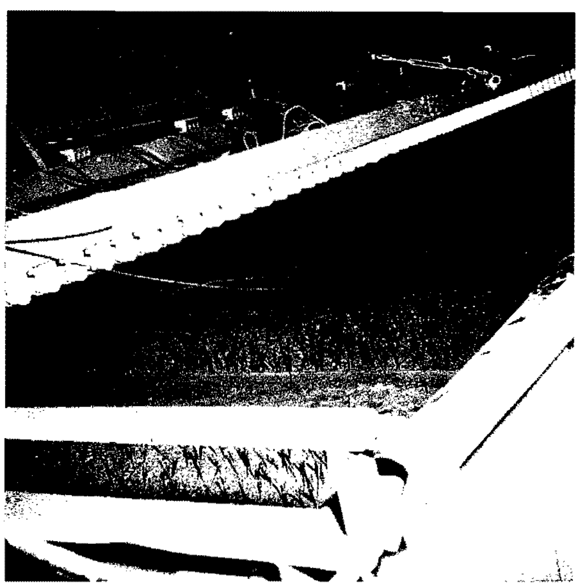


Figure 5. Barley growing beneath sunlight simulator.

Figure 6. Barley growth after seven days.

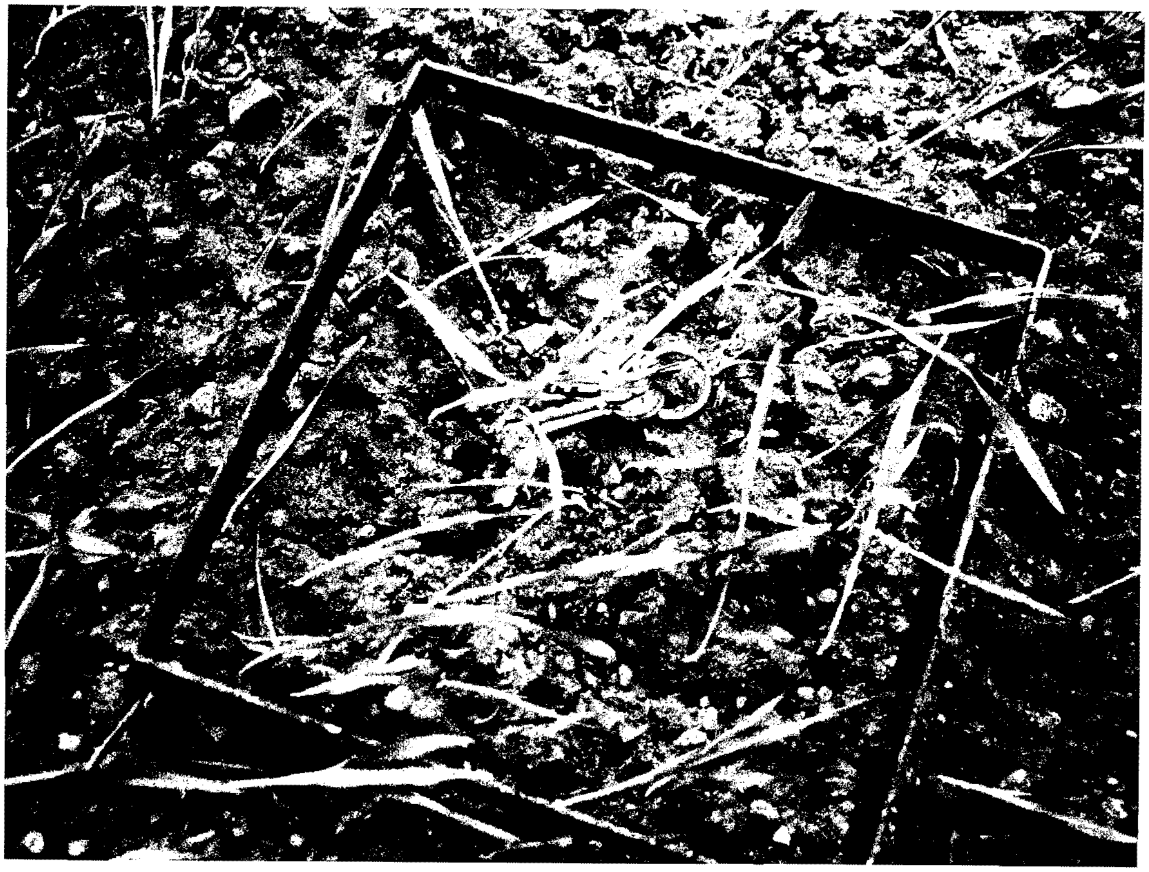


Figure 7. Metal template for isolating sampling areas in test plots.

plant height and dry weight, although these were not statistically significant at alpha = 0.05. Treatment 2-a showed a significantly (alpha = 0.05) higher germination percentage when compared to the other mulches (Table 1). There was no significant difference in the number of plants per square foot between these treatments.

Soil temperatures in conjunction with mulch 3-a were significantly greater than either 1-a or 2-a (Table 1). Treatment 1-a exhibited a significantly more negative water potential than the other two mulches.

There was no visible movement or removal of seeds, soil, or mulch from the upper to lower ends of the plots on any of the runs

Table 1. Effects of various mulches on plant height, soil temperature, plant dry weight, water stress (in bars $-\psi_w$), and percentage germination of barley seeds.

Test No.	Treatment	Pl. Ht. cm $\bar{x}$	± sd	Soil Temp. ^oC $\bar{x}$	± sd	Dry Wt. gms $\bar{x}$	± sd	No. Plts. $\bar{x}$	± sd	No. Seeds Not Germinated $\bar{x}$	± sd	% germ.	$-\psi_w$ bars $\bar{x}$	± sd
1.	Mulch 1-a	10.6	2.4	26.1	2.5	0.30	0.10	28.6	9.6	12.7	3.5	69.3	2.1	1.7
2.	Mulch 2-a	10.4	2.3	26.6	1.2	0.26	0.07	27.6	4.5	6.3	2.3	81.3	1.1	0.3
3.	Mulch 3-a	9.9	2.3	27.2	1.5	0.22	0.08	26.2	7.9	15.2	5.9	63.3	1.1	0.2

during the rainfall period. It was noted that whenever a seed was lying in a depression made by rain droplets, it did not germinate. This phenomenon was observed however in the upper ends of the plots, but not in the middle or lower ends. Generally plants in upper portions of the plots exhibited greater plant heights (Table 2). There were no other plant parameters that seemed to follow any general patterns (Tables 3, 4, and 5).

Soil temperatures and measured water stresses were higher in the upper end of each plot (Tables 6 and 7). It is interesting to note

Table 2. Effects of various mulches on plant height (cm) as a function of position in the experimental plot.

Test No.	Treatment		Position		
			Upper	Middle	Lower
1.	Mulch 1-a	$\bar{x}$	11.4	10.4	10.0
		sd	2.3	3.0	1.6
2.	Mulch 2-a	$\bar{x}$	10.9	10.4	10.0
		sd	1.6	2.4	2.6
3.	Mulch 3-a	$\bar{x}$	10.7	9.4	9.5
		sd	2.7	2.0	2.0

Table 3. Effects of various mulches on plant dry weight (gms) as a function of position in the experimental plot.

Test No.	Treatment		Position		
			Upper	Middle	Lower
1.	Mulch 1-a	$\bar{x}$	0.24	0.31	0.33
		sd	0.07	0.17	0.02
2.	Mulch 2-a	$\bar{x}$	0.25	0.29	0.24
		sd	0.04	0.07	0.11
3.	Mulch 3-a	$\bar{x}$	0.31	0.18	0.18
		sd	0.05	0.04	0.04

Table 4. Effects of various mulches on the number of plants per square foot as a function of position in the experimental plot.

Test No.	Treatment		Position		
			Upper	Middle	Lower
1.	Mulch 1-a	$\bar{x}$	22.7	31.0	32.0
		sd	7.6	15.0	2.6
2.	Mulch 2-a	$\bar{x}$	24.3	30.0	28.3
		sd	3.0	6.1	3.2
3.	Mulch 3-a	$\bar{x}$	35.3	21.3	22.0
		sd	5.5	5.0	2.6

Table 5. Effects of various mulches on the number of ungerminated seeds as a function of position in the experimental plot.

Test No.	Treatment		Position		
			Upper	Middle	Lower
1.	Mulch 1-a	$\bar{x}$	13.3	15.3	9.3
		sd	2.1	0.6	4.2
2.	Mulch 2-a	$\bar{x}$	6.0	6.7	6.3
		sd	2.0	2.5	3.2
3.	Mulch 3-a	$\bar{x}$	15.0	18.7	12.0
		sd	3.6	8.4	5.0

Table 6. Effects of various mulches on soil temperatures as a function of position in the experimental plot (temperature shown in ^{o}C).

Test No.	Treatment		Position		
			Upper	Middle	Lower
1.	Mulch 1-a	$\bar{x}$	26.8	25.4	25.8
		sd	1.1	4.1	0.8
2.	Mulch 2-a	$\bar{x}$	26.9	26.7	26.0
		sd	1.1	1.2	1.2
3.	Mulch 3-a	$\bar{x}$	27.5	27.2	26.9
		sd	1.5	1.4	1.6

Table 7. Effects of various mulches on water stress (in bars - ψ_w) as a function of position in the experimental plot.

Test No.	Treatment		Position		
			Upper	Middle	Lower
1.	Mulch 1-a	$\bar{x}$	2.39	2.09	1.79
		sd	2.44	1.25	0.76
2.	Mulch 2-a	$\bar{x}$	1.20	1.08	1.11
		sd	0.39	0.26	0.32
3.	Mulch 3-a	$\bar{x}$	1.19	1.10	1.12
		sd	0.20	0.32	0.18

(Table 1) that treatment 3-a resulted in the highest soil temperature and the lowest water stress.

Erosion

In the erosion control tests the rainfall rate, its height of fall, the type of soil, and the soil slope were all held constant. A standardized procedure for preparing the test plots was also used so that this parameter was kept as constant as possible. Soil moisture at the beginning of each test run was more difficult to control because of the variable amounts of water that were required to cause the different mulches to fail.

If, using the recorded data (Table 8), we divide the total time until failure by the weight of the material eroded, we come up with an "apparent" rate of erosion which reflects the effect of each mulch on the time until erosion begins as well as its effect on the erosion rate. Even though this method could not be used for calculating

Table 8. Eroded material under 4 inches/hr rainfall and 2:1 slope.

Test No.	Treatment		Replications		
			North	Center	South
1.	Mulch 1-a (1600 lbs/ac)	Elapsed time until erosion begins	4'-40"	6'-02"	9'-24"
		Total elapsed time	29'-0"	24'-40"	26'-50"
		Runoff material	3.57 lbs	4.27 lbs	4.02 lbs
		Apparent erosion rate	0.123 lbs/min	0.173 lbs/min	0.150 lbs/min
			Avg.	= 0.149 lbs/min	
2.	Mulch 2-a (1600 lbs/ac)	Elapsed time until erosion begins	11'-45"	12'-0"	12'-15"
		Total elapsed time	33'-10"	31'-30"	31'-0"
		Runoff material	3.77 lbs	3.27 lbs	6.4 lbs
		Apparent erosion rate	0.114 lbs/min	0.104 lbs/min	0.206 lbs/min
			Avg.	= 0.141 lbs/min	
3.	Mulch 3-a (1600 lbs/ac)	Elapsed time until erosion begins	13'-20"	13'-30"	14'-0"
		Total elapsed time	40'-20"	44'-20"	45'-18"
		Runoff material	3.02 lbs	3.05 lbs	3.07 lbs
		Apparent erosion rate	0.075 lbs/min	0.069 lbs/min	0.068 lbs/min
			Avg.	= 0.071 lbs/min	

actual rates of erosion, it is an effective way of comparing one erosion control product with another. Using this method and averaging the replications we obtain the results shown in Table 9.

There is very little difference in the performance of mulches 1-a and 2-a according to the acquired data, but 3-a is noticeably better than either of them for controlling erosion.

Intrepretations

Figures 8, 9, and 10 show the means and two-sided confidence intervals ($\alpha = 0.05$) plotted for each treatment. A conservative test for the difference between any two treatments can be obtained by noting whether or not the two confidence intervals overlap. If they do overlap, no statistical differences are indicated. Thus it can be seen from Figures 8 and 9 that mulches 1-a and 2-a are statistically the same with respect to both apparent and actual erosion rate. Mulch 3-a is less than the other two in apparent erosion rate and significantly less in actual erosion rate.

The data for elapsed time until runoff begins exhibit some characteristics which may be important. The variation in the observed times on the three plots is much greater for mulch 1-a than for the other two. Because no physical explanation for these differences can be assumed at this writing, it has been interpreted as a random phenomenon which could have affected the other mulches as well. Thus the variances have been pooled to compute the confidence intervals in Figure 10. Under this assumption of homogeneous variance it is evident that all treatments are significantly different. Because of the large variance due to mulch 1-a, this is a very conservative test for mulches 2-a and 3-a thus, evidence of a difference is stronger than appears in Figure 9.

Table 9. Mulch effectiveness ranking as indicated by apparent erosion rate.

Test No.	Treatment	Apparent Erosion Rate	Ranking of Effectiveness of Products
1.	Mulch 1-a	0.149 lbs/min	3rd
2.	Mulch 2-a	0.141 lbs/min	2nd
3.	Mulch 3-a	0.071 lbs/min	1st

There is very little difference in the performance of mulches 1-a and 2-a according to the acquired data, but 3-a is noticeably better than either of them for controlling erosion.

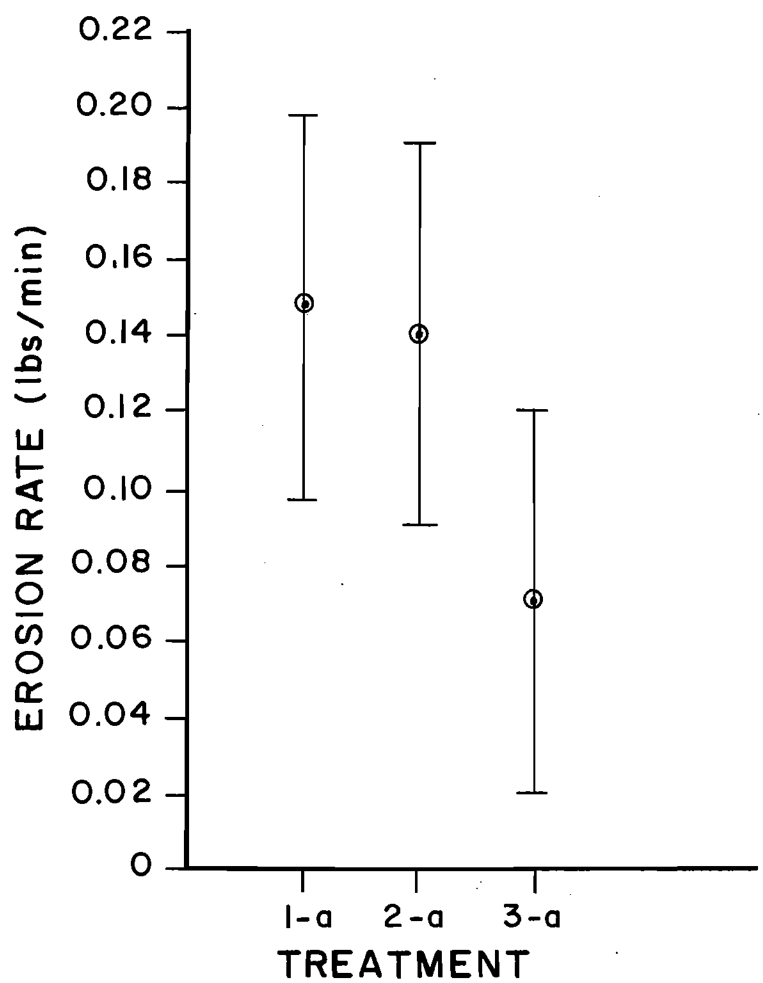


Figure 8. Apparent rate of erosion.

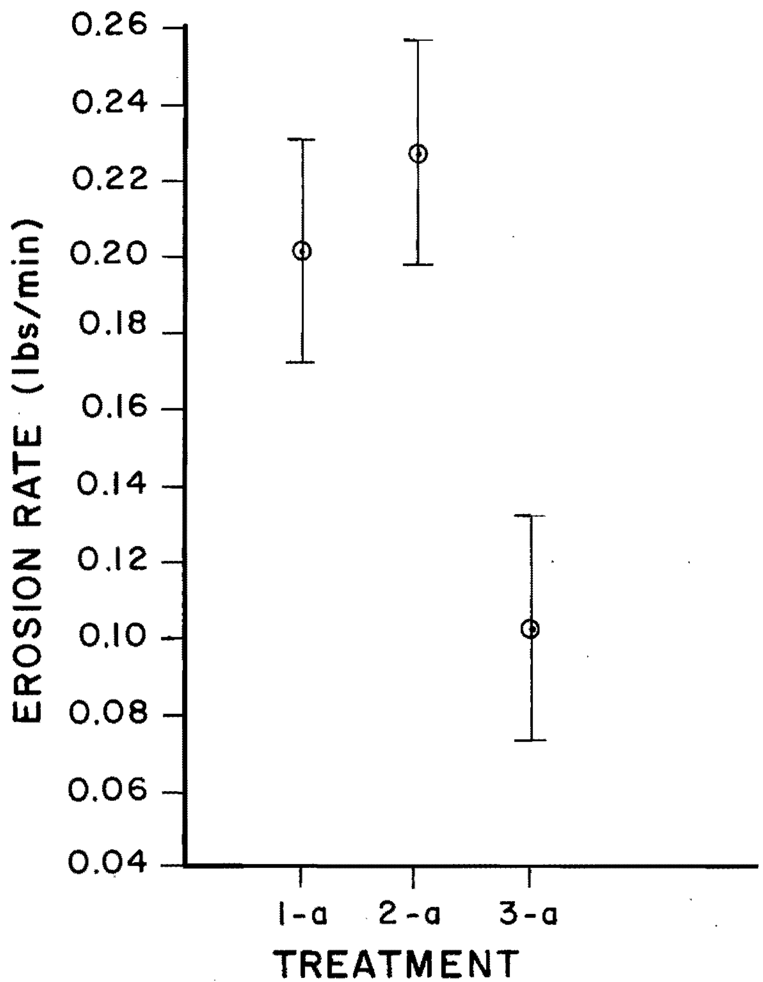


Figure 9. Actual rate of erosion.

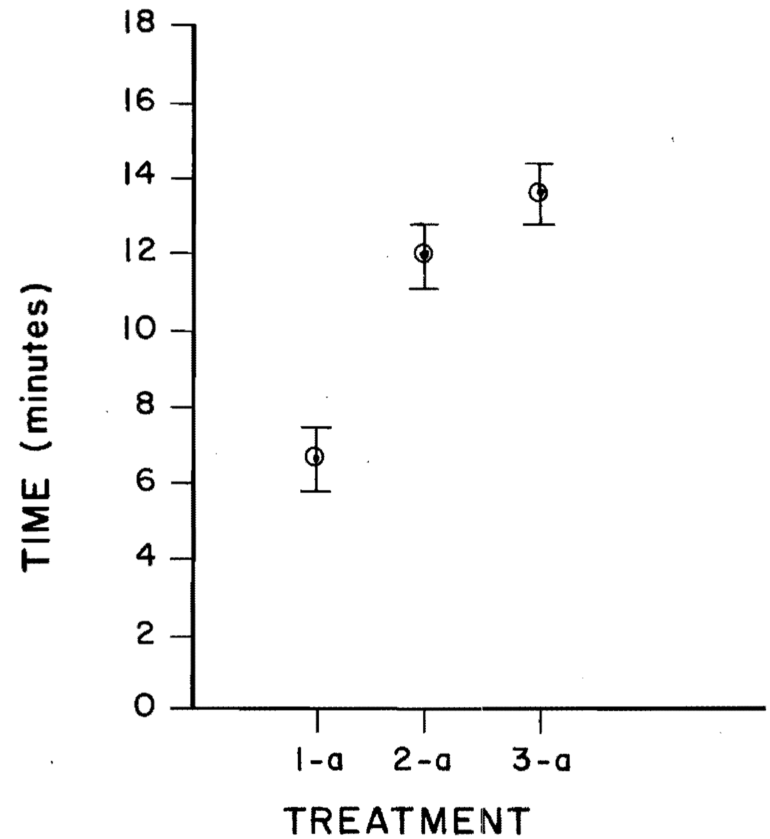


Figure 10. Elapsed time from beginning of rainfall until runoff begins.

SUMMARY

The mulches tested did not differ noticeably in fostering plant growth, but mulch 3-a did seem to hold moisture a bit longer which resulted in higher soil temperature. They did, however, perform differently in controlling erosion with mulch 3-a eroding at only one-half the rate of mulch 1-a. In comparing these erosion results with those of tests run previously, it is noted that mulches 1-a and 2-a perform about the same as did CONWED Hydromulch 2000 applied at 1600 lbs/acre. Mulch 3-a is the most effective for controlling erosion.

SELECTED BIBLIOGRAPHY

Blaser, R. E. 1962. Soil mulches for grassing. p. 15-20. In: Roadside development. Pub. 1030. Highway Research Board, NAS-NRC.

Bollen, W. B., and D. W. Glennie. 1961. Sawdust, bark and other wood wastes for soil conditioning and mulching. For. Prod. J. 11:38-48.

Borst, H. L., and R. Woodburn. 1942. Effect of mulches and surface conditions on the water relations and erosion of muskingum soils. USDA Tech. Bull. 825.

Clyde, C. G., C. E. Israelsen, P. E. Packer, E. E. Farmer, J. E. Fletcher, E. K. Israelsen, F. W. Haws, N. V. Rao, and J. Hansen. 1978. Manual of erosion control principles and practices. Hyd. and Hydrol. Series Rep. H-78-002, Utah Water Research Laboratory, College of Engineering, Utah State University, Logan, Utah.

Duley, F. L. 1939. Surface factors affecting the rate of intake of water by soils. Soil Sci. Soc. Am. Proc. 4:60-64.

Gilbert, W. B., and D. L. Davis. 1967. An investigation of critical problems of establishing a satisfactory sod cover along North Carolina highways. School of Engineering, N.C.S.U. and N.C. Div. of Highways. Final Report ERD-100-S, Raleigh, N.C.

Israelsen, C. E., W. F. Campbell, E. K. Israelsen, R. V. Canfield, and D. Ianson. 1980. Evaluation of particular mulches as plant growth media and erosion inhibitors. Final Report to CONWED Corporation. Utah Water Research Laboratory and Plant Science Dept., Utah State University, Logan, Utah 84322.

Janick, J. 1963. Horticultural science. 1st ed., W. H. Freeman and Co., San Francisco, CA.

Kidder, E. H., R. S. Stauffer, and C. A. Van Doren. 1943. Effect on infiltration of surface mulches of soybean residues, corn stover, and wheat straw. Agric. Eng. 24:155-159.

Latimer, L. P., and G. P. Percival. 1947. Comparative value of sawdust, hay, and seaweed as a mulch for apple trees. Proc. Am. Soc. Hort. Sci. 50:22-30.

McKee, W. H., Jr., R. E. Blaser, and D. G. Barkley. 1964. Mulches for steep cut slopes. p. 35-42. In: Roadside development 1963. Highway Research Board, NAS-NRC, Washington, D.C.

Osborne, D. J., and W. B. Gilbert. 1978. Use of hardwood bark mulch for highway slope stabilization. Agron. Jour. 70:15-17.

Russell, E. W. 1961. Soil conditions and plant growth. 9th ed., John Wiley and Sons, Inc., N.Y.

Swanson, N. P., A. R. Dedrick, H. E. Weakly, and H. R. Haise. 1965. Evaluation of mulches for water erosion control. Trans. Am. Soc. Agric. Eng. 8:438-440.