MULCH CHOICES FOR EROSION CONTROL AND PLANT ESTABLISHMENT

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Mulching nearly always shortens the time needed to establish a suitable plant cover. The conventional mulches of agricultural or industrial residues have recently encountered competition from many chemical stabilizers or mulches introduced largely as supplements to the increasingly popular hydraulic methods (hydroseeding — application of a water slurry of seed, fertilizer, mulch, etc.).

Seed coverage with soil to the proper depth is essential in dry regions. Mulch, particularly hydromulching, is sometimes substituted for seed coverage when moisture is adequate. Showing the most promise in excessively dry areas are mulches applied after seed has been covered to the proper depth with soil, as with a grain drill (Springfield 1971).

Mulches can both protect soil and enhance plant establishment. The soil is protected by shielding it from raindrop impact, retarding water flow and soil movement by trapping silt on the sites, increasing water penetration, and sometimes shedding water. Properly anchored, mulches may reduce wind velocity. They enhance plant establishment by holding seed and fertilizer in place, retaining moisture, preventing crusting, and modifying temperatures.

Mulches on dry sites may also encourage plant suicide! Properly mulched seeds may often be fooled into germinating with the first rainfall and soon die from lack of sufficient moisture for continued growth. The use of soil mulch (seed coverage) is probably the best insurance against such a calamity. Soil which is sufficiently wet for a long enough period to effect germination is more likely to sustain plant growth than is a surface organic mulch or chemical. Also, planting as near as practical to a date when adequate moisture is expected may avoid this problem.

ORGANIC MULCHES

Organic mulches are often an agricultural crop residue or industrial product. The price usually reflects transport and handling cost more than any intrinsic value of the product.

Most organic mulches require additional nitrogen to compensate for the tie-up of nitrogen in the decomposition process.

Effectiveness is roughly related to the size and shape of the mulch particles. Long narrow particles are superior to finely ground products. Following is a discussion of the organic mulches commonly used.

Straw and Hay

Straw and hay are the mulches used most often in the West. 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. 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.

The mulch effect of straw can be expected to increase plant establishment. 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. Comparisons of straw with hydromulch show that straw mulch produced the best grass stands (Kay, 1974; Perry et al., 1975).

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, 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 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 should 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 US tons/acre reduced losses by 95%. Straw to be crimped is commonly used at 2 US tons/acre, while straw punched into fill slopes in California is at 4 US tons/acre each. Straw to be held down with net should be limited to 1.5-2 US tons/acre, and straw held with a tackifier at 1-1.5 US 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 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 needs to be held in place until plant growth starts. The problem is wind, not water. Water puddles the soil around the straw and helps hold it in place. Also, 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 specially designed roller. A sheepsfoot roller, commonly used in soil compaction, is not satisfactory for incorporating straw. 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 with top-of-slope access 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 of 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 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, 1976) have shown that 600 gallons is superior to 400 gallons, 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. Terratack I is a gum derived from guar, Terratack II is semi-refined seaweed extract, and Ecology Controls M Binder is a gum from plantain, *Plantago insularis*. The remaining products are emulsions used in making adhesives, paints, and other products. Though wood fiber alone is effective as a short-term tackifier, glue must be added to give protection beyond a few weeks. Increasing the rate/acre of any of the materials will increase their effectiveness.

Hydraulic mulching

Hydraulic mulching, or hydromulching, is a mulch applied in a water slurry. This same slurry may also contain seed, fertilizer, erosion-control compounds, growth regulators, soil amendments, etc., and is increasingly popular because of low labor requirements. Mulches must have a particle size small enough for ready pumping through 0.5-inch nozzles, and must not be too buoyant to remain in suspension with moderate agitation. Used most commonly are specially manufactured fibers of alder and aspen. Hemlock, also used, is more difficult to pump. Many recycled paper and agricultural products have been marketed or tested. Among those marketed are office waste, corrugated boxes (PFM), chopped newspaper, and seed screenings. Also tested by the author were whole and ground rice hulls, ground cereal straw, and washed dairy waste.

The most important quality of a hydromulching material is that it must adhere to the soil even on steep slopes and hold the seed in place during heavy rainfall impact and wind. If it fails in those functions, other characteristics (water-holding capacity, appearance, cost, etc.) are not important.

Hydromulching materials have been tested (by the author) by applying them to the surface of greenhouse flats of 13 x 19 in. filled with decomposed granite. The flats were inclined at 45° (1:1 slope) and subjected to artificial rainfall of 3-mm drops falling 15 feet from a 1-inch grid at 6 in. of water/hr. Virgin wood fibers of aspen and alder offered considerable soil protection and were consistently superior to all other products. The only recycled products to approach their effectiveness were the PFM products made from corrugated boxes. One lot of these fibers had been separated on the basis of length, with the shorter fibers being recycled into other paper products. These longest fibers were at least equal to the virgin wood fibers. Tests of commercial PFM products, however, do not always produce such satisfactory results, apparently because they contain a high proportion of short fibers. Commercial materials made of office waste, newsprint, and seed screenings are vastly inferior. These and other recycled materials wash from the slope with the first raindrops. A satisfactory material could probably be made from

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recycled material if more attention were paid to fiber length.

Working with Mr. Tom Miles of the Oregon Field Sanitation Committee, we found that a satisfactory hydromulch can be made from fibers of grass or cereal straw. Fibrated straw is manufactured by presteaming chopped straw and refining this through rotating close-tolerance discs and drying. Tests show that the process effectively eliminated the allelopathic (germination-depressing) characteristics of ryegrass straw. Fibrated rice straw also makes a satisfactory hydromulch, more resistant to raindrop impact than fiber made from ryegrass.

Fiber testing has been for characteristics which protect the soil surface and hold the seed in place. However, these same characteristics may hold the seed and prevent them from readily falling into natural depressions in the soil where they can become covered with soil. Under these soil conditions it may be better to use very little fiber, or even no fiber. The unsatisfactory products mentioned above may, under these circumstances, result in a better grass stand than using a quality fiber. The best choice would be to broadcast seed or drill first and then cover with a quality hydromulch.

Another important property of mulch is its moisture-holding characteristics. A standard procedure for measuring this characteristic has been developed by the California Department of Transportation (Hoover 1976). In general, products with the longest fibers and best slope-adhering characteristics also have the highest moisture-holding capacity.

Commercial fibers are usually dyed with a fugitive green dye which lasts only a few hours or days. This visual aid assists in obtaining an even distribution on the slope.

Rates of hydromulch vary from 500 to 3,000 lb/acre. The rate of 500 lb/1,500 gal. water is suggested as necessary to disperse seeds evenly in the slurry, and to protect seed in passing through the centrifugal pumps commonly used in hydraulic seeders (Kay, 1976). This would cover one to three acres, with best coverage on one acre and possible distribution problems if used on three acres. A minimum of 1,000 lb/acre is necessary to hold the seed on a slope. An inconsistent "mulch effect" has been observed with less than 1,500 lb/acre. Currier (1970) expressed some concern that "60-70% of the seed hangs up in the mulch and has little or no chance to get its primary roots into mineral soil." Studies with wood fiber (Kay, 1973) showed that under conditions of adequate moisture, small grass seeds such as Durar hard fescue could emerge through as much as 9,000 lb and readily emerge from between two 1,000-lb layers. Placing the seed on top of 2,000 lb speeded emergence and total ger-

Summary of methods and costs of common erosion-control practices.

Treatment	Comments	Pregermination erosion effectiveness*	Effectiveness on plant establishment*	Approx. cost per acre $**
1. Seed and fertilizer broadcast on the surface, no soil coverage or mulch.	Inexpensive and fast. Most effective on rough seedbeds with minimum slope and erodability where seed will cover naturally with soil. Suitable for remote or critical areas where machinery cannot be taken.	1	1-4	250
2. Hydroseeding or hydromulching (seed + fertilizer) with 500 lb. wood fiber, 1,500 gal. water/3 acres.	Similar effectiveness to broadcasting seed and fertilizer. Not enough fiber to hold seed in place or produce a mulch effect. Seed distribution would be improved by increased volume of water.	1	1-4	250
3. Seed and fertilizer broadcast and covered with soil (raking or dragging a chain, etc.).	Does not require special equipment. Generally a very effective treatment. Labor cost is high on areas not accessible by equipment.	1	3-4	320
4. Hydromulching with 1,500 lb./acre wood fiber (plus seed and fertilizer).	Most common hydromulch mix in California. Advantages include holding seed and fertilizer in place on steep and smooth slopes where there may not be an alternative method. Only a minimal mulch effect. Cost is much higher than 2.	2	3-5	425-520
5. Hydromulching with 1,500 lb. woodfiber plus an organic glue: Ecology Control, Terra-tack III etc. plus seed and fertilizer.	The addition of an organic glue will sometimes improve fiber holding and germination. Does not increase labor or machinery cost.	2 +	3-6	550-650
6. Hydromulching with 2,000-3,000 lb./acre wood fiber plus seed and fertilizer.	Produces a true mulch effect and some erosion protection. Commonly better results than 1,000 lb. fiber or fiber plus glue.	2-3	4-7	530-750
7. Seed and fertilizer broadcast and covered with soil as in 3 above, but followed with hydromulch of wood fiber at 2,000-3,000 lb./acre.	Very effective, combine advantages of seed coverage and mulching.	2-3	6-8	680-865
All of the above treatments offer only minimal protection from the impact of raindrops and water flowing over the surface, but are all weed free.				
8. Straw or hay broadcast with straw blower on the surface at 3,000 lb./acre and tacked down (asphalt emulsion, Terratack II, etc.). Seed and fertilizer broadcast with hydroseeder or by hand.	Common elsewhere in U.S. Very effective as energy absorber, mulch; and straw forms small dams to hold some soil. May be weedy depending on straw source. Not for cut slopes steeper than 2:1. Cost would increase significantly if slopes over 50 feet from access, or application is uphill.	5-7	8-10	650
9. Straw broadcast 4,000 lb./acre rolled to incorporate (punched) another 4,000 lb. straw broadcast and rolled, seeded and fertilized. Seed and fertilizer broadcast with hydroseeder or by hand.	Common on difficult fill slopes in California. Very effective. Not possible on most cut slopes. Very weedy. Cost would increase significantly if slopes over 50 feet from access.	6-8	8-10	877-1070
10. Roll-out mats (jute, excelsior, etc.). Held in place with wire staples. Seed and fertilize as in 1 or 2.	Some are a good mulch, weed free, adapted to small areas. Can be installed any season, cuts or fills. Unsightly. Difficult to install on rocky soils.	5-7	5-10	2400-2700
11. Polyethylene sheets. (4 mil) Seed and fertilize as in 1 or 2, use clear plastic, black if no seed is used.	Useful for temporary control. Can be installed any season. Unsightly, wind is a problem in installation and maintenance. May be difficult to establish plants.	10	?	2400-2700
12. Seed and fertilizer broadcast, or hydromulched with fiber (treatment 2 or 4), followed by erosion control chemical such as polyvinyl acetate at 6:1 dilution (6 parts water) at 1,000 lb. solid/acre (approx. 200 gal. PVA).	Very expensive, but will hold soil and seed in some very difficult conditions. May restrict penetration of water into soil. Will not cure below 55°F. Not effective on soils which crack. Will not support animal or vehicle traffic.	10+	?	1070-1370

* 1 = minimal, 10 = excellent.

** Assumes seed plus fertilizer $150.00, fiber $150/con. Ecology Control $1.25/lb., PVA $3.00/gal., 1,500 gal. hydroseeder with 2 man crew $55.00/hr., labor $13/hr., straw $50/T, straw mulcher with 4 man crew $64/hr. (applies 2 T/hr.) and markup of 30% for overhead (including equipment depreciation), and profit. Cost figures were derived from conversations with contractors, and by review of recent Caltrans contracts.

From: Kay, B. L. 1976. Hydroseeding, straw, and chemicals for erosion control. Agronomy Progress Report No. 77. Agronomy and Range Science Department, UCO. Mimeo. 14 p. June.

mination of orchardgrass and did not reduce emergence of any of the other five species tested.

Under conditions of limited moisture, created by applying the mulch over seed broadcast on greenhouse flats filled with various problem soils, inclining the flats at slopes of 1:1, 1.5:1, or 2:1 (horizontal to vertical measurement) and exposing them to natural rainfall yielded the data in Table 2. On the steepest slopes (1:1 and 1.5:1), 1,000-2,000 lb of fiber was necessary to hold the seed in place. Without that amount, no seedlings were established. On the flatter 2:1 slope, the 1,000-lb rate did not improve the stand whereas 2,000 lb did. Increasing the rate to 3,000 lb increased the number of seedlings on the most severe test with either decomposed granite or fine sand. In recent tests by the author near Lake Tahoe, California, 4,500 lb resulted in good grass stands, while 3,000 lb produced only a few seedlings, because of excessive frost heaving.

Wood fiber is an essential addition to most hydraulically applied chemicals, including straw tackifiers. Many soil-binding chemicals will not hold seed, fertilizer, or straw to a slope unless wood fiber is included.

Wood Residues

Wood residues (woodchips and bark) can be used effectively if locally available as a waste from the forest-products industry or chipped on the site during land clearance. Smaller wood-residue particles, such as shavings or sawdust, would be subject to wind loss. Woodchips and bark can be applied with a conventional straw-blower to a distance of 18 m. (Emanuel 1971). The rate must be twice that of straw to obtain the same soil protection (Meyer et al., 1972) or even as much as 6 times the straw rate (Swanson et al. 1965). Observations in California indicate that uneven distribution often results in poor or no plant establishment in the heavier (100% ground cover) applications.

Fabric or Mats

Fabric or mats, including jute, exelsior, and woven paper or plastic fibers, are provided in rolls to be fastened to the soil with wire staples. Fiberglass roving (which is blown on with compressed air and tacked with asphalt and emulsion) is also available as a nonbiodegradable substitute. Use of these products is limited by their cost and effectiveness. The rolls require high labor inputs for installation, cost at least four times as much as tacked straw, and are not adapted to fitting to rough surfaces or rocky areas. Erosion from beneath these products is common because they do not have intimate contact with the soil. They must be heavy enough or anchored in enough spots to prevent wind whipping. Several reports indicate they are not as effective as straw (Springfield, 1971). They have the advantage of being weed-free but may be unsightly, a fire hazard, or (in some cases) nonbiodegradable or too rapidly biodegradable to be effective. Dudeck et al. (1970) found excelsior mat or jute to yield the best seedling grass of eleven mulch treatments tested. Swanson et al. (1967) found jute, excelsior, and prairie hay or fiberglass anchored with asphalt emulsion to be the best of all treatments.

Mats would be used only on small areas, such as to repair failures of other treatments, where time and cost factors are of secondary importance. They should be maintained, repairing tears, etc., before wind or water can cause extensive damage.

CHEMICALS

Chemicals to be used as a mulch, humectant (a substance that absorbs or helps another substance retain moisture), or soil binder are usually applied in a water carrier or as part of a hydraulic seeding slurry. They are expensive and very specialized, and must be used correctly for maximum effectiveness. They are not substitutes for sound agricultural or engineering practices, regardless of glowing advertisements. Products are discussed here as either fiber tackifiers (including humectants) to be used as part of a seeding, or plastic emulsions which may be used with a seeding or alone as a soil binder.

Fiber Tackifiers

Fiber tackifiers are generally advertised to hold fiber in place, promote germination, hold moisture, and retard erosion. Most sales literature acknowledges that fiber should be used with the product. Within this group we have tested Ecology Controls M-Binder, Kelgum, Terratack I, Terratack III, Styrene butadiene, Super Slurper, PVA, and Verdylo Super.

Although virgin wood fibers as a hydraulic mulch adhere well to slopes without the addition of glues or tackifiers, interest continues in products which would improve their resistance to wind or rain. Of the variety of products previously tested, only a few improved the fiber characteristics, and then only slightly or inconsistently. Most products do make the slurry easier to pump, allowing the addition of more fiber/load.

Most existing products are sensitive to fertilizer. Adding 16-20-0 ammonium phosphate-sulfate at 500 lb/acre to 1,500 lb of wood fiber greatly reduced the effectiveness of Terratack III (an alginase), Ecology Controls M Binder (husk of *Plantago insularis*), PVA (polyvinyl acetate homopolymers or vinyl acrylic copolymers), Super Slurper, and SBR (styrene butadiene). These and all following tests involved applying treatments to greenhouse flats, inclining the flats at 1:1 after curing, and exposing them to artificial rainfall of 3-mm drops at 6 inches/hour.

Two new products promise to be much more effective than those previously tested. The two products are of very different composition, an improved SBR (styrene butadiene), and Super Slurper, an absorbent polymer made from starch. Several SBR Products are sold for erosion control. The available SBR products differ considerably in pH (acidity) and can therefore be expected to perform quite differently. The product tested in the current studies is XFS 4163-L Dow mulch binder, a liquid which utilizes a dry powder modifying agent (methyl cellulose). Super Slurper, a USDA patent, promises to have many uses. This dry powder is reported to be able to absorb up to 1,000 times its weight in water. The sample tested is SGP absorbent polymer from General Mills.

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Applications of Super Slurper or Dow SBR without fertilizer in a slurry with 1,500 lb/acre fiber have shown their superiority to other products. Super Slurper at 100 lb/acre is comparable to SBR at 30 gal/acre, but even one-half these amounts is superior to the old products. Super Slurper will require use of aboutt twice as much water/acre as would normally be used to apply wood fiber at these rates.

Super Slurper in a fiber slurry is much less effective when used with fertilizer. SBR, in contrast, is made only slightly less effective by fertilizer. Previously tested was another SBR product which was seriously affected by fertilizer in that rubber balls were formed when fertilizer was added.

These two products are quite different in the form they take. SBR cures to a crust or film, whereas Super Slurper does not cure, but forms a viscous water-absorbing surface if moisture is present.

Recent tests have shown that applying a quality glue after the hydro-seeding-mulching operation, in the same manner that tackifiers are applied to straw, is many times as effective as including the glue in the hydro-seeding-mulching slurry. Particularly effective was the Dow Mulch Binder XFS 4163-L. Rates as low as 20 gpa with 0.75 lb modifier and 86 lb of wood fiber in 344 gal water as a tackifier over 1,500 lb of fiber with seed and fertilizer gave a surface that was more resistant to rainfall impact than 60 gpa applied in the single slurry or resistant for a much longer period than 20 gal in a single application. Similarly PVA applications were improved by a split application. Super Slurper performance was similar in single or split applications. Plant emergence or growth were not adversely affected by splitting the application of any material. Germination may be reduced and delayed by use of fertilizer with SBR. Using higher rates of seed will compensate for this loss. The low total volume of SBR required will call for careful application.

There is a hazard to the seed in using highly effective mulches or additives. These products or combinations may retain enough moisture to allow germination when the moisture in the soil is too low to permit establishment. Simply covering the seed with soil may be more effective in that the seedbed will remain dry until enough moisture is available for both germination and growth. Where enough moisture for growth is present or can be provided, Super Slurper might help keep the soil surface moist during the germination period.

Soil Binders

Plastic emulsions have been used for about a decade to bind surface soil particles for protection from wind and water erosion. Their use has been limited, however, by relatively high cost and by numerous reports of ineffectiveness and negative effects on plant establishment (Sheldon and Bradshaw 1977). Among the emulsions used are polyvinyl acetate homopolymers or vinyl acrylic copolymers, generally called PVA. Commercial versions are Aerospray 70, Crust 500, Curasol AK, Enviro, MGS, Stickum, Terra Krete, and Soil Bond. Soil Seal, similar in effectiveness, is a copolymer of methacrylates and acrylates. Another chemical group is styrene butadiene (SBR). All are an intimate mixture of high-molecular-weight polymeric particles dispersed in a continuous aqueous phase. They are basic ingredients in paint, glue, and other products.

1. Effectiveness and rate

Plastic emulsions give better initial protection than do other commonly used erosion-control practices. The optimum rate determined by the California Department of Transportation is 1,000 lb/acre of dry solids (about 200 gpa) for the polyvinyl acetates (750-1,100 lb/acre on various soils). Most emulsions are about 9 lb/gal and 55% solids. Recent tests compared PVA with an experimental SBR from Amsco Division, Union Oil Company at rates of 500 and 1,000 lb/acre solids. SBR at 500 lb. was similar in effectiveness to PVA at 1,000 lb.

2. Dilution rate

All products tested to date are sold as a liquid concentrate to mix with water. The amount of water used is critical.

Dilutions of 5:1 to 10:1 PVA are far more effective than higher dilutions. Comparison of water, with 5:1-7:1 optimum, 8:1 and 9:1 satisfactory, and 10:1 less effective. All of the tests were conducted on dry sand. Emulsions were applied to a horizontal surface of 13 x 19 inches and allowed to cure at about 60°F for at least two days. The surface was then inclined at 1:1 (steeper than the natural angle of repose sand). The surface was then exposed to artificial rainfall at 6 inches/hr. 3-mm drops, or 6 inches/hr composed of 2 inches/hr, 2-mm drops, plus 4 inches/hr as a mist. Some treatments survived over 120 inches of the latter type of rainfall.

The optimum dilution rate could be expected to be different with other products, on other soil materials, and with other soil-temperature and moisture conditions. Optimum dilution is far less critical for SBR. Tested were 6:1, 12:1, 24:1, and 36:1 at 500 lb/acre solids. The lower these dilution rates, all equally effective, were superior to the 36:1 dilution.

The poor performances of commercial applications can often be traced to the use of too much water. When the emulsion is applied as a component of hydroseeding, a frequent practice, the water required to carry the wood fiber and other components is often greater than the desired PVA dilution. Hydroseeding machines will normally pump 3-5% fiber by weight. If the contract called for 1,500 lb fiber and 200 gpa PVA the dilution rate would be 30:1 at 3% and 18:1 at 5%. (Both the liquid and solid effect of the PVA as well as the possibility of an easier pumping effect of PVA are ignored in these calculations as a safety factor to avoid a plugged hydroseeder full of expensive components.) This means that the PVA must be applied separately—after the first application (containing the fiber, seed, and fertilizer). A material which is less restrictive as to dilution rates would then be advantageous by allowing a single rather than split application. However, the benefits discussed

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earlier of split applications allowing reduced chemical rates should easily make up for the cost of a second application.

3. Curing of emulsion film

A primary limitation of emulsions is the restriction placed on curing. The minimum curing temperatures generally recommended are 55° F for PVA and 40° F for SBR. Also required are proper drying conditions. Fog will prolong by many days the curing time of either emulsion, and rain before the emulsion is properly cured may prove the crust to be ineffective. A logical use of the materials would be when the construction project halted for the winter. Unfortunately, however, weather conditions which halt construction are the same as those which slow the curing of emulsions.

4. Effect on plants

Plastic emulsions are not generally toxic to plants even if sprayed directly on them. They commonly reduce establishment, however, and delay emergence of grass seedlings. Grass seedlings may have a tip burn. These problems are apparently the effect of fertilizer used with the emulsion and seed, rather than the emulsion itself, and are particularly a problem on sandy soils, and not on clay soils. Fertilizing separately, after seeds have germinated, has avoided the problem of fertilizer burn.

The most practical way so far of offsetting reduced seedling numbers has been to increase the seeding rate. Doubling the rate of Blando brome from 50 lb to 100 lb/acre has generally compensated for plant losses due to fertilizer, and sometimes resulted in an increase in numbers, ground cover, and pounds of grass growth. Wood fiber is an essential part of an emulsion treatment, particularly if seeds are used. PVA emulsions will not stick seed or fertilizer to a soil slope. Unless a fiber is added the seed and fertilizer will wash off readily. Do not apply fiber and seed after the emulsion, for they will wash off.

5. Other considerations

Freezing temperatures destroy all uncured emulsions. Biological activity also may limit the storage life of emulsions. Crusts formed by emulsions may shed most of the rainfall. Therefore they may limit plant establishment and growth in low rainfall areas and soils of low water-holding capacity. Crusts are not self-healing. The treated area must be protected from vehicles and animals, and breaks should be repaired. Crusts will not survive frost heaving. The emulsion could be used very effectively with transplanted shrubs. A soil-active herbicide could be used with them to provide a weed-free erosion control program.

SOIL AND ROCK MULCHES

Soil and rock mulches are often overlooked as the most practical solution to plant establishment and soil protection problems. The microsites created by rough seedbeds or rock provide seed coverage, separation of seed and fertilizer, and a mulch effect.

The importance of microsites to the establishment of plants was illustrated by Evans and Young (1972). In their Nevada study, seedling emergence and the growth of downy brome, medusahead, and tumblemustard were favored by seed burial, pitting of the soil surface, and soil movement. Air temperatures were continuously measured at the soil surface and 3 cm. above, and soil moisture from the surface to 1 cm. deep, and at 3 cm. Results showed that depressed sites retain moisture longer at the surface and have more favorable atmospheric moisture and temperature regimes than the flat soil surface. Conditions are also created for more adequate soil coverage of the seeds, which in turn further modified their environment.

A practical approach on steep slopes, such as highway cuts, is the use of benches, serrations, or simply rough grading. The rough effect can often be achieved by simply eliminating the final grading operation. Special pitting equipment is available for nearly-level sites. "Track walking" (walking a tractor on a slope to create cleat marks) is widespread and very effective.

Mulches of crushed stone or gravel one inch deep provided more effective erosion control than 4,000 lb/acre of straw, and heavier rates of stone were even more effective (Meyer et al., 1972). Field observations in Nevada and California also show a ground-cover of gravel to be effective for reducing wind and water erosion and encouraging invasion by indigenous plant species.

RELATIVE EFFECTIVENESS AND ECONOMICS

Mulching practices vary considerably in cost and effectiveness. Sometimes the characteristics of the site to be stabilized determine the only practical treatment. Usually, however, there are alternative methods which should be considered.

Seed coverage and mulch should be the first consideration. Seed germination and plant establishment will be improved more by seed coverage than by any other treatment. Mulch treatments increase in effectiveness with both the amount of mulch per acre and the length of the fiber. While it is possible to apply excessive amounts of mulch, economic considerations usually prevent it. The importance of fiber length, however, should not be overlooked. Increasing the fiber length (as from wood cellulose fiber to straw) may greatly increase the effectiveness of erosion control and germination (Kill et al., 1971; Perry et al., 1975). This relatively large increase in effectiveness can be achieved at little or no increase in cost. Even increasing the length of wood-cellulose fiber from a recycled paper product to virgin wood fiber improves results with little effect on cost. Table on page 19 (adapted from Kay, 1976) compares relative effectiveness and costs as observed on roadside erosion-control projects in California. Ranges of cost figures are based on conversations with contractors and review of California Department of Transportation contract bids (all bids, not just low bids) for the 1973-1975 period. Labor costs are at union scale.

The most expensive practice is not necessarily the most effective. For example, straw plus a tackifier is more effective for both erosion control and plant establishment than many of the more expensive treatments. A rough seedbed or covering the seed may be the cheapest and most effective treatment for establishing vegetation. **WTT**