Final Report

Research Project HR-155

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Research project HR-155 was initiated to study soil erosion problems along the secondary road system in Iowa and to find a substitute for straw for the control of soil erosion during the period of seed establishment. Accordingly, six field research sites were established to test the ability of commercial soil conditioners to control soil erosion. The six field research sites were selected (Figure 1) on the basis of terrain and type of soil material exposed on the cut-slope areas. The sites are described in Table 1 according to the regions delineated in Figure 1.

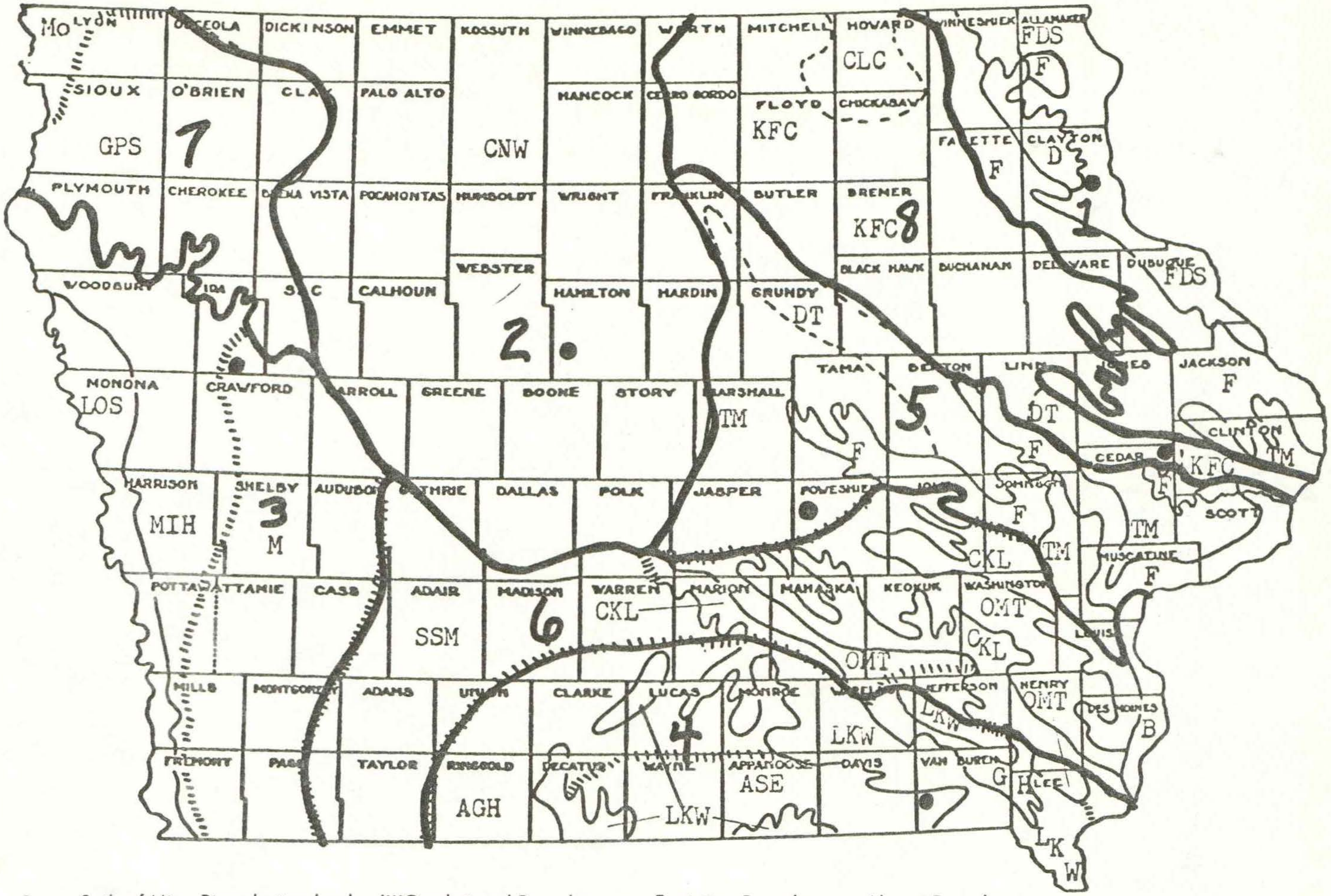
Table 1. Location and description of field research sites.

Region*	Field Research site location	Soil materials exposed
1	Clayton County south of Farmersburg	loess, glacial till, limestone residuum
2	Hamilton County 2 miles north of Stanhope	Cary glacial till
3	Ida County 6 miles south of Battle Creek	silty loess over calcareous till
4	Van Buren County 4 miles west of Lebanon	clayey loess over dense clayey glacial till
5	Poweshiek County 2 miles south of Grinnell	loess over Kansan glacial till
-	Cedar County 3 miles north of Massillon	eolian sand

*Regions are delineated on Figure 1.

These six sites cover the more extensively exposed subsoil material and also some of the more unfavorable soil materials in Iowa.

The materials exposed in areas 2 and 8 are principally clay loam glacial till. In area 2 most of the till material exposed in highway construction is calcareous. In area 8 many areas of shallow exposure are noncalcareous but are not strongly acid. The Hamilton County site is entirely in calcareous clay loam till.



B : Soils of Miss. River bottomland IIIIGradational Boundary — —Tentative Boundary—— Abrupt Boundary

AGH: Adair-Grundy-Hair
ASE: Adair-Seymour-Edina
CKL: Clinton-Keswick-Lindley
CLC: Cresco-Lourdes–Clyde
CNW: Clarion-Nicollet-Webster
D: Downs
DT: Dinsdale-Tama
F : Fayette
FDS: Fayette-Dubuque-Stonyland
GPS: Galva-Primghar-Sac
GH: Grundy-Haig
KFC: Kenyon-Floyd-Clyde
LKW: Lindley-Keswick-Weller
LOS: Luton-Onawa-Salix
M : Marshall
MIH: Monona-Ida-Hamburg
Mo: Moody
OMT: Otley-Mahaska-Taintor
SSM: Shelby-Sharpsburg-Macksburg
TM: Tama-Muscatine

• Field Research Sites

Figure 1. Soil Association Areas and Management Regions.

In western Iowa there are large areas in which silty calcareous loess is the principal material exposed in highway construction. However, in deep cuts clay loam glacial till, usually calcareous, is frequently encountered. The site in Ida County in region 3 is representative of these soil conditions and also is similar to conditions in area 7 in extreme northwest Iowa.

The next most extensive exposures are in southern Iowa where shallow weathered loess overlies highly weathered glacial till. Clay contents in this region are higher and soil fertility is lower than in the regions previously described. The Van Buren County site in region 4 is representative of this soil condition.

In northwest Iowa in region 1 there are extensive areas where silty loess mantles paleosols that are formed or highly weathered limestone and limestone residuum. Pockets and lenses of glacial till are also common in many roadside cuts. This combination of soil conditions occurs on the study site in Clayton County in region 1.

A somewhat similar set of soil conditions occurs on the study site in Poweshiek County in region 5. Here the road cut studied is noncalcareous silty loess over a moderately weathered paleosol formed on till.

These 5 study sites represent most of the range of soil conditions encountered on highway backslopes in Iowa. There are problems of vegetative extablishment on any of these materials but compared to problems encountered in other states, expecially in the eastern and southern United States, the problems of vegetative establishment are relatively minor. Satisfactory vegetative establishment is possible on any of these materials.

One of the more troublesome materials encountered along roads in Iowa are scattered sand deposits. These sand deposits present special problems of erosion control and stand establishment and were studied at the Cedar County site in region 8.

In addition to the 6 field sites, a laboratory study was made using the more effective polyvinyl alcohol (PVA) and polyacrylamide (PAM) chemicals as soil conditioners. Results for the field research sites except the Poweshiek site were reported previously and are attached as exhibit A. The laboratory and Poweshiek County results are given in exhibit B.

The PVA and PAM compounds studied effectively controlled erosion under average Iowa weather conditions during the seeding period where water did not run onto the slopes from adjoining fields. Under extremely high intensity rains, erosion will occur on the treated areas but erosion will usually be less on the treated than on the untreated areas.

The PVA and PAM compounds are no more effective than a properly applied straw mulch but are easier to apply and in some cases such as on very steep banks the chemical stabilizers can be used in areas where straw can not be properly applied. Cost of the PVA materials is about $200 per acre. The PAM material is not available at present. A summary of observations made at each experiment and erosion control recommendations by region are given in this report.

General Observations for Roadside Stabilization Along the Secondary Road Systems

For each of the field research sites, observations were made on seed and fertilizer applications, seedbed preparation, and general slope construction practices.

Seed and Fertilizer

Seed and fertilizer applications were made according to the State Highway Commission recommendations and were adequate at all experimental sites. The main factor is to apply good quality seed at recommended rates and to adequately fertilize the area.

Seedbed Preparation

Although no tillage experiments were made, it was apparent at all field sites that a good seedbed is a necessity. Ideally the soil should be cultivated to a depth of 4 to 6 inches to insure a good mellow seedbed in which the roots can develop. At the Clayton County experiment a ridged-surface seedbed was successful because the furows caught and held the seed until it had germinated. The seedbed should not be overtilled, since this causes complete breakdown of the soil structure which results in puddling of the soil and massive sheet erosion. It is desireable to have small clods 1 to 2 inches in diameter to maintain a porous soil surface.

Poor seedbed preparation is a major problem along the secondary road systems. Many counties have only disc and harrow implements to prepare the seedbed, but a disc is not always adequate. A Rome disc or larger implements may be needed in hard and dense soil materials.

Cut-slope Construction

Steepness of the cut-slope areas studied varied from 4:1 slopes at the Van Buren County site to 2:1 slopes at the Clayton County site. The 2:1 slopes are very difficult to work on especially in preparing the seedbed. The 2:1 or 2½:1 slopes were unstable when constructed on approximately 20 feet of loess overlying a more impermeable till material. Water is commonly perched on top of the impermeable till and a plane of failure exists in the loess above the loess-till contact. Therefore the 2:1 and 2½:1 slopes are likely to slip and slump if constructed in Regions 1, 5, 6 or 7 and precautions must be taken to stabilize these cut-slopes against slipping and slumping. It is recommended that 3:1 or gentler cut-slopes be used in these regions.

Runoff water from upslope farm fields commonly drained across cut-slope areas at the experimental sites and caused severe rill erosion on the cut-slopes. This could be prevented by diverting the runoff water from the cut-slope areas, which is required for adequate soil stabilization by the chemical soil conditioners. In many cases, cuts were made through natural drainage-ways without concrete chutes or drop inlet structures which are needed to control erosion in these situations.

General Recommendations

The following recommendations for erosion control are made from the results reported in Exhibit B. The chemical stabilizers, polyvinyl alcohol (PVA) and polyacrylamide (PAM), are applied with a hydroseeder. Both can be applied with the seed and PVA can be applied with both seed and fertilizer. They are applied as 2 percent solutions in approximately 1500 gals of water/ac for a 300 lb/ac application of the chemical and 1000 gals of water/ac for a 200 lb/ac application. The large quantities of water add to seeding expenses but are also advantageous since a more uniform seed application results and the salt effect of the fertilizers is greatly reduced.

The polyvinyl alcohols as described in exhibit B were obtained from the Dupont Company and the polyacrylamide was obtained from Cosden Chemical Company, Big Spring, Texas.

Recommendations by Regions

Regions 3, 5, 6, 7.

These regions have loess overlying glacial till. The loess ranges in thickness from 6 feet in Region 7 to more than 50 feet in Region 3. The loess materials are very erodible and require either chemical or straw mulch stabilization practices. According to the equations in Exhibit B, approximately 300 lbs/ac (336 kg/ha) of PVA or PAM is required to stabilize the loess in

Regions 3 and 7 and 250 to 300 lbs/ac in Regions 5 and 6. These rates are adequate for any glacial till material that is exposed in these regions.

In general, the loess, which is exposed in these regions, is easily tilled, but if glacial till is exposed a Rome disc or other special equipment may be needed to adequately prepare a seedbed.

Region 1

This region has loess material overlying either glacial till or limestone residuum. The loess in this region is stabilized with 300 lbs/ac PVA or PAM. The standard highway seed mixture was adequate in this region, however, very few legumes were established on the limestone residuum. This soil material at the Clayton County site was completely covered with the grasses in the seed mixture. The limestone residuum, unlike the loess, was resistant to water erosion, but required special equipment for seedbed preparation.

Region 4

Materials in this region are high in clay, acid at the surface, dense and hard to till. Approximately 6-9 feet of clayey weathered, loess overlies a dense, gray, clayey gumbotil material. Because of the high clay content 100 lbs/ac of PAM and 200 lbs/ac of PVA will stabilize these materials against soil erosion.

Good seedbed preparation is the major problem in this region due to the high clay and dense soil material. A scarifier was used to break the dense, gray gumbotil at the Van Buren County site. This gave a cloddy but loose seedbed. The clods broke down with subsequent rains and covered the seed, which resulted in a complete vegetative cover on the exposed subsoil materials. After three years of growth, the subsoil materials have as good as or better cover than areas where the topsoil was put back on the cut-slopes. The more neutral subsoil areas have equal growth of grasses and legumes while areas where the acid topsoil was replaced have little legume growth.

A lime experiment was also conducted at the Van Buren County site, but little difference was detected between the limed and unlimed plots. The limed areas appear to have more legume growth but the difference is negligible, therefore the application of lime is not necessary, especially if the topsoil is not replaced since subsoil materials below 4 feet approach a neutral pH.

Regions 2 and 8

Cut-slopes in these regions expose glacial till materials, Cary till in region 2 and eroded Kansan till in Region 8. These regions have relatively low relief as compared to the other regions, therefore cut-slopes are usually small in extent and are not severe and revegetation is simpler if the seedbed is adequately prepared and the soil materials are stabilized against soil erosion. Approximately 200 to 300 lbs/ac of PVA or PAM will stabilize these soil materials.

Sandy Soils

The Cedar County experiment was located on eolian sand materials along the Wapsipinicon River. Because of the severity of the seed environment, a straw mulch was used to lower surface temperatures and conserve soil moisture. The seed should be cultipacked into the soil before mulching with straw. The chemical stabilizers were not tested on sandy soil since they do not function well on materials of low clay content.

It is extremely important that runoff from upslope areas be diverted from the sandy cut-slopes to avoid severe rill and gully erosion. In many cases special precautions are needed to control runoff water from the road surface in order to prevent severe erosion of the fill-slope.

Summary

1. Soil erosion during the period of seedling establishment can be controlled on most cut-slopes along Iowa highways with 200 to 300 lbs/acre of the PVA and PAM chemical mulches during a season of average or less intensive rainfall. During periods of extremely high intensity rainfall the PVA and PAM chemicals will usually lessen erosion damage.
2. Seedling growth is usually more rapid and more uniform on treated than in untreated areas.
3. The chemicals (PVA and PAM) are inadequate for erosion control on areas where runoff from upslope areas runs across the cut-slopes.
4. Adequate fertilization, good seedbed preparation and timely operations are essential for the success of any seedings.
5. Slopes of greater than 3:1 are undesireable in any region but are extra troublesome in areas where an impermeable layer is exposed in the cut. In such areas slides commonly develop regardless of the success or failure of the seeding.
6. In Van Buren County where the road cut was in very dense gumbotil, replacing the silt loam surface on the back slope did not result in improve vegetative growth. Satisfactory vegetative cover was obtained both in the areas with and without surface soil.
7. At the Van Buren County site liming did not measureably effect plant growth. It is possible that all lime needs of plants was supplied in road dust from the graveled road.
8. The chemicals PVA and PAM are not recommended on sands.
9. With proper cultural practices in years of normal rainfall the PVA and PAM chemicals can be used, an adequate vegetative cover obtained and erosion controlled with a single seeding, fertilization and erosion control treatment.

Exhibit A

ROADSIDE EROSION RESEARCH IN SELECTED IOWA COUNTIES[1/]

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Stabilization of erosion on roadsides after construction is an essential part of highway building. Vegetation is usually the most economical and satisfactory stabilizing material. A period of not less than 6 weeks and as much as a year, however, may elapse between the time construction is completed and the time a live vegetative cover can be established. This period before the successful establishment of a living vegetative cover is a period of high erosion risk and of risk of severe damage to the environment.

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Iowa has an active roadside stabilization program along the interstate and primary road systems. Many studies have been conducted along these highways to investigate methods for soil erosion control before revegetation and to find the best seed mixtures and fertilizer rates. Roadside stabilization along secondary roads, however, is a recent development brought about, in part, by stronger Federal restrictions. Roadside stabilization along secondary roads presents special problems. These roads have smaller right-of-ways and, as a result, steeper backslopes than along the primary roads. Because of this, many practices, such as straw mulching, used to control erosion along the primary roads cannot be used on these steeper backslopes. Therefore, a research project was started to study these special problems along the county road system. Another objective of this study was to investigate various commercial soil stabilizers, as a replacement for straw mulch, to control soil erosion before revegetation.

Methods and Materials

Commercial equipment commonly owned or used by county highway departments was used in this study. Products tested had to conform to use of this equipment. Before any soil stabilizer is recommended for use, therefore, it must perform satisfactorily under these conditions. The soil stabilizer materials, seed, and fertilizer were applied with a hydroseeder. In Cedar County, a Finn Straw Mulcher was used to apply the tack along with the straw except for the 3M-XB2386 material where the tack was applied with a hydroseeder. In Van Buren County, the tack was applied with a hydroseeder. Proven seed mixtures and fertilizer rates were used in each study area. Study areas (County sites) were selected on the basis of terrain and type of soil material. A brief description of each site is given in Table 1 and located in Figure 1.

Table 1. Description of research sites

Site location	Time established	Soil material at the site	Backslope Slope (%)	Backslope Ave. length (meters)
Hamilton County	April, 1971	Clay loam glacial till	37 (2½:1)	3
Clayton County	June, 1971	Loess over limestone residum over limestone bedrock	45 (2:1)	9
Van Buren County[a]	Sept., 1971	Leached and weathered loess over dense clay glacial till	24 (4:1)	12
Cedar County	April, 1972	Eolian sand	45 (2:1)	9
Ida County	May, 1972	Thick silt loam loess	32 (3:1)	24

[a]Topsoil vs. no topsoil replacement also studied here.

The "stake method" was used to make erosion measurements. Stakes were driven into the soil, and the amount of surface erosion was measured from marks on the stakes. Fourteen stakes were placed at equal distances from the top of the backslope in each study area, and soil loss is reported as an average of these 14 values. Percentage cover was estimated by randomly tossing a 50 cm x 50 cm quadrat and estimating the percentage cover of grasses and legumes. An average of four readings per plot is reported.

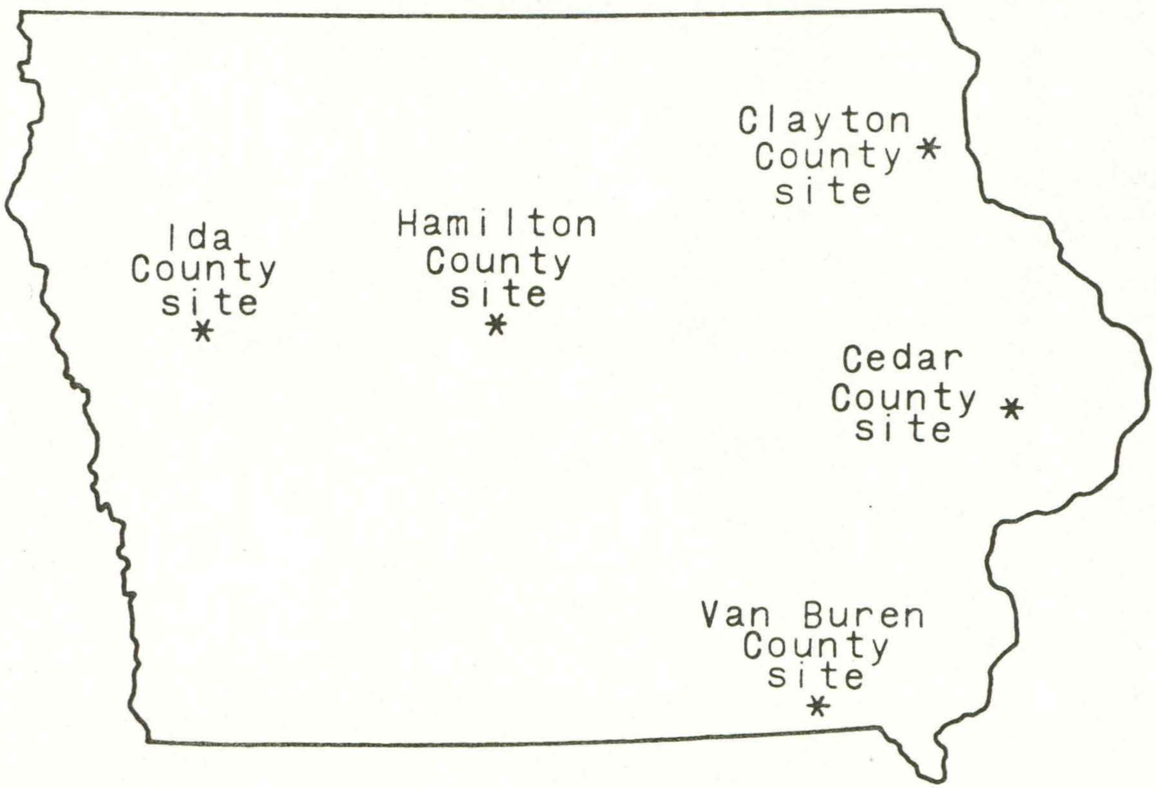

Figure 1. Location of county sites

The various materials tested include Aquatain, Curasol AE, Conwed, Petroset SB, Conwed + Curasol AH, Terra Tack, 3M-XB2386, 3M-XB2386 + Conwed, Aerospray 70, and Polyvinyl alcohol (PVA).[2/] Studies also were made on straw alone, straw mechanically tied down, and straw tacked with 3M-XB2386, Petroset, Aerospray-70, Terra Tack and Asphalt. Recommended rates for all materials were used. A brief description of the materials as well as the areas in which each material was tested, are given in Table 2.

Results

All results are for backslope areas.

Hamilton County Site. Seeding of the Hamilton Country Site was completed on April 24, 1971. Normally May is a period of frequent and abundant rain, but in 1971, rainfall in May (Figure 2) was only 7.6 cm, some 3 cm below normal, and the first large rain did not come until 2 months after seeding. As a result of drouth, all seedings on all treatments were essentially failures.

Soil loss data and percentage cover data are presented in Figures 2 and 3, respectively. These measurements were taken on July 23, 1971, 3 months after seeding.

Soil loss was greatest on the straw-treated areas and least on the Conwed treatments. The straw was not tied into the soil because of the steepness of the backslopes and was blown away within hours after application (Figure 4). Both the Conwed and straw areas had the

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[2/]Mention of a commercial product or firm does not consitute endorsement by Iowa State University or cooperating agencies, nor is criticism implied of commercial products or firms not mentioned.

Table 2. Soil stabilizer treatments and areas applied

Name	Chemical composition	Recommended amount/ hectare	Water needed /hectare (hectoliters)	Area(s) applied	Manufacturer
Aerospray-70	polyvinylacetate copolymer	470 1[a]	100	Ida County	American Cyanamid
Aquatain	sodium polypectate, glycerin & ammonia	1200 1	100	Hamilton County	Larutan
Conwed	wood fiber mulch	1700 Kg	400	Hamilton, Clayton, Van Buren, & Ida Counties	Conwed Corporation
Conwed +	wood fiber	1700 Kg	400	Clayton County	Conwed Corp.
Curasol AH	polyvinylacetate copolymer	370 1			American Hoechst Corp.
Curasol AE	polyvinylacetate copolymer	570 1	300	Hamilton & Clayton Cos.	American Hoechst Corp.
Petroset SB	rubber emulsion	1200 1	200	Clayton County	Phillips Petroleum Co.
PVA	polyvinyl alcohol	220 Kg	100	Ida County	E.I. duPont de Nemours

[a] 1 = liters.

Table 2. Continued.

Name	Chemical composition	Recommended amount/ hectare	Water needed /hectare (hectoliters)	Area(s) applied	Manufacturer
Terra Tack	polysaccaride	56 Kg	200	Clayton County	Grass Growers Inc.
3M-XB2386	unknown	730 Kg	100	Ida County	Minnesota Mining & Manufacture
3M-XB2386 + Conwed	unknown wood fiber	490 Kg 660 Kg	100	Ida County	Minnesota Mining & Manufacture Conwed Corp.
The following are the chemicals used as a tack with 3.5 metric ton of straw per hectare.					
Aerospray-70	polyvinylacetate copoloymer	370 1	20	Cedar County	American Cyanamid
Asphalt	cationic emulsion	2700 1	None	Cedar County	----
Petroset SB	rubber emulsion	590 1	20	Cedar County	Phillips Petroleum Co.
Terra Tack	polysaccaride	56 Kg	200	Van Buren County	Grass Growers Inc.
Straw alone		3.5 metric tons	--	Hamilton County	
Straw mechanically tied down		3.5 metric tons	--	Van Buren County	
3M-XB2386	unknown	490 Kg	100	Cedar County	Minnesota Mining & Manufacture

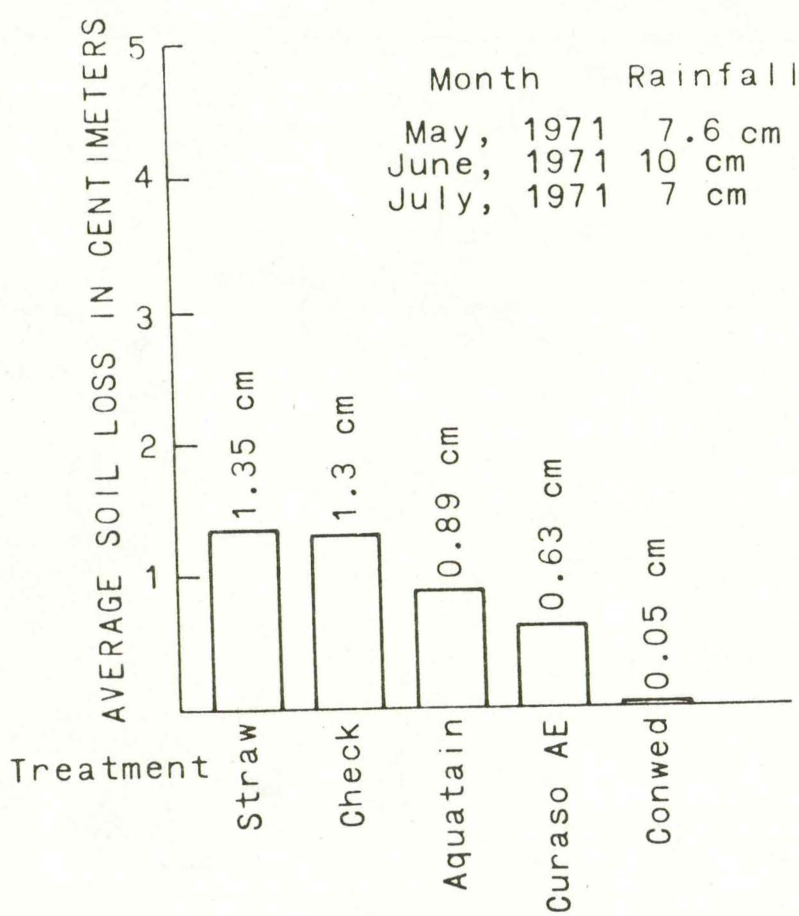

Figure 2. Soil loss and monthly rainfall at the Hamilton County site

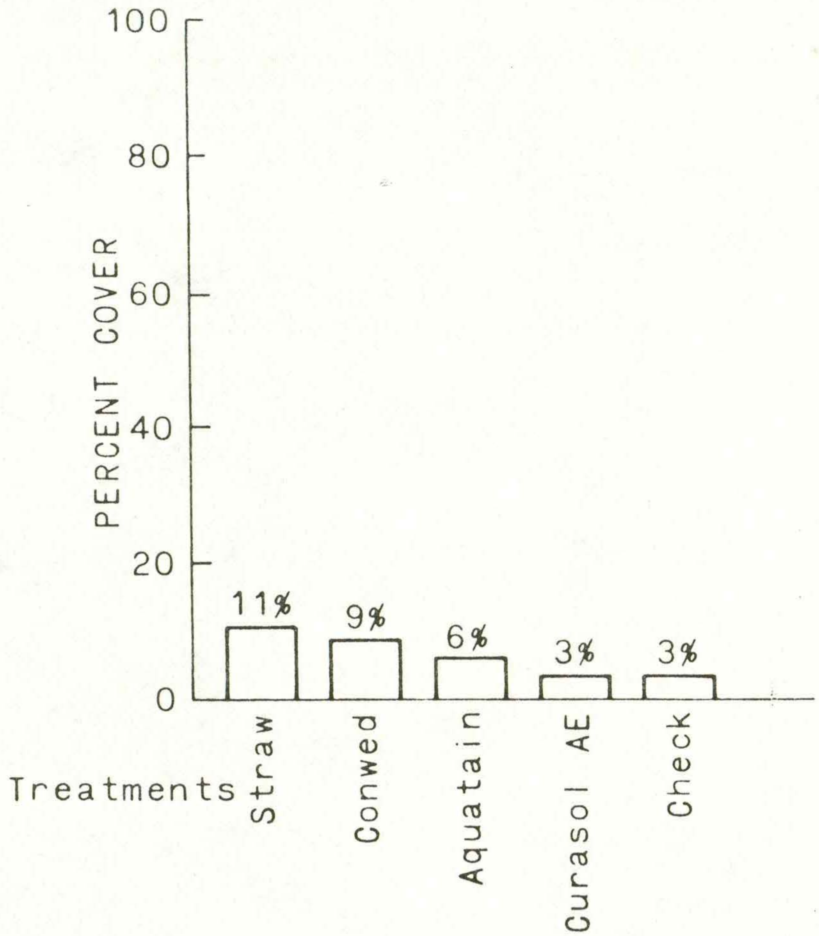

Figure 3. Cover at the Hamilton County site

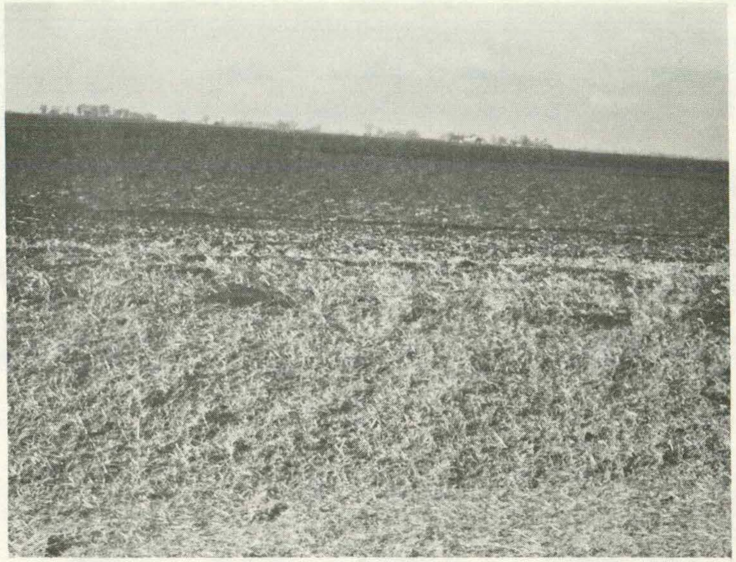

Figure 4a. Effect of wind on straw not anchored in Hamilton County at time of application

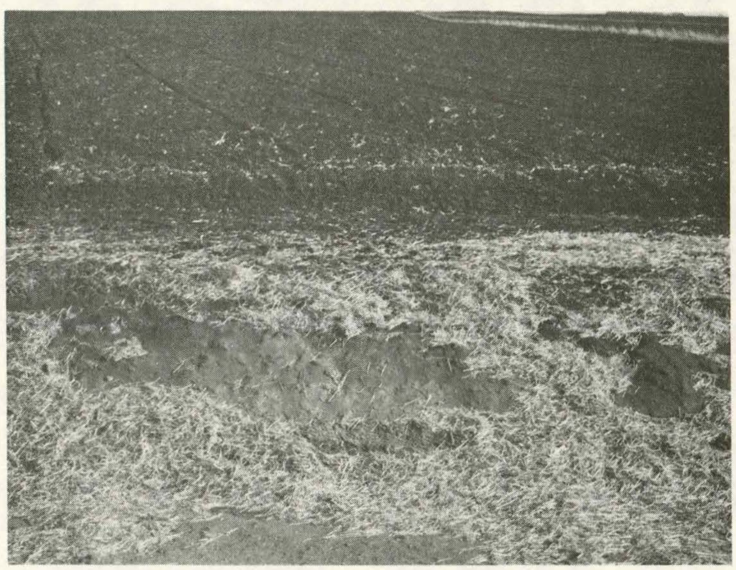

Figure 4b. Effect of wind on straw not anchored in Hamilton County 24 hours after application

greatest amount of cover, about 10%, which is extremely low for 3 months after seeding. The estimation of cover on the straw-treated plots is biased upward because measurements were made on the few areas on which some straw remained on the plots, and the areas from which straw had blown away were essentially bare of vegetation.

Because of abnormally dry conditions at this site during the seeding year, the results obtained are of limited predictive value. The study indicates that high rates of erosion occur on these soil materials when there is appreciable rainfall or when the backslopes are incompletely vegetated or inadequately mulched.

In 1972, a year of about normal rainfall, a satisfactory stand was obtained over all treatments with an additional overseeding in the spring of 1972 but without further treatments.

Clayton County Site. Seeding was completed June 10, 1971. Rain fell soon after seeding; moisture was adequate for rapid germination, and seedlings started to emerge within about 10 days.

As is shown in Figure 5, there were large differences in erosion between treatments. Erosion, however, was excessive on all plots. The lowest rate was 147 metric tons per hectare on the Curasol AE treatment. As is shown in Figure 6, the Conwed, Curasol AE, and Conwed + Curasol AH treatments had better vegetative cover and more uniform growth than the other treatments. This cover difference was more pronounced in July than it was in late summer. The Petroset SB treatment seemed to inhibit

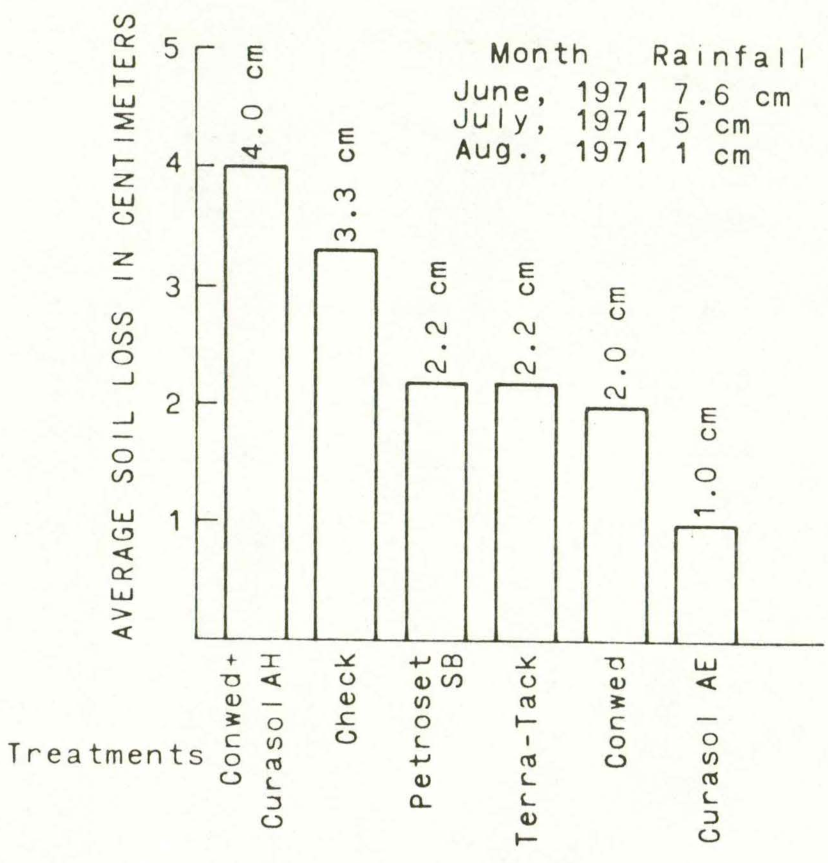

Figure 5. Soil loss and monthly rainfall at the Clayton County site

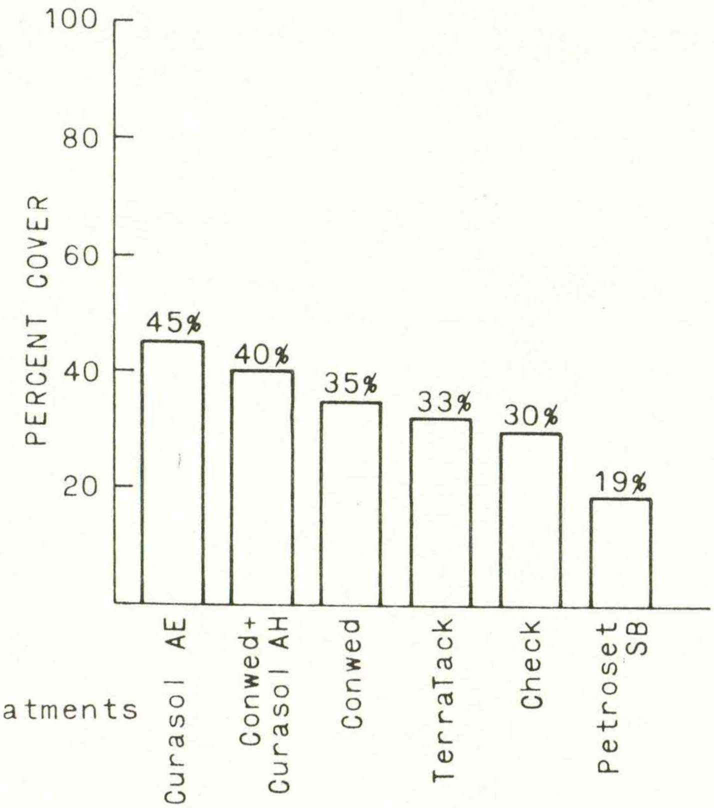

Figure 6. Cover at the Clayton County site

growth or germination of seeds when sprayed along with the seeds (Figure 7).[3/] This project was overseeded in the spring of 1972, and satisfactory cover was obtained on all plots.

This study indicated that several of the materials studied had an effect on soil losses and on seedling establishment but none could furnish adequate protection from high intensity rain before seed germination.

Van Buren County Site. This experiment was established during the first week of September, 1971. Weather at time of seeding was dry, and the subsoil, which is a very dense clay, was very hard and cloddy.

Soon after seeding several light rains fell that were adequate for germination but did not produce much runoff. By late November, when the ground froze, a vigorous plant growth was established on all plots.

Soil-erosion measurements, made on May 5, 1972, and percentage of cover, measured on June 2, 1972, are presented in Figures 8 and 9, respectively. Soil loss for each treatment is an average over both the topsoil and no-topsoil areas. Erosion was much less than at other sites, but as is shown in Figure 8, it was influenced by treatment. The untreated plots and the Conwed-treated plots had approximately 3 times as much erosion as the straw-mulched plots. Backslopes at this site are on a 4 to 1 slope, and the mulch for the straw treatment was disced into the soil.

[3/] The toxicity of Petroset SB applied directly to the seeds was confirmed in a greenhouse study.

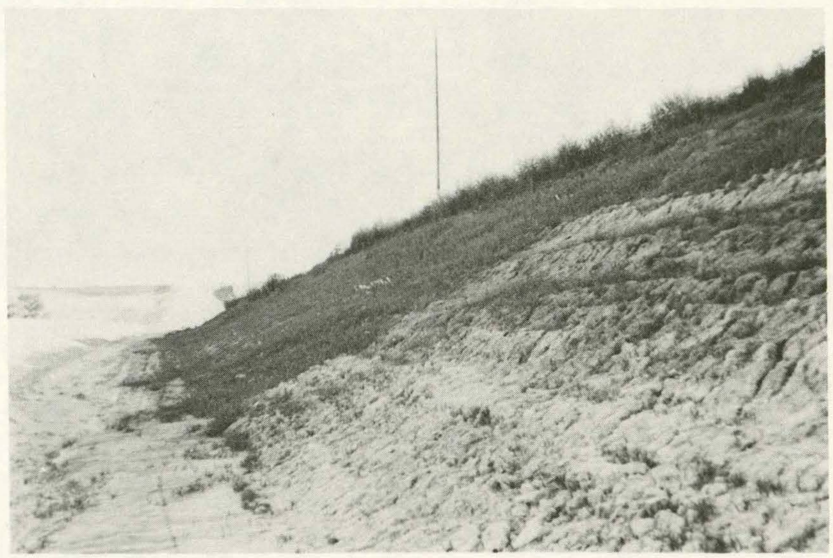

Figure 7. Comparison of Petroset SB in the foreground with Conwed + Curasol AH in background (Clayton Co. site)

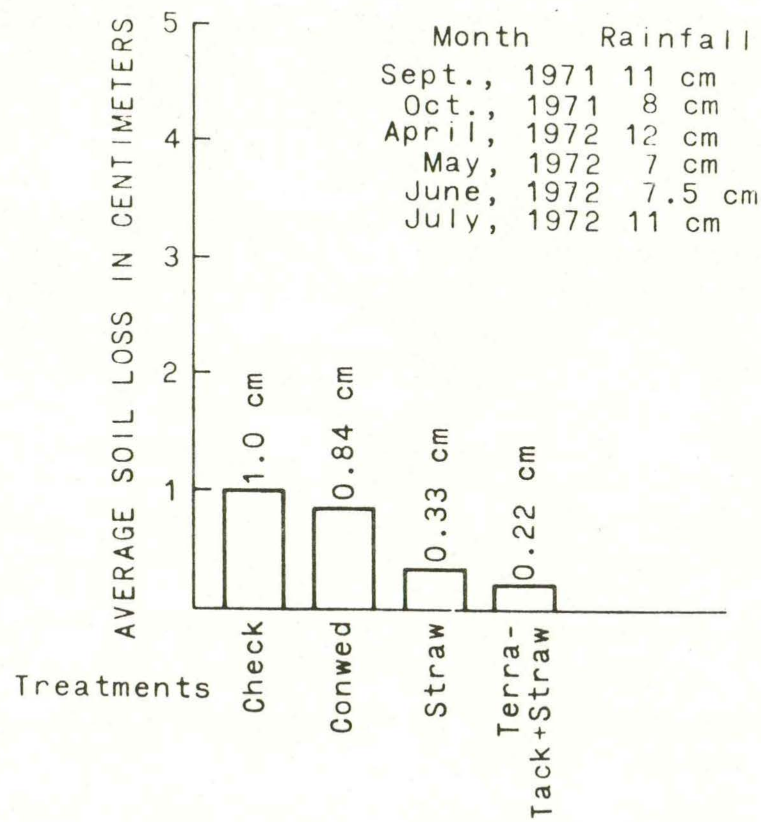

Figure 8. Soil loss and monthly rainfall at the Van Buren County site

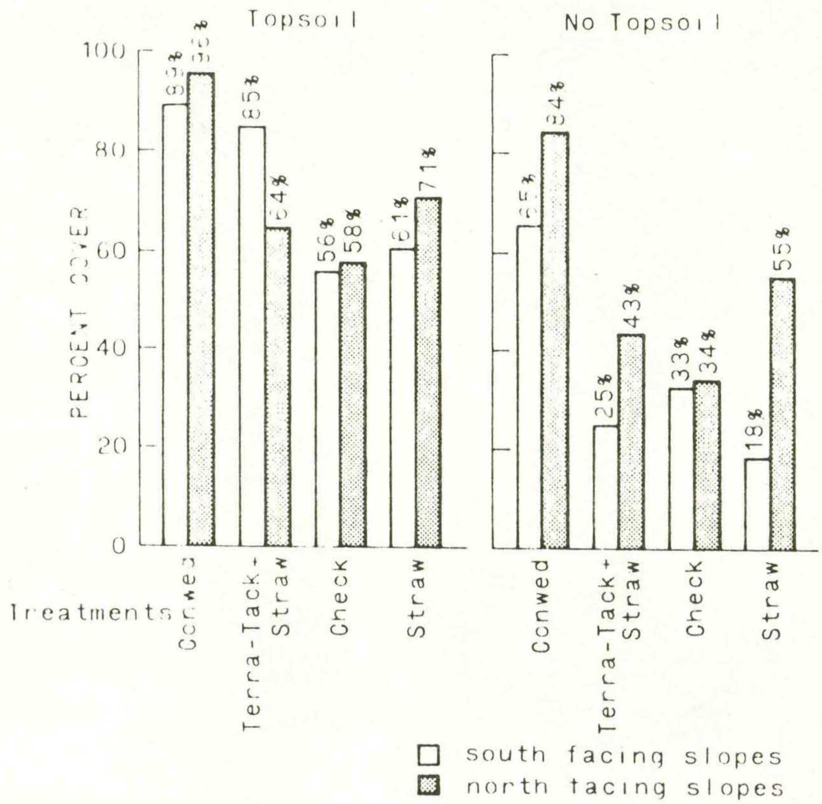

Figure 9. Cover at the Van Buren County site

The Terra Tack treatment, which was to be applied to the straw mulch, was a failure because the hydroseeder could not pump the Terra Tack solution. In this test, the Terra Tack solution was supposed to hold the straw in place so that straw could be used in areas where it could not be tilled into the soil. Because of gentle backslopes, abundant gentle rains, and lack of strong winds during the germination period, the straw, even though not disced in, remained in place, and the treatment had very little erosion. This study indicates that straw is effective in controlling erosion if it can be kept in place, even though not anchored into the soil.

The Conwed mulch did not control erosion, but its use resulted in the greatest and most uniform cover on both the topsoil and no-topsoil areas. Within the topsoil and no-topsoil areas, there were two replications, one on the south-facing backslope and one on the north-facing backslope. The slope aspect did not affect cover on the topsoil areas as much as on the no-topsoil areas (Figure 9). The Conwed treatment was the only one that resulted in an effective vegetative cover on the south-facing no-topsoil area early in the spring. Note in Figure 9 that cover values for the no-topsoil Conwed treatment compare favorably with cover values for all treatments on the topsoil areas. The south-facing straw areas with initially sparse cover are now, approximately 9 months after seeding, completely covered with the legumes seeded.

To summarize, the straw treatments controlled erosion, and the Conwed treatments gave the best cover. Averaging over-all treatments, the topsoil areas had better cover than the no-topsoil areas. This difference is more pronounced on the south-facing slopes and on the straw-treated areas.

Cedar County Site. Percentage of cover data measured Aug. 18, 1972, are presented in Figure 10. Although rainfall was plentiful after seeding (Figure 10), it was gentle and not erosive. Therefore, little soil erosion was detected. Cover is sparse for all treatments except the straw + Petroset treatment at this site. The 3M-XB2386 treatment areas have very little cover, which indicates that the product might restrict germination. The seed was sprayed on the surface and not covered with soil because of the steepness of the backslope. The 3M-XB2386 product seems to create a less dense layer, approximately 1 cm thick, which may hinder germination by creating a drier environment for the seeds.

Ida County Site. Soil loss measured June 23, 1972, and percentage of cover measurements from Aug. 1, 1972 are presented in Figures 11 and 12, respectively. Rainfall again was plentiful at this site after seeding (Figure 12), with the area receiving a high intensity 9 cm rain approximately 2 weeks after seeding. Soil erosion, therefore, was great for all treatments. There are apparent differences between treatments, but no treatment effectively controlled erosion. The largest difference is in cover measurements with only the PVA-treated area adequately covered. The PVA treatment seemed to prevent surface seal and allowed a good environment for germination of the seeds (Figure 13). The Conwed treatment was next in cover, with all the other treated areas very low in cover. Further studies with PVA are in process at this site.

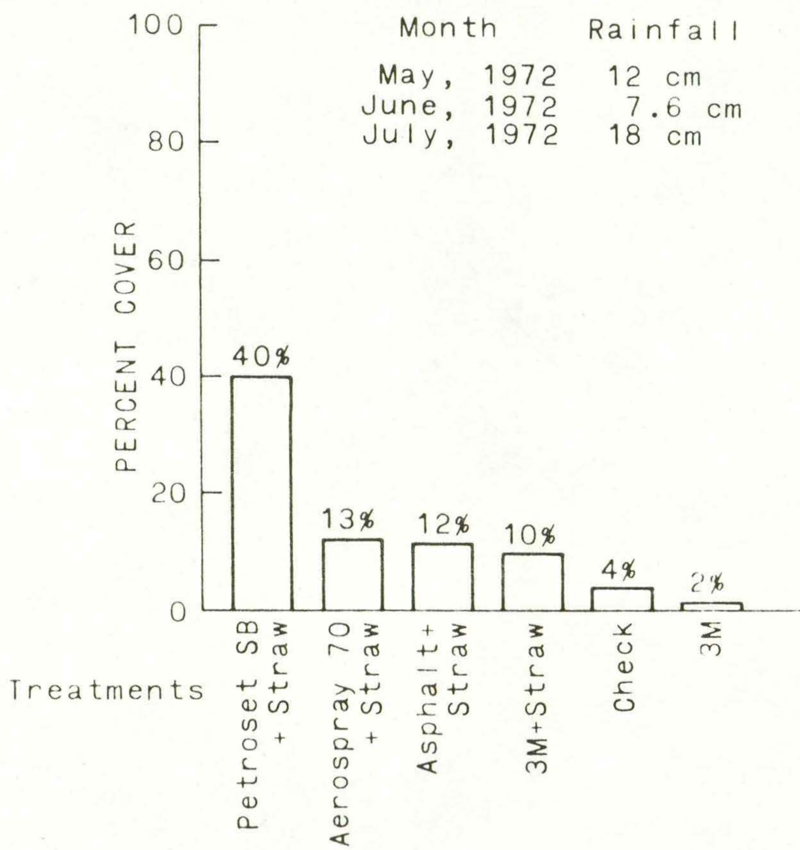

Figure 10. Cover and monthly rainfall at the Cedar County site

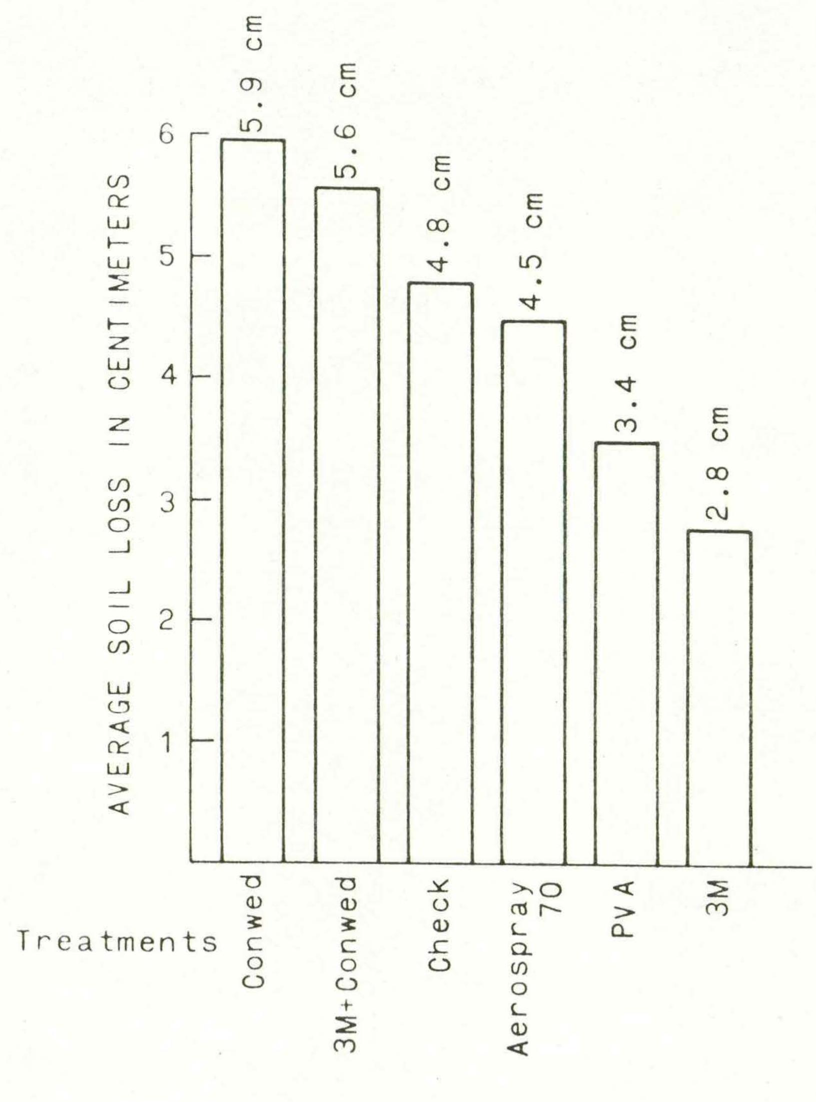

Figure 11. Soil loss at the Ida County site

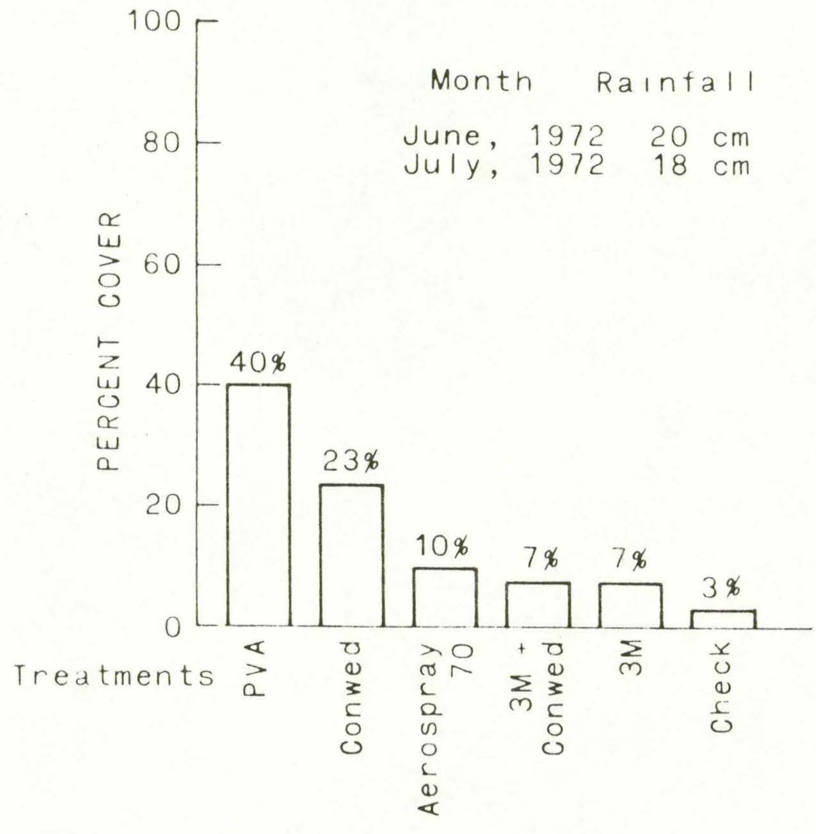

Figure 12. Cover and monthly rainfall at the Ida County site

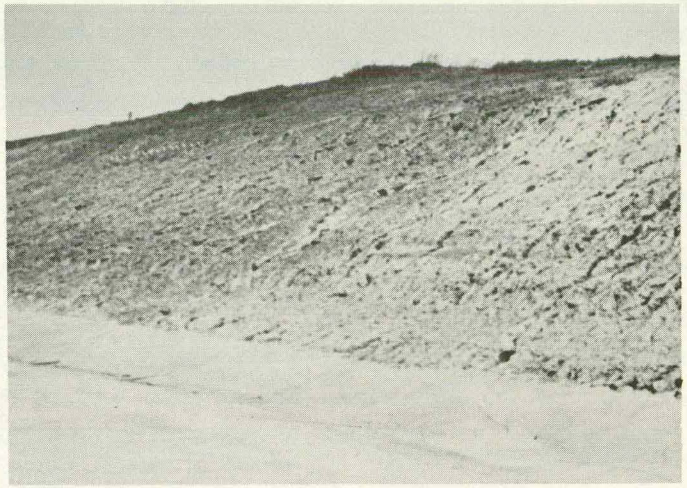

Figure 13a. Comparison of PVA with Aerospray-70, Ida County site -- soil surface difference of PVA in background and Aerospray-70 in foreground

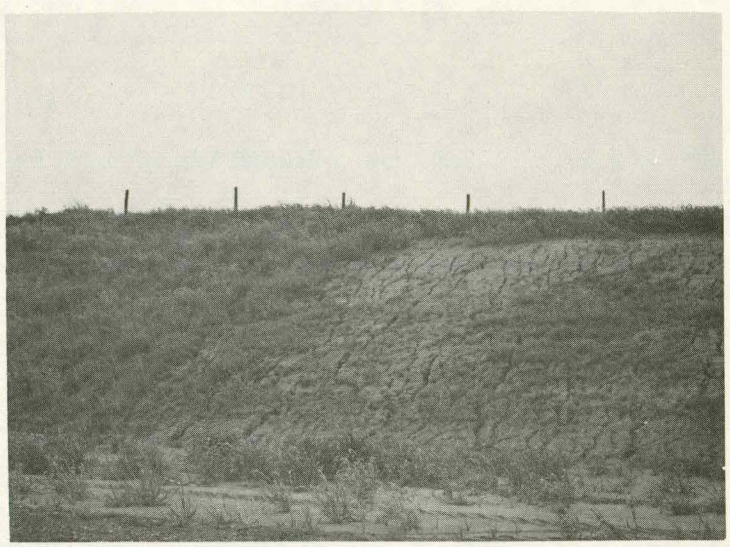

Figure 13b. Comparison of PVA with Aerospray-70, Ida County site -- vegetation difference of PVA on the left and Aerospray-70 on the right

Discussion

At the five sites studied, none of the chemical stabilizers was completely satisfactory. A discussion follows concerning the ability of the soil stabilizers to control erosion, promote plant growth, and stabilize or tack straw. Costs of the various materials that show promise also are discussed.

No soil stabilizer studied controlled erosion as well as the standard straw mulch. In Ida County, where a very intense rain of infrequent occurance fell, the PVA treatment prevented surface seal (Figure 13), which precedes runoff and erosion. Rill erosion resulted because rainfall exceeded the infiltration capacity of the soil. Perhaps, under more normal conditions, this treatment may control erosion. It was effective in preventing erosion in laboratory studies.[4/] The 3M-XB2386 soil stabilizer also was studied at the Ida County site. It did not control erosion, but there are doubts over the quality of the 3M-XB2386 material used at this study site. Consequently, it will be retested when production problems are solved. None of the other soil stabilizers studied showed promise for the control of soil erosion, or even the prevention of surface sealing.

The Conwed treatment consistently gave even, vigorous stands of vegetation, but did not effectively control erosion. The wood fiber material provided for an even distribution of the seeds and retained

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[4/] F. J. Blavia, W. C. Moldenhauer, and D. E. Law. Materials for stabilizing surface clods of cropped soils. Soil Sci. Soc. Amer. Proc. 35: 119-122. 1971.

moisture long enough for the seeds to germinate. It has the added advantage that more water is needed for application (see Table 2), which may relieve some of the salt effect of the fertilizers on seed germination. Other treatments that required large quantities of water, however, such as Curasol AE and Aerospray-70, did not consistently affect ground cover.

The PVA treatment also gave a satisfactory cover at the Ida County site. This is mainly a result of surface seal prevention. The soil in these areas remained in the same aggregated state as the original seed bed. Petroset SB and 3M-XB2386 stabilizers seemed to inhibit plant growth in these studies. The solvents used in the Petroset SB stabilizer are toxic when applied directly to the seed. Because of this, Petroset SB should not be applied along with the seed or directly on top of the seed. The Phillips Petroleum Company has a new Petroset, which is not toxic, but it has not been tested in this study. The 3M material is not toxic, but created a surface layer about 1 cm thick that is less dense than the underlying material. This layer may dry rapidly, thus preventing germination, expecially at the sandy, Cedar County site.

The PVA material costs approximately \$170-220 per hectare; the 3M material costs approximately \$1600 per hectare. Both materials use approximately 100 hectoliters H_2O per hectare and require a hydroseeder. At present, the cost of the 3M material is prohibitive, but if it does stabilize the soil it may be adaptable to small areas with severe erosion hazards. The cost of the PVA material compares favorably with the cost of straw when added costs of application of the straw are included. The cost of the Conwed material is approximately $270 per hectare, but this material requires four times as much water as the PVA material. Total estimated costs of application run as high as $570 per hectare for the Conwed, $370 per hectare for PVA, and $470 per hectare for the straw. These figures include seed and fertilizer plus equipment rental and labor.

All the chemicalstested for tacking straw deteriorate in a short time, with the exception of the asphalt emulsion and the 3M-XB2386 material. However, all chemicals in our study, except Terra Tack, which could not be pumped because of improper solution, seemed to tie the straw down and prevent soil erosion. More study is needed since few erosive rains fell on these experiments with straw. Applying the chemical tack with a hydroseeder resulted in a more even application than with the Finn mulcher. Aerospray-70, Petroset SB, and Terra Tack all cost approximately $240 per hectare for the material needed to tack the straw. The cost of the 3M-XB2386 material is $1100 per hectare, which is prohibitive at present.

Summary

Nine soil stabilizer materials and various combinations of these materials were studied in five counties along the secondary road system in Iowa. These materials were Aerospray-70, Aquatain, Asphalt emulsion

(cationic), Conwed, Curasol AE and AH, Petroset SB, PVA, Terra Tack, and 3M-XB2386. Five of these, 3M-XB2386, Aerospray-70, Asphalt emulsion, Petroset SB, and Terra Tack, were applied as a tack on straw.

The study indicated that the PVA material has the greatest potential for both preventing soil erosion and promoting a good stand of vegetation. Costs of this material compare favorably with the costs of straw mulching. Other materials did not consistently control erosion satisfactorily in this study, but may be useful under different conditions. Slopes in this study were very steep, which gave a severe test for the soil stabilizers.

Although the Conwed material was inconsistent in controlling erosion, it did give consistently better cover when compared with both the other soil stabilizers in the study and the check treatment. This material, therefore, may be useful in establishing a good stand of vegetation.

All materials tested as a tack for straw helped to hold the straw in place and may provide a substitute for asphalt on these steep slopes. A hydroseeder is the best means of applying the tack.

Although present estimated costs of the 3M-XB2386 material are prohibitive, further studies are planned using this material. It seems to have the strength to resist soil erosion and may be useful for erosion control where the erosion hazard is severe. Further testing should also indicate whether the material indeed retards seed germination.

Exhibit B

Influence of Surface Treatment of Selected Subsoil Materials on Infiltration and Erosion[1/]

M. J. Mausbach and W. D. Shrader[2/]

ABSTRACT

Two polyvinyl alcohols (PVA) and a polyacrylamide (PAM) were applied to Iowa subsoil clods for rainfall simulation and field tests of their effectiveness at three rates in controlling surface seal and erosion caused by rainfall. Rainfall-simulator tests showed that energy required to initiate runoff (ENTOR) was much greater on treated clods than on untreated clods. PVA and PAM polymers were most effective on subsoils which contained 30 percent clay. More polymer was required on soils with more or less than 30 percent clay. The measurement, energy required to reach 6.5 cm/hr infiltration capacity (ENT065),was a good indication of response of the polymer under field conditions. The polymers controlled sheet erosion at the field experiments,but did

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[2/] Formerly Research Associate, Iowa State Univ., now Soil Scientist USDA Soil Conservation Service, Huron, S. Dak., and Professor of Agronomy, Iowa State University.

not control rill erosion that resulted from runoff water from upslope fields. Prediction equations were developed for the polymers with rate and percentage clay as independent variables and ENT065 as the dependent variable. These equations were used for obtaining rate of polymer required to maintain an 6.5 cm/hr infiltration capacity for subsoil materials under field conditions.

Additional Key Words: Chemical soil stabilization, soil conditioners, soil erosion, raindrop erosion, surface sealing

Influence of Surface Treatment of Selected Subsoil
Materials on Infiltration and Erosion

Erosion during seedling establishment remains a serious problem on backslopes along highways. Straw mulches are frequently used to control erosion, but are not completely satisfactory, are expensive, are not always available, and in some instances, cannot be used because of slope steepness. Thus, there is continued interest in chemical soil conditioners that might be used as replacement for straw on newly seeded highway backslopes.

A series of field and laboratory studies indicated that 3 commercially available materials of a dozen or so tested were effective enough to warrant further study. This study is a report of laboratory and field tests of these 3, which include 2 different polyvinyl alcohols and a polyacrylamide (PAM) polymer.

In recent studies on Iowa surface clods, Blavia, Moldenhauer, and Law (1971) and Gabriels, Moldenhauer and Kirkham (1973) have shown that polyvinyl alcohol (PVA) and polyacrylamide (PAM) polymers effectively stabilize surface clods against rainfall energy received between a vegetative seeding and a complete cover from the seeding. Wang and Lin (1967) found that PVA reduced dispersion ratios and was more effective than either organic matter or calcium carbonate as a soil conditioner. Dowdy (1972) found that PVA substantially increased tensile strength of calcium-saturated montmorillonite systems.

Subsoils have less organic matter and more massive structure than most surface soils. The earlier studies with surface materials are not completely applicable to the subsoil material exposed during highway construction. Therefore,a rainfall-simulator and field study of the two PVA polymers and of a PAM polymer were made to test their effectiveness in stabilizing subsoil materials commonly exposed during road construction.

Prediction equations were developed to estimate amounts of each polymer required to stabilize soil materials of various clay contents against breakdown under average rainfall energies during seedling establishment. The prediction equations were developed from rainfall-simulator results and tested with the field study.

Materials and Experimental Procedures

Soils

Clods 12 mm to 22 mm in size were collected according to the method of Moldenhauer (1965) and Blavia et al. (1971). Clods were obtained from the following subsoil materials: loess material from the Marshall soil association, Marshall C horizon; the Shelby-Sharpsburg-Macksburg soil association, Sharpsburg B horizon; and the Grundy-Haig soil association, Belinda B horizon (Oschwald et al., 1965); and from Kansan and Cary till subsoils. Sample sites for these materials are given in table 1. These subsoil materials represent a majority of the soil material commonly exposed during road construction in Iowa. The three loess subsoils range from 24 percent to 47 percent clay (table 1). Clay content, pH,and apparent density of the clods are given in table 1.

The field experiment is in the Tama-Muscatine soil association in Poweshiek County, Iowa. Loess and Kansan till materials are exposed on the cut-slopes at this site. The slopes were constructed on a 45-percent grade,and the loess had an average of 25 percent clay content (T. E. Fenton, personal communication) at the field site.

Polymers

The PVA polymers, Elvanol 71-30 and Elvanol 72-60[1/], are commercial products obtained from Du Pont in 6-percent aqueous solutions. Evanol 71-30 is fully hydrolyzed, has an average molecular weight of 114,000, and is a medium-chain polymer. The fully hydrolyzed Elvanol 72-60 polymer has an average molecular weight of 134,000 and is a long chain polymer. PAM was obtained from Cosden Chemical Company, Big Spring, Texas, as an 8-percent aqueous solution. The PAM polymer was cross-linked with a special agent before application.

The polymers were sprayed onto the air-dried clods with a paint sprayer for the rainfall-simulator laboratory study and applied with a

[1/]Mention of a commercial product or firm does not constitute endorsement by Iowa State University or cooperating agencies, nor is criticism implied of commercial products or firms not mentioned.

hydraulic seeder in the field study. Three rates, 112 kg/ha, 224 kg/ha, and 336 kg/ha (coded 1, 2, and 3, respectively) were applied to the surface of the clod beds for the laboratory study. The 112 kg/ha rate was applied as a 1-percent solution,and the 224 kg/ha and 336 kg/ha rates as 2-percent solutions for the rainfall simulator study. The 336 kg/ha rate was applied in the equivalent of 150 hl water/ha (2-percent solution) in the field study.

Experimental Procedures

The Adams, Kirkham and Nielsen (1957) portable rainfall simulator, as modified by Moldenhauer and Kemper (1969), was used for the rainfall-simulator study. Clods were placed in metal pans,10 cm square,to a depth of 4 cm over 7 cm of sand according to the procedure of Blavia et al. (1971). The pans were tilted to a 9-percent slope. Simulated rain was applied at an intensity of 10-12 cm/hr,and rainfall energy was calculated from raindrop velocity data of Laws (1941) for the 5 mm diameter drop size as determined by Moldenhauer and Kemper (1969). Results are reported as energy to initiate runoff (ENTOR), energy required to reach an infiltration capacity of 6.5 cm/hr (ENT065),and soil loss after 0.15 joules/cm^2 of rainfall energy (ST015). Energy required to initiate runoff represents the point where the clods have broken down and infiltration capacity is less than rainfall intensity; energy required to reach 6.5 cm/hr infiltration capacity was chosen as a parameter because this is the average rainfall intensity in Iowa

(U. S. Department of Commerce, 1955, p. 15); therefore, it represents the point of runoff in average field conditions, and the parameter ST015 represents soil loss under normal spring rainfall amounts and intensities. These parameters were calculated from total runoff and soil loss collected at 5 minute intervals after runoff began. The rainfall simulator tests were duplicated, and means of the duplicates are reported.

The field experiment was started in spring, 1973. The polymers were applied immediately after the plot areas were fertilized and seeded at recommended rates. Soil loss was measured by the "stake method" in which 14- to 26-cm stakes were driven 12 cm into the soil to a mark and placed 30 cm apart. Soil loss is the mean depth of surface material lost as measured on the stakes.

Table 1. Physical properties of soil clods

Soil	Clay	Cosi*	Fisi+	Sand	Apparent‡ density	pH	Sampling site
	percent						
Marshall C horizon	24.0	42.9	30.8	2.3	1.41	6.1	Ida County
Sharpsburg B horizon	33.0	33.1	32.1	1.5	1.36	6.3	Madison Co.
Belinda B horizon	47.0	20.4	32.0	0.7	1.55	5.2	Van Buren Co.
Cary till	25.7	15.2	21.5	37.6	1.60	7.5	Hamilton Co.
Kansan till	31.8	34.8	19.9	13.5	1.67	7.4	Madison Co.

*Cosi = coarse silt 0.050 - 0.020 mm

+Fisi = fine silt 0.020 - 0.002 mm

‡Apparent density determined by method of McIntyre and Stirk (1954).

Results

The rainfall simulator results are given in Tables 2, 3,and 4 for ENT065, ENTOR,and ST015, respectively. Energy required to initiate runoff and energy required to reach 6.5 cm/hr infiltration capacity for the clods treated with polymer of the lowest rate are approximately double that of the untreated clods. In general, successively higher rates are significantly more effective than the lower rates, and rate 3 gives the highest ENTOR and ENT065 and lowest soil loss for each polymer. The PAM polymer is significantly better than the PVA polymers for increasing rainfall energy required to initiate runoff and rainfall energy required to reach 6.5 cm/hr infiltration rate and for reducing soil loss on the loess subsoils. The reverse is true for the Kansan and Cary till soils,except that control of soil loss is equal for all polymers on the Cary till material.

The ENTOR variable and clay content of the loess materials are compared in Figs. 1-3 for the PVA 71-30, PVA 72-60,and PAM polymers, respectively. At all rates, ENTOR increases sharply with an increase from 24 to 33 percent clay content for all polymers. With a further increase to 47 percent clay, ENTOR decreases slightly at rate 1 for all polymers. At rates 2 and 3 for PVA 71-30 and PAM polymers, ENTOR increased when the clay content was increased from 33 to 47 percent.

Soil loss measurements taken 3 weeks after seeding at the Poweshiek experiment are given in Table 5. The area received 10 cm of rain (0.05

joules of energy) in this 3 week period. The north-facing PVA 71-30 plot had the greatest amount of soil loss when compared with both the treated and untreated plot areas. All other treated areas had no detectable soil loss. The north-facing PVA plot received runoff water from an upslope farm field that caused severe rill erosion on this plot.

The treated plots successfully stabilized the surface clods and prevented surface crusting, but untreated plots had complete surface crusts. This is shown in plates 1 and 2 where the rough-appearing surface (plate 1) is stabilized and the smooth-appearing surface (plate 2) has a complete surface crust.

Discussion

The rainfall simulator variables, ENTOR, ENT065, and ST015,are highly intercorrelated with correlation coefficients of 0.90 and -0.86 for ENT065 correlated with ENTOR and ST015, respectively. Energy required to reach 6.5 cm/hr infiltration capacity was chosen as the laboratory variable to represent field response of the polymers because 6.5 cm/hr is the average rainfall intensity for Iowa, 6.5 cm/hr represents the point after which rapid surface sealing occurs for the soils of this study, and 6.5 cm/hr is the rainfall intensity used in previous studies (Moldenhauer, 1970, Blavia et al., 1971; Gabriels et al., 1973).

Table 2. Effect of chemical treatment of clods on rainfall energy required to reach 6.5 cm/hr infiltration capacity (ENT065) under rainfall simulation.

Polymer	Rate	Marshall C Horizon	Sharpsburg	Belinda	Kansan till	Cary till
		joules/cm^2				
Check*	0	.065	.038	.051	.043	.039
PVA 71-30	1	.065	.119	.109	.101	.086
	2	.065	.109	.136	.128	.115
	3	.098	.105	.155	.138	.151
mean over rates		.076	.111	.133	.122	.117
PVA 72-60	1	.058	.132	.105	.096	.076
	2	.074	.153	.141	.117	.117
	3	.110	.151	.161	.119	.189
mean over rates		.081	.145	.136	.111	.127
PAM	1	.076	.136	.145	.071	.089
	2	.136	.162	.225	.071	.114
	3	.141	.183	.229	.080	.148
mean over rates		.118	.160	.200	.074	.117

Error mean square rates 37 df 0.0002 LSD 0.029
Error mean square polymers 15 df 0.0002 LSD 0.017

*Check values were not included in the statistical analysis because of inadequate replication.

Table 3. Effect of chemical treatment of clods on rainfall energy needed to initiate runoff (ENTOR) under rainfall simulation.

Polymer	Rate	Marshall C Horizon	Sharpsburg	Belinda	Kansan till	Cary till
		joules/cm^2				
Check*	0	.025	.033	.037	.032	.026
PVA 71-30	1	.041	.070	.065	.063	.062
	2	.043	.071	.086	.080	.082
	3	.070	.080	.095	.102	.113
mean over rates		.051	.074	.082	.082	.088
PVA 72-60	1	.040	.070	.067	.065	.065
	2	.052	.086	.112	.086	.084
	3	.067	.117	.102	.100	.122
mean over rates		.053	.091	.094	.084	.087
PAM	1	.042	.097	.084	.067	.057
	2	.056	.118	.130	.067	.092
	3	.092	.125	.158	.074	.111
mean over rates		.063	.113	.124	.069	.087

Error mean square rates 37 df 0.0001 LSD 0.020
Error mean square polymers 15 df 0.0001 LSD 0.012

*Check values were not included in the statistical analysis because of inadequate replication.

Table 4. Effect of chemical treatment of clods on soil loss after 0.15 joules of simulated rainfall energy (ST015).

Polymer	Rate	Marshall C Horizon	Sharpsburg	Belinda	Kansan till	Cary till
		joules/cm^2				
*Check	0	24.0	21.0	23.1	30.1	37.3
PVA 71-30	1	12.2	5.9	7.0	12.8	8.2
	2	15.7	9.7	4.4	8.4	2.8
	3	7.1	7.4	1.6	4.0	6.6
mean over rates		11.7	7.7	4.6	8.4	5.9
PVA 72-60	1	20.5	6.7	6.7	15.0	13.2
	2	13.0	2.6	2.0	7.3	7.2
	3	7.7	1.7	2.1	5.7	0.3
mean over rates		13.7	3.7	3.6	9.3	6.9
PAM	1	11.9	5.6	3.7	17.8	11.5
	2	8.3	2.9	0.7	16.6	5.3
	3	4.3	1.6	0.0	9.1	1.3
mean over rates		8.2	3.4	1.5	14.5	6.0

Error mean square rates 37 df 2.86 LSD 3.45
Error mean square polymers 15 df 5.38 LSD 4.95

*Check values were not included in the statistical analysis because of inadequate replication.

Moldenhauer and Kemper (1969) and Moldenhauer (1970) calculated that rainfall energy between corn planting and protective cover from corn in Iowa is 0.18 joules/cm^2. The period required to establish a grass seeding is similar to the period between corn planting and complete cover of the corn canopy. An average of 0.15 joules/cm^2 of rainfall energy is assumed for both spring and fall seeding operations in the following section.

Practical Application

The objective of this study was to first test the usefulness of the PVA and PAM polymers for stabilizing subsoil clods against 0.15 joules of rainfall energy. Energy required to reach 6.5 cm/hr infiltration capacity is in excess of 0.15 joules for all soil materials except the leached loess material,and the amount of polymer required to maintain a 6.5 cm/hr infiltration capacity varied with the clay content of the soil material. Since the polymers were effective in maintaining a 6.5 cm/hr infiltration capacity against 0.15 joules of rainfall energy, prediction equations were developed to aid in planning roadside-stabilization projects in which PVA and PAM polymers are used to control water erosion and surface crusting.

Multiple regression techniques were used to develop equations that predict ENT065 for PAM, PVA 71-30,and PVA 72-60 as a function of rate and clay percentage. Rate and clay content are the independent variables of the equations,which are in the form ENT065 = $b_o + b_1$

Table 5. Effects of polymers on soil loss at Poweshiek field experiment

Polymer	Blocks	Mean soil loss cm	Soil loss Metric tons/ha
PVA71-30	S	0	0
	N+	2.5	178
PVA72-60	S	0	0
	N	0	0
PAM	S	0	0
	N	0	0
Check	S	0.8	59
	N	1.4	104

MS Polymers = 0.74 Blocks = 0.72 Error = 0.81

*Blocks are slope aspect: S = south-facing and N = north facing.

+This plot received runoff water from an upslope field.

(rate) + b_2 (clay), where b_o is the intercept, b_1 is the regression coefficient for rate, and b_2 is the regression coefficient for clay.

Clay is the only physical parameter used since it is normally available from published soil survey reports or soil series descriptions and is highly related to other physical properties of the soil clods (Peperzak and Shrader, 1956).

The equations were developed for all materials (full model) and for loess materials (loess model) and are given in Table 6. The R^2 values are relatively high for all the equations, with values ranging up to 0.89 for the PAM polymer. This indicates the independent variables, rate and clay, may account for much of the variation of the ENT065 variable. Clay-squared and rate squared terms were inserted into the regression equations, but were not significant. Rate and clay were independent. Therefore, an interaction term was not required.

The principal use of the equations is to estimate the amount of chemical mulch which is needed to maintain an infiltration capacity of 6.5 cm/hr after 0.15 joules of applied rainfall energy. Therefore, the equations are solved for rate, with ENT065 set at the desired energy level and clay at the percentage clay content of the material to be stabilized.

The prediction equations were used for planning the field experiment. An average of 25 percent clay was used for the loess model, and 32 percent clay for the full model (till material) to estimate amounts of material needed to maintain a 6.5 cm/hr infiltration capacity after 0.15 joules of rainfall energy. The equations indicated 336 kg/ha of each polymer was required. The chemical treatments controlled soil detachment and clod breakdown,which resulted in the control of sheet erosion. Sheet erosion strips the soil, seed, and fertilizer from the slope and is a major factor in failure of road-side seedings. The chemicals did not protect against rill erosion caused by runoff from upslope farm fields. Where runoff water was diverted from the treated cut-slope areas, however, the three chemicals controlled soil erosion in this study.

Table 4. Prediction equations for each polymer

Polymer	Equation	R^2
	Full Model	
PVA71-30	ENT065 = 0.026 + 0.017 (rate) + 0.0016 (clay)	0.52
PVA72-60	ENT065 = 0.004 + 0.026 (rate) + 0.0019 (clay)	0.60
PAM	ENT065 = -0.070 + 0.026 (rate) + 0.0047 (clay)	0.76
	Loess Model	
PVA71-30	ENT065 = 0.001 + 0.011 (rate) + 0.0024 (clay)	0.79
PVA72-60	ENT065 = 0.003 + 0.021 (rate) + 0.0020 (clay)	0.61
PAM	ENT065 = -0.027 + 0.033 (rate) + 0.0350 (clay)	0.89

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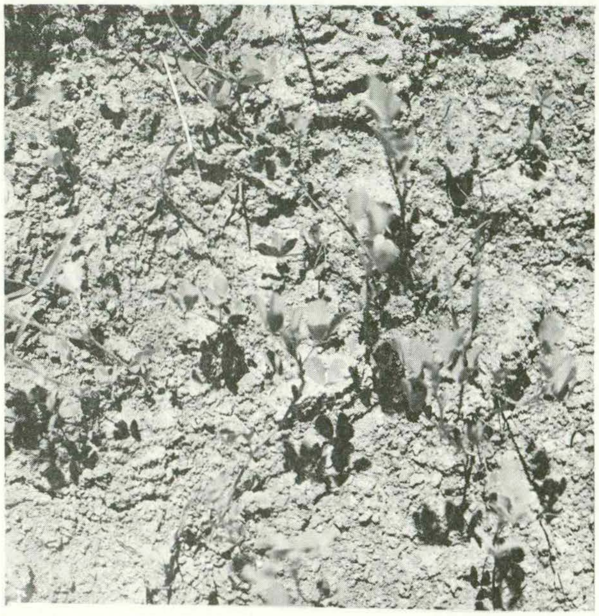

Plate 1. Roadbank in Poweshiek County, Iowa treated with PVA 72-60 polymer.

Plate 2. Roadbank in Poweshiek County, Iowa. Untreated.

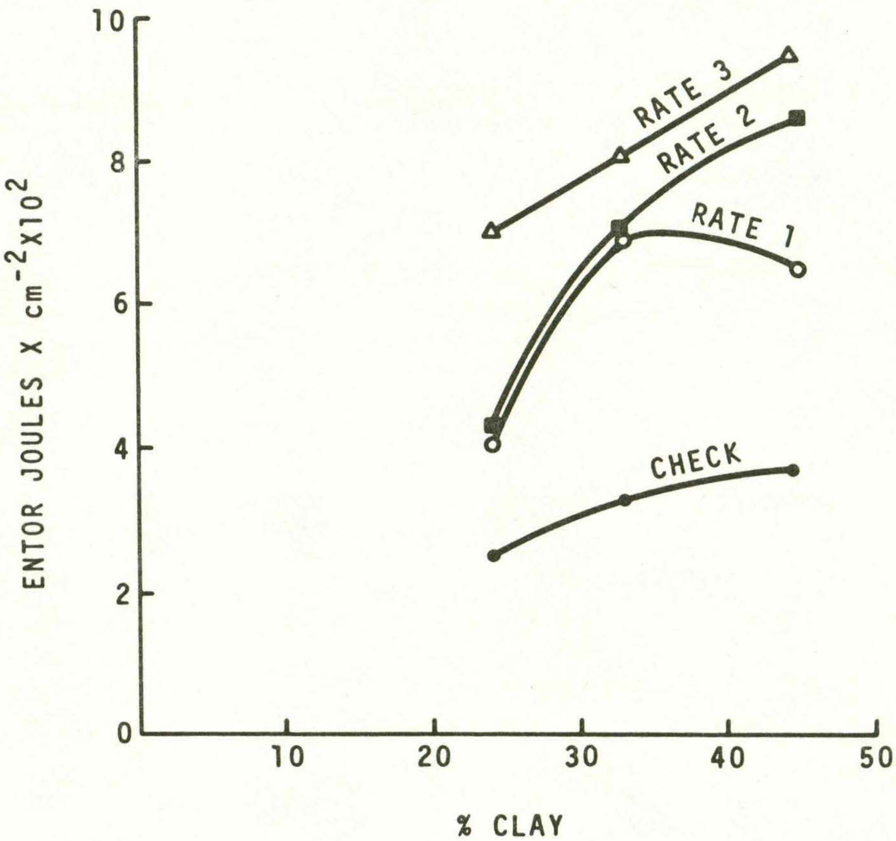

Figure 1. Comparison of energy required to initiate runoff (ENTOR) with percent clay for 3 rates of PVA 71-30 polymer.

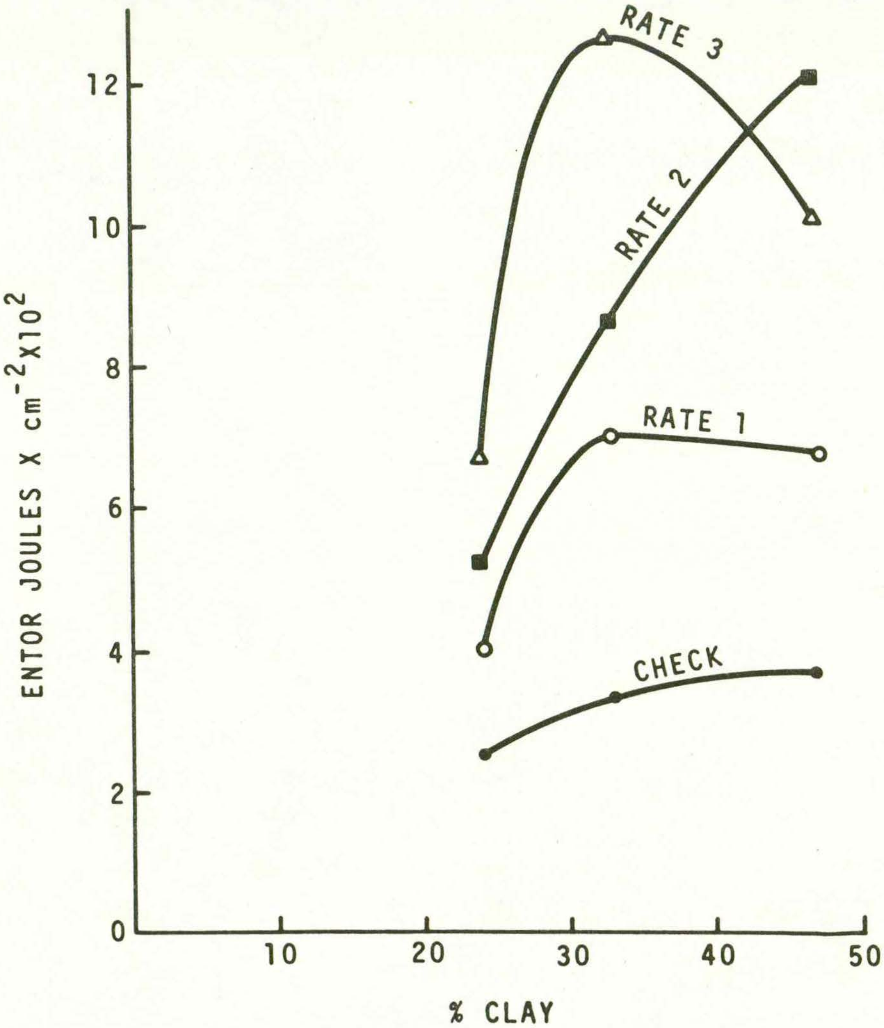

Figure 2. Comparison of energy required to initiate runoff (ENTOR) with percent clay for 3 rates of PVA 72-60 polymer.

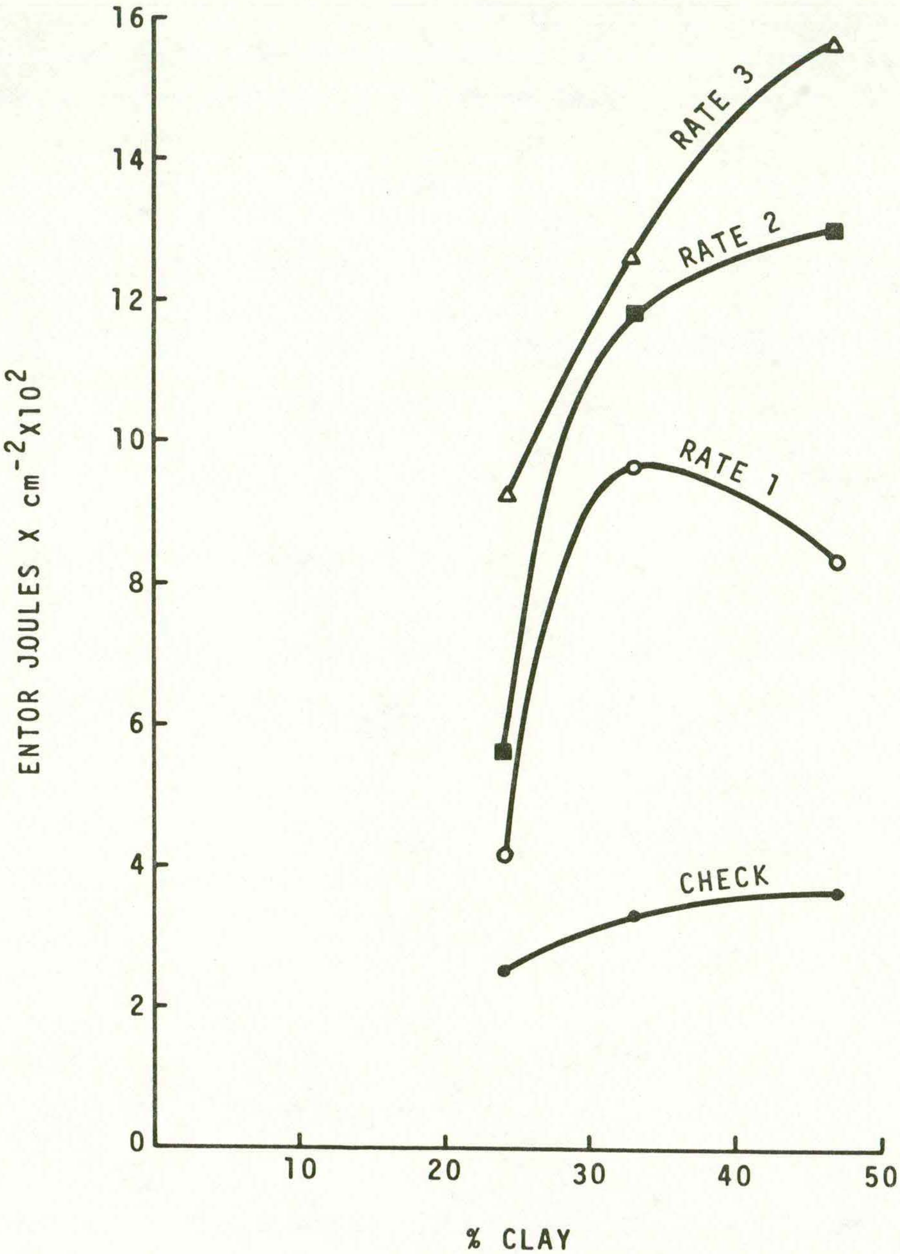

Figure 3. Comparison of energy required to initiate runoff (ENTOR) with percent clay for 3 rates of PAM polymer.