EROSION CONTROL ON ROADSIDES IN TEXAS

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SUMMARY AND RECOMMENDATIONS

Field seedings installed since 1960, and complemented by laboratory measurements, showed that grass stands adequate for erosion control can be established on roadsides in northwestern Texas without the expensive practice of topsoiling. Specifications (Table 3; Figures 7A and B) recommend seeding mixture by soil type, date of planting, tillage and mulching. Specifications based on experimental seeding results have been proven on both contract and maintenance seedings. Cost of seeding in place using maintenance forces and following the recommended procedure has been verified as \$200.00 per acre or 4.1¢ per square yard.

Problems remaining to be solved include:

1. Delineating the western limits, or the least rainfall in areas VI and VII, where seeding for erosion control is feasible (Figures 7A and B).
2. Establishing seed mixtures and planting dates for southwestern Texas, areas VI, (Figures 7A and B).
3. Devising treatments for unfavorable physical conditions of extremely plastic clays (PI greater than 25) and techniques to neutralize acid materials uncovered in construction in northeastern Texas, area V, (Figure 7A and B).

INTRODUCTION

The entire cross-section of a finished highway should be paved. Concrete or asphalt pavements support vehicular traffic, while the major portion of a right-of-way is paved with living plants for soil conservation.

Paving an area with plants and maintaining this living pavement requires technology, just as does the installation of a first-class travel surface. The live pavement is managed much less intensively than pavement used as a riding surface. This living pavement contrasts with rigid pavement in its requirements for base material, both require management. Road pavement requires a firm base, while a pavement of living plants does best on a base that is not compacted. Both the paved road surface and roadside vegetation require scheduled maintenance but with good management the vegetative portion is permanent.

The objectives of this research were to review the established specifications for erosion control used by the Texas Highway Department and to determine better plant materials and operational practices for establishing a plant cover on roadsides.

REVIEW OF LITERATURE

Soil erosion on roadsides bare of vegetation or on cross-sections under construction is a major concern of the highway engineer because it can endanger highway structures, increase maintenance costs and damage adjoining property.

Development of specifications for erosion control begins with design (Byrd, 1968; Committee on Roadside Development, 1966; Dudeck, et al., 1967), and considers such operational items as soil preparation, selection of plant materials, fertilization, mulching and the use of special methods to solve unique problems. Recommendations for seeding roadsides in a local area, such as an urban or rural section in part of a district, combine and amplify the general design and operational principles (Committee on Roadside Development, 1966). Several states are accumulating technology for establishing vegetation (Beavers and Cox, 1965; Blaser and Woodruff, 1968; Spooner, et al., 1966; Sturkie, 1966). For Texas, choices of planting materials, time of seeding, tillage, mulching and fertilizing were covered in an earlier report (McCully and Bowmer, 1967).

An area as large as Texas supports a wide variety of plant communities, reflecting differences in soil, climate and other habitat factors (Gould, 1969; Gould, et al., 1964). Several of the native grasses form the basis for roadside seeding mixtures in western portions of Texas, and bermudagrass is planted most commonly in more humid areas (McCully and Bowmer, 1967).

Once a seed mixture has been selected technology must promote an environment which favors seed germination and early seedling development.

Planting should be accomplished when optimum moisture and temperature conditions for plant growth are expected. Tilling the seedbed to encourage water intake and storage, mulching to conserve moisture and modify temperatures in the seed zone and fertilizing to promote early growth help maintain these conditions (McCully and Bowmer, 1967).

In addition to assembling lists of adapted plant materials, equipment and mulching materials are needed to install a seeding. Most farm machinery is not rugged enough to withstand use in roadside operations. Specialized equipment is being developed continually for tilling, seeding, fertilizing and mulching (Butler, 1967; Button, 1958; Garmhausen, 1960; Dudeck, et al., 1967). A number of materials have been suggested and used as surface mulches, many of them industrial by-products (Bailey, 1966; Garmhausen, 1960; Hudspeth and Ellis, 1959). Asphalt has been used widely on highway plantings (Vordenbaum, 1956).

Many of the materials exposed in roadcuts or used for fill are marginal or unsuitable as a growth medium for plants (Peperzak, 1958; Thornton, 1965). These materials range from caliche and sandstone to shale and clay. Occasionally, extremely acid materials are encountered (Beavers and Cox, 1965; Normand and Colmer, 1965; Grafton, 1968) which must be neutralized before vegetation can be established.

Establishing a vegetative cover on roadsides for erosion control is an art. A better understanding of the principles involved through research will enhance the success of plantings installed.

PROCEDURE

The primary objective of a roadside seeding operation is to obtain the best stand of grass in the shortest period of time. Research prior to 1964 (McCully and Bowmer, 1967) established general seed mixtures for various parts of Texas, fixed planting times and pointed out the necessity for tilling and mulching.

Experimental seedings were restricted to cut and fill slopes, with each seeding installation covering five to ten acres. Slopes constitute a major portion of the roadside acreage (Hottenstein, 1963), and present more exacting conditions for evaluating seeding performance (Fig. 1). Seeding locations ranged from Lubbock and Big Spring east to Beaumont and Atlanta, and from Lubbock south to Corpus Christi.

Prior to the seeding operation, the experimental location was organized to accommodate the variables under consideration (Table 1a, 1b). Replications were assigned on the basis of exposure, obvious soil differences or from soil survey reports. After the experimental organization had been completed the field operations of tilling, seeding, fertilizing and mulching were done. Tillage was accomplished using a pulvimixer, a scarifier and drag, or a combination of these (Fig. 2).

Traffic was not allowed on the slopes following tillage. The prescribed seed mixture, together with 400 pounds of fertilizer having an analysis of either 16-20-0 or 16-8-8, was applied in a water slurry from a hydroseeder (Fig.3). Hay and excelsior mulches were applied from a straw blower (Fig. 4), while asphalt mulches were applied using hand distributors. Hay or straw mulches were applied at rates of 1.5 to 2.0 tons per acre, depending upon the skill of the operator. Excelsior mulch was applied at 0.75 and 1.50 tons per acre. The straw blower delivered the mulch material to the seeded area using an air stream and the mulches were held in place by 0.05 gallons of asphalt per square yard injected into the mulch stream as it left the blower.

Soil samples were taken before and after tillage, and were subjected to laboratory measurement of textural grade, pH, bulk density, plasticity index, conductivity and water holding capacity. Stands were evaluated periodically beginning with emergent seedlings and were correlated with the laboratory soil measurements.

Some special practices to promote establishment of satisfactory stands also were investigated. These involved post-planting applications of fertilizer, eliminating competition from transient companion grasses and the initiating of work on liming and other soil amendments. Two hundred to four hundred pounds per acre of 16-20-0 fertilizer were applied during the spring of 1965 to seedings made in Taylor County the previous spring. Response to fertilizer was measured by changes in plant stand and grass production. Methods of overcoming competition from ryegrass to favor the establishment of bermudagrass (Bowmer and McCully, 1968) was continued in Cass County with the seeding made during the fall 1966. Certain geologic sediments in northeastern Texas become extremely acid when exposed to oxidation and methods of overcoming this acidity are being studied. Work initiated in 1966 is continuing on the addition of various organic and inorganic materials as soil amendments to extremely plastic clay materials to favor the establishment of grass stands for erosion control.

The efficiency of various materials proposed as mulches were compared under standard conditions of temperature and humidity in a controlled environment chamber. Various rates of such materials as grass hay, bagasse, wood chips, composted garbage and asphalt were compared for their capability to reduce moisture evaporation from the soil surface.

RESULTS AND DISCUSSION

Before installing any practice, an engineer asks three questions: (1) what will work best, (2) how is it applied, and (3) how much will it cost. This technology is developed by studying and comparing various alternative practices. Answers to the first two questions are found in the job specifications, cost estimates are based on experience.

The Committee on Roadside Development (1966) related the active and passive factors which influence soil erosion by wind or water forces. Many of these factors should concern design and construction engineers, as well as those in maintenance, who are planning and installing erosion control practices in roadside development. Such erosive forces as degree and length of slope, granulation and permeability of soil material and the amount and distribution of rainfall also determine the habitat in which plants are grown to control soil erosion.

Erosion control can be simplified to selecting proper plant materials and tempering the habitat to favor the establishment of these plants (Fig. 5). Modifying the habitat involves tillage before seeding and mulching following seeding. Tillage increases water infiltration rate, reduces runoff and improves the plant-soil-moisture relationship.

Granular soils usually are more permeable and absorb more water. Regardless of permeability, water runs off steeper slopes faster, and becomes more erosive as the length of slope increases. Slopes steeper than 3:1 are difficult to cover with plants, partly because any loose surface material moves toward the base of the slope. Tillage to loosen the surface of these steep slopes to improve water intake is not only difficult and hazardous, but creates a highly erosive condition.

Tillage is essential on all but the sand sites. Seedling stands generally are about equal regardless of tillage depth. However, following the first growing season differences are evident (Table 4). Both number of plants occurring and frequency of occurrence increase with depth of tillage. Tilling four inches deep increased the number of plants per unit area by one-third while eight inch plowing doubled the number when compared with the minimum (2 inch) tillage depth. Although frequency of seeded species increased with tillage depth this increase was not as great as the increase in number of plants present (Table 4).

Depth of tillage required depends on the material present. The slope face should be tilled at least four inches deep and deeper tillage improved plant stands on some slopes. A pulvi-mixer leaves the soil surface in excellent tilth, but its use is expensive. Any equipment which stirs the soil to the specified depth and leaves the surface smooth and covered with small granules (0.5 inches or smaller) is satisfactory. Scarifiers followed by some sort of drag have been used successfully in seeding operations on medium texture soils (Fig.2).

After the surface is loosened, a water slurry of seed and fertilizer is placed on the soil surface. The splashing action of the 1,000 gallons of water used per acre seems to settle the surface layer of soil material around the seed. This is a broadcast method of distributing seed and teamwork by the crew is necessary for proper coverage.

Seed mixtures are planned to accommodate local soils and climate. Sandy soils support a different group of plants than clay and the selection of plants changes as one moved to a wetter or drier climate (Table 1a and 1b). Experimental seed mixtures used in the western portion of Texas (Table 1a and 1b) are upright growing native grasses common in that area. Sand dropseed and plains bristlegrass failed to germinate in experimental seedings and were deleted from mixtures recommended (Table 3). Green sprangletop and sideoats grama came up to good stands the first year, while other species such as blue grama germinated as late as two years following seedling. The stands of green sprangletop generally decline if the other grasses came up to a good stand. Bermudagrass and other species requiring more moisture may be present occasionally in ditches, but are seeded only where rainfall is 30 inches or higher.

Following seed placement, a surface mulch of hay or straw with asphalt incorporated is applied. One and one-half to two tons of hay or straw mulch per acre with 0.05 gal/sq yd of asphalt conserves moisture in the seed zone needed for germination and protects the soil from washing until the plant cover becomes functional. The layer of mulch should cover all except the larger soil aggregates; a thicker layer smothers the grass seedlings. Grass stands reflect the efficiency of a mulching material. A comparison of hay at 1.5 tons per acre and asphalt at 0.30 gal per square yard was made in the seeding in Taylor County during the spring of 1964 (Table 4). The hay mulched areas supported only slightly better seedling stands than the asphalt mulched areas but by the end of the growing season the number of plants had doubled with a slight increase in occurrence under the hay mulch while on the plots mulched with asphalt the number of plants remained about constant but with severe reduction in distribution (Table 4). Generally, plants growing in a hay mulch were more vigorous than those in asphalt.

A number of materials have been compared under standard conditions of 90°F and 70% relative humidity for their efficienty in retarding evaporation from the soil surface. Hay, excelsior, bagasse and other materials giving a loose porous cover were more efficient as vapor barriers than compact layers of asphalt or wood chips. The moisture depletion for 0.75 and 1.5 tons per acre of excelsior in laboratory studies help explain the better stand obtained with the heavier application of mulch. The higher rates of composted garbage suppressed moisture loss, but the mulch layer was too thick for seedling emergence (Fig. 6; Table 2). A good mulch properly applied may be expected to double the time that moisture in the seed zone is adequate for germination (Table 2).

Time of planting varies with latitude; the more northern districts plant later. The specified spring seeding dates (Table 3) also precede the early season rains. In drier western Texas fall plantings of mixtures of permanent perennials and temporary companion species should not be made. Early seedlings of the permanent grasses do not survive the winter and those emerging the following spring do not successfully compete with the established annual companion plants.

Benefits of a starter fertilizer at the time of seeding have been reported (McCully and Bowmer, 1967). Several rates of fertilizer were applied to a seeding one year old in an attempt to improve stands. Increasing fertilizer rates results in increased production with the greatest increase experienced on thinnest stands of shallow tilled areas (Table 5). Areas tilled 8 inches deep and fertilized with 200 pounds per acre produced about the same as shallow tilled areas receiving 400 pounds per acre. This again points advantageously to the deeper tillage depth at time of installation.

Local maintenance forces learned to install seedings by participating in these field plantings. Jones (1966) analyzed the cost of a seeding in place:

Tillage	$ 15.00 per acre
Seed and Fertilizer	55.00 per acre
Hay and Asphalt	130.00 per acre
Total	$200.00 per acre

Fall seedings of bermudagrass and annual ryegrass common in the more humid eastern one-third of Texas can be managed to encourage the establishment of bermudagrass. The seeding rate of ryegrass should not exceed 15 pounds per acre. Bermudagrass begins to sprout soon after February 1, and the ryegrass cover must be suppressed after that time. The ryegrass can be mowed frequently so that it will not shade out the bermudagrass, or it can be sprayed with a contact herbicide. Paraquat applied at rates of either 0.5 or 1.0 pounds per acre effectively reduced ryegrass competition and improved the stands of bermudagrass obtained (Fig. 8). DSMA, an organic arsenical, showed some potential but applications were made when the daily temperature high was about 55° F. These materials should be applied when the temperature is above 65°F. Materials such as dalapon and TCA either are not selective enough or residual activity is too long to use for this purpose.

Soil materials on roadsides are classified into three broad categories: (1) sands, (2) sandy clays, and (3) plastic clays. If the entire face of a slope consists of a loose sandy material, the planting can be installed without tillage. Caliche banks in Liveoak County and sandstone beds in Jasper County yielded a porous material with tillage, and good stands of grass were secured. With tillage, sandy clays supported good stands of grass (Cass, Garza, Howard, Jasper, Liveoak, Lubbock, Scurry, Wood, Taylor counties), while seedings on plastic clays failed to furnish adequate cover for erosion control (Bexar, Jefferson, Johnson, Refugio, San Patricio, Washington counties). Seeds either do not germinate or the emerged seedlings soon die. From our limited studies soil materials with a plasticity index (PI) greater than 25 did not yield a stand of grass, even with tillage and mulching. PI and pH were the only measurements which could be associated with failure to secure a stand; bulk densities, conductivity and textural analysis (clay content) were not so positive. Soil amendments may be useful in establishing a plant cover on these materials.

Still another soil problem exists in northeastern Texas. Soils produced by some geologic formations in the Claiborne Group registered a pH as low as 1.8. Plant growth stops when pH reaches a low of 4.0. The acidity in these soils is caused by the sulfides in some "iron-ore" and lignitic materials reacting with air and water to form sulfuric acid. Reserve acidity exists throughout the sediment bed and is activated on exposure to air. Initial applications of lime as high as 50 tons per acre may be necessary to establish grass, but the surface layer of most sediments can be neutralized with 20 to 25 tons. A survey of IH 20 from Van east to the state line revealed that slopes bare of vegetation needed treatment with lime. Most slopes were mildly acid and could be treated with 2 to 6 tons of lime per acre. Work is continuing on the lime schedule needed to maintain a stand of grass on these acid materials.

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Table 1a. Location of experimental seedings, including year seeded, season of planting, number of seedings and variables studied.

Year	Season	County	No. of Seedings	Seed Mixture	Tillage Depth 0-2"	Tillage Depth 4-6"	Tillage Depth 6-9"	Mulch Hay	Mulch Asphalt	Mulch Excelsior
1964	Spring	Washington	2	1*	x	x	x	x	x	
		Taylor	1	11	x	x	x	x	x	
	Fall	Washington	2	2	x	x	x	x	x	
		Taylor	3	3	x	x	x	x	x	
1965	Spring	Howard	1	4		x		x		
		Bexar	1	5	x	x	x	x		
		Jefferson	1	1	x	x	x	x		
		Jasper	1	1	x	x	x	x		
		Scurry	1	4		x		x		
	Fall	Johnson	1	2A	x	x	x	x		
1966	Spring	Bexar	1	1	x	x	x	x		
		Jasper	1	1	x	x	x	x		
		Washington	1	1	x	x	x	x		
		Lubbock	3	6		x		x		
		Garza	1	6		x		x		
		Wood	1	1		x	x	x		
		Liveoak	1	7		x	x	x		
		Refugio	1	8		x	x	x		
		San Patricio	1	9		x	x	x		
		Cass	1	1		x	x	x		x
	Fall	Cass	1	2A		x	x	x		
1968	Spring	Smith	1	-	-	-	-	-		
		Brazos	1	1		x		x		
		Rusk	1	1		x		x		
		Taylor	1	10		x		x		

* Designated seed mixtures are listed in Table 1b.

Table 1b. Seed mixtures used in experimental plantings at various locations listed in Table 1a.

Number	Components	lb/A Bulk Seed
1	Green sprangletop (*Leptochloa dubia* (H.B.K.) Nees)	4
	Bermudagrass (*Cynodon dactylon* (L.) Pers.)	8 (hulled)
2	Annual ryegrass (*Lolium multiflorum* Lam.)	20
	Bermudagrass (*Cynodon dactylon* (L.) Pers.)	12 (unhulled)
2A	Annual ryegrass (*Lolium multiflorum* Lam.)	15
	Bermudagrass (*Cynodon dactylon* (L.) Pers.)	12 (unhulled)
3	Annual ryegrass (*Lolium multiflorum* Lam.)	40
	Blue grama (*Bouteloua gracilis* (Willd. ex H.B.K.) Lag.ex Griffiths)	15
	Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)	5
	Sand dropseed (*Sporobolus cryptandus* (Torr.) Gray)	5
	Green sprangletop (*Leptochloa dubia* (H.B.K.) Nees)	5
	Plains bristlegrass (*Setaria macrostachya* H.B.K.)	5
	Western wheatgrass (*Agropyron smithii* Rydb.)	5
	Cane bluestem (*Andropogon barbinodis* Lag.)	5
4	Green sprangletop (*Leptochloa dubia* (H.B.K.) Nees)	4
	Plains bristlegrass (*Setaria macrostachya* H.B.K.)	5
	Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)	5
	Sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray)	5
	Blue grama (*Bouteloua gracilis* (Willd. ex H.B.K.) Lag. ex Griffiths)	15
5	Green sprangletop (*Leptochloa dubia* (H.B.K.) Nees)	4
	Bermudagrass (*Cynodon dactylon* (L.) Pers.)	8
	KR bluestem (*Andropogon ischaemum* L.)	10
6	Mixture No. 4 plus:	
	Switchgrass (*Panicum virgatum* L.)	5
	Western wheatgrass (*Agropyron smithii* Rydb.)	5
7	KR bluestem (*Andropogon ischaemum* L.)	10
	Buffelgrass (*Pennisetum ciliare* (L.) Link)	8
	Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)	5

Table 1b. continued

Number	Components	lb/A Bulk Seed
	Green sprangletop (_Leptochloa dubia_ (H.B.K.) Pers.)	4
8	Mixture No. 7 plus:	
	Bermudagrass (_Cynondon dactylon_ (L.) Pers.)	8
9	Alkali sacaton (_Sporobolus airoides_ (Torr.) Torr.)	3
	Weeping lovegrass (_Eragrostis curvula_ (Schrad.) Nees)	3
	Bermudagrass (_Cynodon dactylon_ (L.) Pers.)	8
10	Green sprangletop (_Leptochloa dubia_ (H.B.K.) Pers.)	5
	Sideoats grama (_Bouteloua curtipendula_ (Michx.) Torr.)	5
	Blue grama (_Bouteloua gracilis_ (Willd. ex H.B.K.) Lag. ex Griffiths)	15
	Switchgrass (_Panicum virgatum_ L.)	5
11	Mixture No. 4 plus:	
	Switchgrass (_Panicum virgatum_ L.)	5

Table 2. Mulch treatments, application rate and rating index based on area under the soil moisture depletion curves for each treatment compared to the prairie hay standard together with days required to reach 15 atmospheres tension for each treatment.

Mulch Treatment	Application Rate[1]	Rating Index[2]	Days to 15 atmos.
Prairie Hay	1.50	100	4.00
Excelsior	1.50	90	4.00
	0.75	74	3.25
Bagasse	2.50	117	4.00
	2.00	84	3.50
	1.50	84	3.50
Composted garbage	3.50	93	3.75
	2.50	78	3.50
	1.50	57	2.50
	0.50	39	2.00
Asphalt	0.20	73	3.50
#8 Bark Chips	3.00	60	2.50
	2.50	67	2.75
	2.00	54	2.50
	1.50	62	2.50
#4 Bark Chips	3.00	62	2.50
	2.50	54	2.25
	2.00	52	2.25
	1.50	51	2.25
Bark Shreds	4.00	68	2.75
	3.00	61	2.50
	2.00	55	2.25
Check	Bare Soil	34	2.00

[1] All mulches applied on a ton per acre basis except asphalt which was applied at 0.2 gallons per square yard.

[2] Rating index is expressed as percent based on the prairie hay standard.

Table 3. Recommended seed mixtures for roadside plantings in northwestern Texas.

PLANTING AREA Texas Highway Department Districts	SOIL TEXTURE Clay Soils (lbs. seed per acre)	Sandy Soils	PLANTING DATES
I Amarillo (4) and Lubbock (5)	4# Green sprangletop 5# Sideoats grama 15# Blue grama 5# Buffalograss 5# Western wheat	4# Green sprangletop 5# Sideoats grama 15# Blue grama 5# Switchgrass	March 15 to June 15
II Wichita Falls (3W), Abilene (8) and Childress (25)	4# Green sprangletop 5# Switchgrass 5# Sideoats grama 5# Caucasian bluestem 1/ 5# Western wheat 1/ 8# KR bluestem 2/	4# Green sprangletop 5# Switchgrass 5# Sideoats grama 5# Caucasian bluestem 1/ 2# Lehman lovegrass 2/	March 1 to May 15 (District 8) March 1 to June 1 (Districts 3W and 25)
III San Angelo (7), Austin (14W), San Antonio (15NWO, Del Rio (22N) and Brownwood (23SW)	4# Green sprangletop 5# Sideoats grama 10# KR bluestem	4# Green sprangletop 5# Sideoats grama 8# KR bluestem 3/ 4# Switchgrass 3/ 6# Buffelgrass 4/ 4# Rhodesgrass 4/	March 1 to May 15 (Districts 7 and 23SW) February 15 to May 15 (District 14W) February 1 to May 1 (Districts 15NW and 22N)

Table 3. Continued

IV			
Fort Worth (2W),	4# Green sprangletop	4# Green sprangletop	March 1 to May 15
Wichita Falls (3E),	5# Sideoats grama	5# Sideoats grama	(Districts 2W and 23NE)
Waco (9W) and	5# Switchgrass 5/	5# Switchgrass	
Brownwood (23NE)	10# KR bluestem 6/	10# KR bluestem 6/	March 1 to June 1
	5# Western wheat 7/	2# Lehman lovegrass 8/	(District 3E)
	5# Caucasian bluestem 7/	5# Caucasian bluestem 7/	
			February 15 to May 15
			(District 9W)

1/ except District 8

2/ District 8 only

3/ District 23SW only

4/ District 15 NW only

5/ except District 23NE

6/ except District 3E

7/ District 3E only

8/ District 2W only

Table 4. The effects of mulch type and tillage depth on seedling and established stands of a native grass seeding in Taylor County in the spring of 1964. Seedling evaluations were made at approximately 60 days post seeding and established stand data are from fall evaluations 1964.

	Seedling		Established Plant	
Mulches	Density 1/	Frequency 2/	Density	Frequency
Hay 1.5 T/A	0.7	59%	1.4	61%
Asphalt	0.5	50%	0.7	39%
Tillage Depth				
2 inches	0.6	55%	0.9	43%
4 inches	0.6	55%	1.2	50%
8 inches	0.6	53%	1.4	56%

1/ Density is the average number of seeded plants occurring in a square foot sample unit.

2/ Frequency is the percent of the square foot sample units containing one or more seeded plants.

Table 5. Effects of 200, 300 and 400 lb/A of fertilizer on herbage production on seeded areas tilled 2, 4 and 8 inches deep. Fertilizer was applied one year following seeding in Taylor County.

RATE OF 16-20-0 FERTILIZER PER ACRE	POUNDS OF HERBAGE PRODUCED PER ACRE BY TILLAGE DEPTH		
	2"	4"	8"
200	851	862	1177
300	1117	1040	1208
400	1463	1027	1178

Figure 1. Erosion of an unprotected cut or fill slope becomes progressively more severe and may endanger the highway structure, become unsightly and deposit silt on neighboring properties.

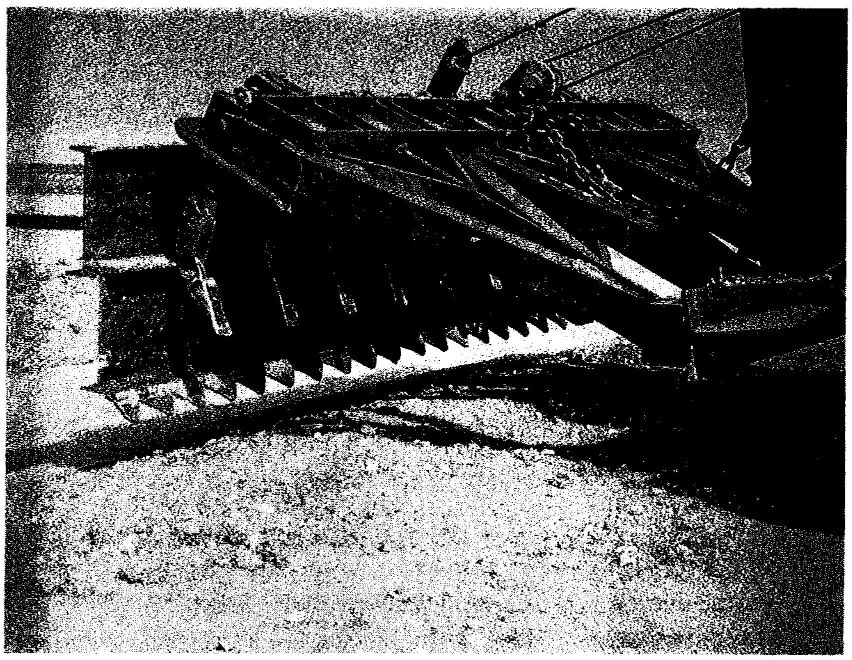


Figure 2. A pulvimixer (above) leaves a seedbed in excellent tilth, but other equipment has been designed in district shops (below) to do an equivalent tillage job at a much lower rental rate.

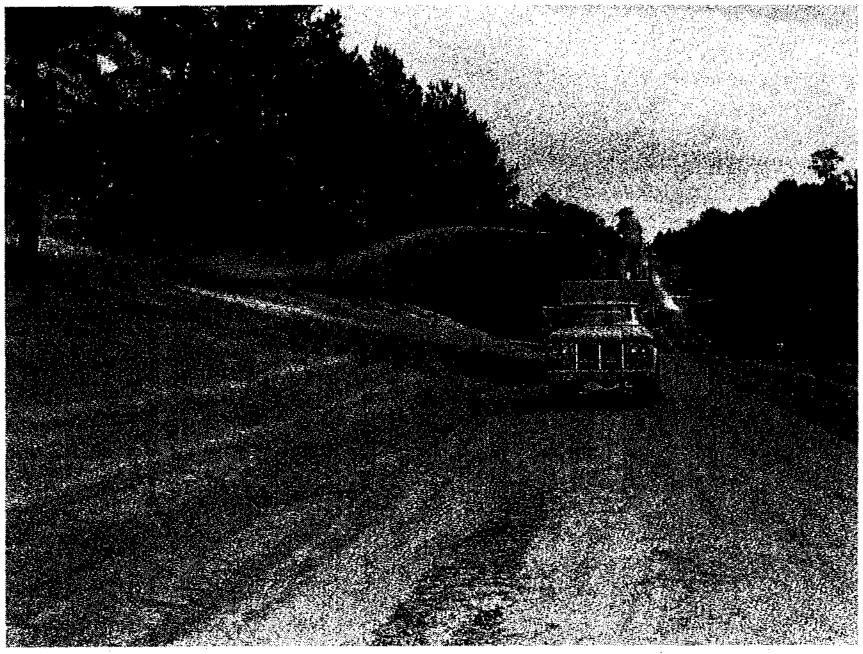


Figure 3. Seed and fertilizer are broadcast onto a tilled slope in a water slurry without the necessity of putting traffic back on the prepared seedbed.

Figure 4. Straw or hay impregnated with asphalt as it leaves the blower makes an excellent mulch. Maintenance crews have often covered guard rails already in place with paper to prevent spotting by asphalt spray.

Figure 5. A protective cover of grass can be installed if the recommended practices are followed.

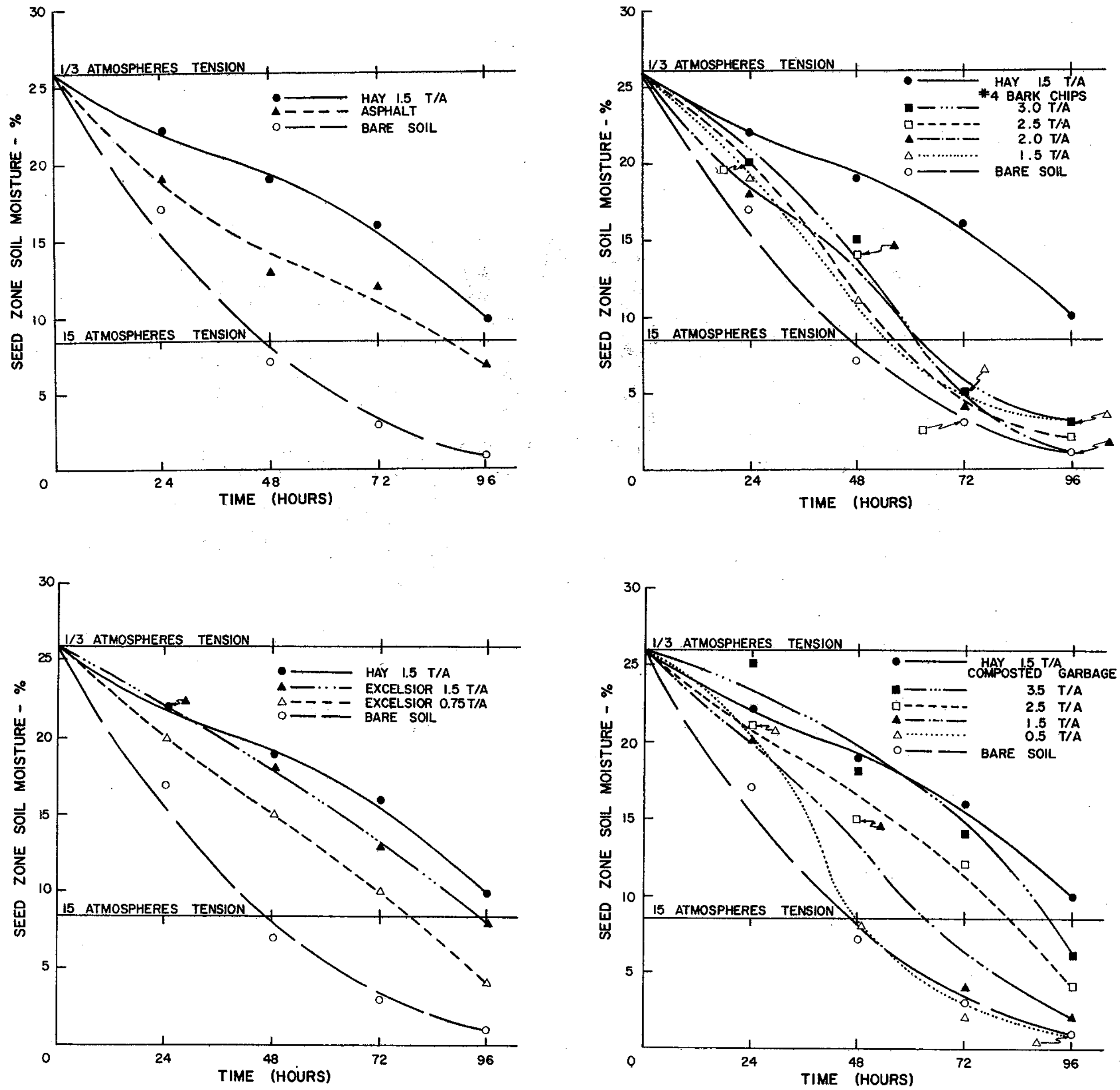


Figure 6. The influence of various mulching treatments on water depletion from a sandy soil under standard conditions of temperature and humidity from 1/3 atomspheres moisture tension (field capacity) to 15 atomspheres moisture tension (approximately wilting percentage).

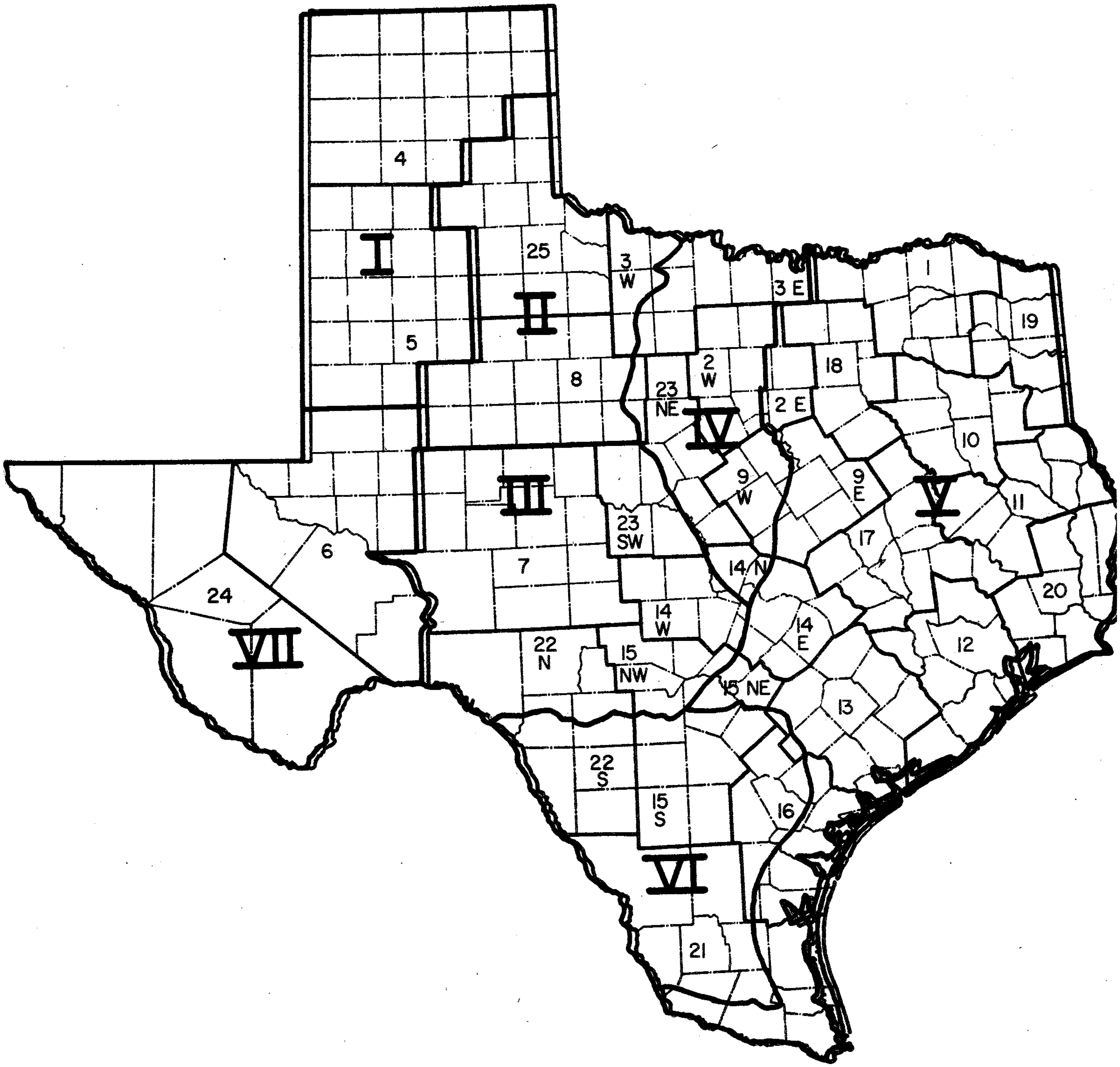
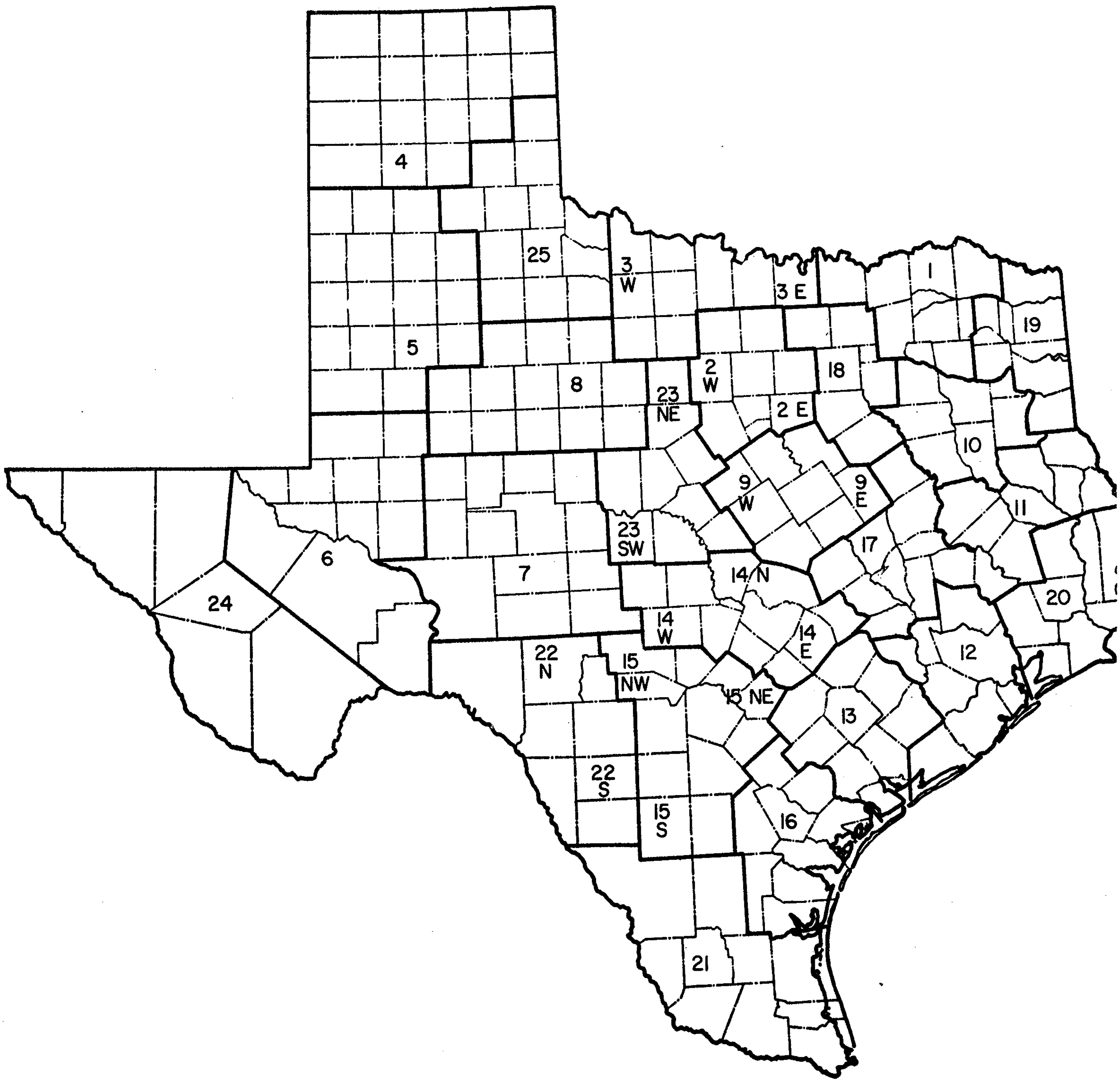


Figure 7B. Status of recommended seeding practices for roadsides in Texas. Cultural specifications have been developed for Area I - IV (see Table 3); soil problems are prevalent over much of Area V; specific seed mixtures and locations to be planted need to be developed for Areas VI - VII.

Figure 7A. Districts within the Texas Highway Department. Letters designate sub-districts for which a different roadside planting mixture is specified (see overlay and Table 3).



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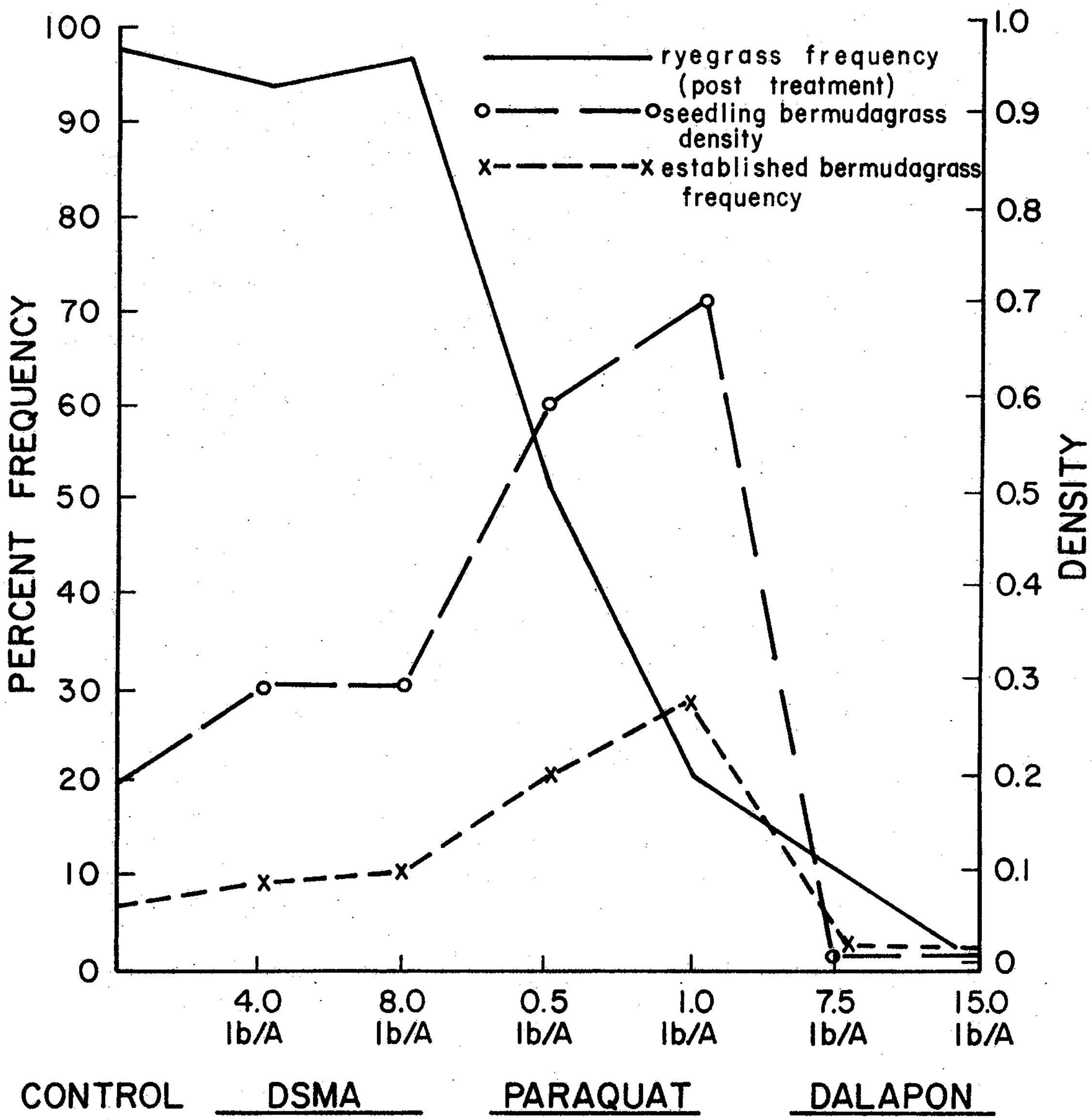

Figure 8. Results of herbicide treatments used to control annual ryegrass and subsequent effects on seedling and established stands of bermudagrass.