Current Trends in Equipment for Roadside Cover Establishment and Maintenance

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The purpose of this report is to present information on the equipment and practices now being used in the United States for establishing and maintaining roadside cover. It is hoped that from it those persons who are already well acquainted with the field of roadside development will learn of new equipment and practices in other States which will be helpful to them, whereas those who are new in the field can get a wider view of the field than would otherwise be possible in their local areas.

The material for this report was gathered primarily from two sources: (1) first-hand information obtained from the various highway authorities in the States and turnpike or tollway commissions, and (2) a cooperative research project with the Illinois Division of Highways. A comprehensive questionnaire was sent to the 48 continental States, Hawaii, Puerto Rico, and the thruway and tollway commissions. Fifty-four questionnaires were completed and returned with the following distribution: 46 from the States, six from the tollroad authorities, one from the District of Columbia, and one from Puerto Rico. A second questionnaire necessary to expand and clarify information obtained from the first one was completed and returned by 56 different highway authorities. The response was therefore excellent in both cases. Such cooperation adds to the success of the project and is much appreciated.

To illustrate the text, pictures of equipment and roadside cover practices were obtained from various individuals and equipment companies. They are an essential part of the report, and the authors thank those who supplied them.

It seems desirable to point out that the information given here is a resumé of current trends in roadside equipment and practices and perhaps an indication of future trends. No large-scale attempt has been made to evaluate either the equipment or the individual practices because of the wide variation in local conditions among the States.

INTRODUCTION

The operations performed in establishing and maintaining roadside cover can be divided into two phases: (a) the roadside cover establishment phase, and (b) the roadside cover maintenance phase. These are discussed separately, with the various operations in each phase presented in essentially a chronological order.

The roadside cover establishment phase begins with seedbed preparation or tillage performed after the final shaping of the roadway and continues throughout all the operations that are performed primarily to insure a good cover. These operations include both primary and secondary tillage, fertilizing, mulching, seeding, sodding (or sprigging), watering, and postseeding fertilization. The roadside cover maintenance phase includes mowing, tree and shrub maintenance, use of chemicals to control weeds and brush, removal of litter, and application of maintenance fertilizers.

Of those who completed the questionnaire, checked it, or helped in its completion, landscape architects or engineers completed 34 percent; chief engineers, 28 percent; and maintenance engineers, 22 percent, for a total of 84 percent. Others who completed forms were construction engineers, assistant chief engineers, design and district engineers, and foresters. In many cases more than one person assisted in fillin out the form. For instance, a maintenance engineer and a landscape architect may have cooperated, each answering only those questions that pertained to his specific field of interest.

A high percentage of completed questionnaires was returned from all areas. In States where information was not obtained from the State highway authorities, information from the turnpike authorities was usually available. If information was not obtained from a State, usually the surrounding States returned their questionnaires. Thus it was felt that, at least on a regional basis, enough returns were received to give a good picture of the situation. For use in this report, the continental United States was divided into twelve separate regions with reasonably similar geographic and climatic conditions (Fig. 1).

Both questionnaires contained several general questions on rights-of-way, maintenance records, maintenance and construction contracts, specifications, etc. As background information, answers to these questions are discussed before the individual practices. These questions were asked to determine how other States differed from Illinois in their operations so that the effect of these differences on the handling of equipment and on roadside practices might be evaluated.

The two questions on highway specifications referred to the steepest slopes permitted on cuts and fills and right-of-way widths on different types of highways.

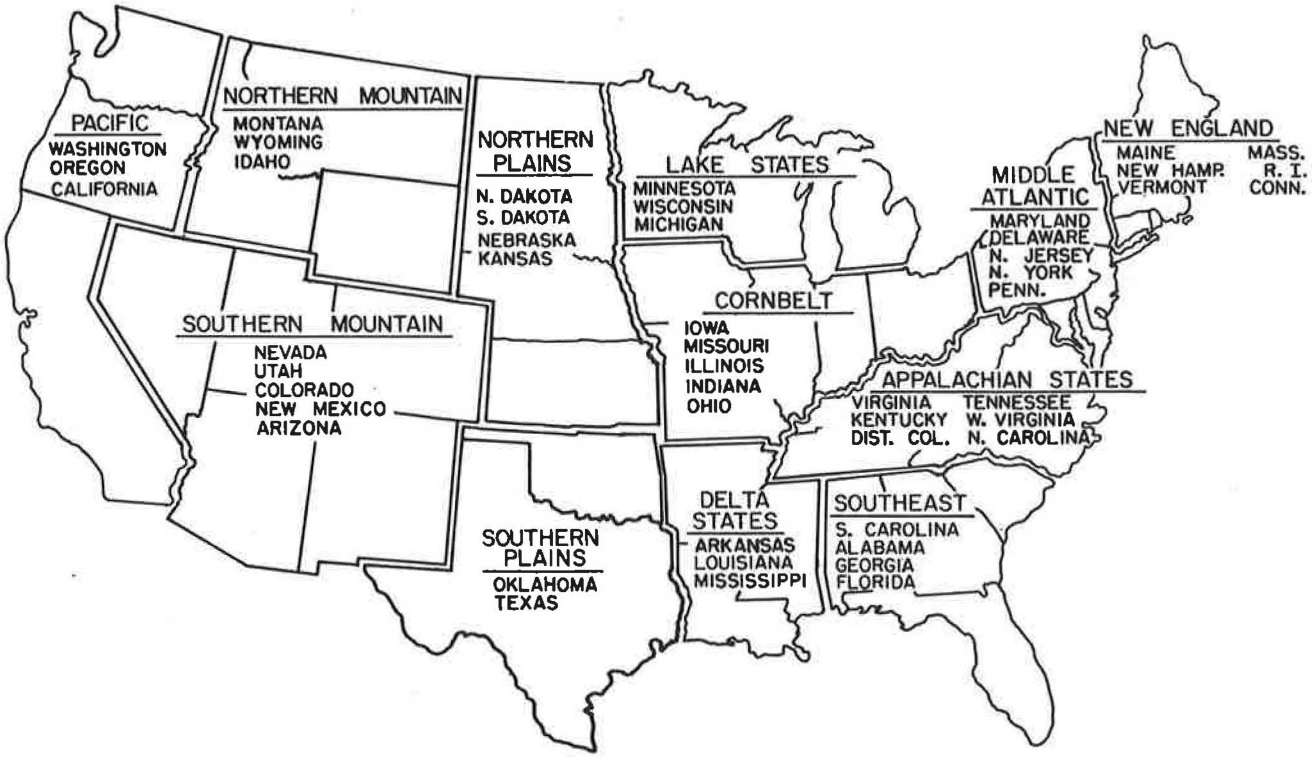

Figure 1. Regions of United States as used in study.

Table 1 summarizes the right-of-way widths given for the various types of highways. Right-of-way widths for Interstate routes, toll roads, and thru ways were in the range of 200 to 400 ft, with 300 ft a common width for all three. As expected, the widths decreased for State and county roads which would normally be subjected to lighter traffic and designed to lower standards. County rights-of-way averaged 78 ft, or about one-fourth the average width of Interstate rights-of-way (288 ft). There was a tendency for States to use wider rights-of-way on Interstate systems than the minimum required by Federal regulation.

Table 2 gives average right-of-way widths in the different regions for turnpikes, Interstate routes, and U.S. routes. Turnpikes and Interstate roads are usually about 300 ft wide. With a few exceptions, U.S. routes, although considerably narrower than turnpikes and Interstate roads, tend to be wider where land values are not so high or the terrain is flatter. For instance, in New England the average width was 107 ft, whereas in the Southeast, where the terrain is flatter and land values are normally lower, the average width was 167 ft. In the Northern Mountain States, where the terrain is rougher, the average width was 130 ft; in the flatter Southern Mountain States, it was 190 ft.

Table 2 also gives the maximum slopes normally permitted on cuts and fills. Although the slope figures given by the different States and tollways were not based on the same standards, reasonable comparisons were obtained by averaging the slopes by regions. Two apparently valid conclusions are possible from these data: (a) the current trend is toward flatter slopes, and (b) slopes are nearly always flatter for turnpikes and Interstate routes than for the U.S. routes.

TABLE 1

NORMAL RIGHT-OF-WAY WIDTHS

Roads	Right-of-Way Width (ft)			
	Min.	Max.	Avg.	Typical
Interstate	200	400	288	300
Turnpike, toll, and thruway	200	300	282	300
U.S. route	66	260	154	150
State route	50	200	122	100
County	30	150	78	60

TABLE 2

RIGHT-OF-WAY WIDTHS AND MAXIMUM SLOPES

Region	Normal Right-of-Way Width (ft)		Maximum Slope Normally Permitted on Cuts and Fills			
	Turnpike and Interstate	U.S. Routes	Turnpike and Interstate		U.S. Routes	
			Past	Current	Past	Current
New England	283	107	2.0:1	2.7:1	1.8:1	2.4:1
Middle Atlantic	263	130	1.9:1	2.5:1	1.8:1	2.2:1
Appalachian	292	132	1.8:1	2.3:1	1.1:1	2.0:1
Southeast	300	167	2.0:1	3.3:1	1.8:1	3.0:1
Delta	300	113	2.0:1	3.0:1	2.3:1	3.0:1
Corn Belt	292	171	2.1:1	2.7:1	2.1:1	2.6:1
Lake	308	142	2.5:1	2.8:1	2.7:1	2.7:1
Northern Plains	310	155	2.7:1	2.8:1	2.7:1	2.7:1
Southern Plains	300	160	2.3:1	2.8:1	2.3:1	2.5:1
Northern Mountains	200	130	2.2:1	2.2:1	2.0:1	2.0:1
Southern Mountains	320	190	2.0:1	2.2:1	1.9:1	1.9:1
Pacific	250	175	1.8:1	2.0:1	1.5:1	1.7:1
Hawaii		75			3/4:1	3/4:1
Puerto Rico						1:1[a] 4:1[b]
Over-all Avg.	285	147	2.19:1	2.61:1	1.91:1	2.29:1

[a]Cuts.

[b]Fills.

No attempt was made to analyze the trend toward flatter slopes to determine whether it is due to problems of establishing and maintaining cover on steep slopes or to the availability of more powerful equipment for moving earth. It is probably due to a combination of the two. Highway authorities have probably been influenced to use flatter slopes for the Interstate system because of the knowledge that many more acres of roadside per mile will need to be maintained, and that flatter slopes will reduce maintenance costs. This is also a good argument for flatter slopes on other highways.

There are several arguments for and against separating contracts for seeding operations and landscape plantings (trees and shrubs) from construction contracts. Table 3 gives present practices by regions. The most common method was for cover establishment contracts to be included in the construction contract. In several regions, all the State routes and thruways used this method. In the entire United States, 78 percent used contracts combining construction, tillage, seeding, fertilizing, etc., but not landscape planting. A higher percentage of agencies let separate contracts for seeding in the drier areas, primarily because of the time interval between final shaping and seeding. As a whole, 73 percent let separate landscape planting contracts, again primarily because of the time interval between the completion of construction and actual planting. The highly specialized nature of landscape planting also has some effect in determining the procedure followed.

All highway departments were asked to estimate the average time elapsed from initial cutting of slopes until final shaping and from final shaping to seeding. It was hoped to correlate this timing with results in establishing seedings, but no correlation could be found. Table 3 gives these times by regions. No consistent pattern in average time was noted from cutting of slopes to final shaping. However, most respondants considered the time interval too long. There was a more definite pattern in time interval from final shaping until seeding. Table 3 shows the interval is greater in the more arid areas, where a certain time of year is more suitable for seeding. Here seeding, if done at all is performed normally only in one or two months. In the humid areas, seeding can be done more nearly the year round or at two or three different times during the year. Especially in the more humid areas, a common comment was that the delay between shaping and seeding was entirely too long. In general, it was indicated that seeding should be done as soon as final shaping was completed.

An attempt was made to correlate with the type of contract the time from cutting of slopes to final shaping, and from final shaping to seeding (whether the contracts for seeding and landscape planting were let separately, or in combination with the construction contracts). No apparent relationship was found. One comment from Missouri stated that they had been using maintenance forces for seeding, and an average interval of about four months had elapsed between final shaping and seeding. They hoped to shorten this interval considerably by combining seeding and construction in the same contract. Many of those currently operating under a combined system in which seeding was included in the construction contract felt that the

TABLE 3

CONTRACTING POLICIES AND TIME INTERVALS AFTER SHAPING

Region	Separate Contracts Let: For Cover Establishment	Separate Contracts Let: For Roadside Landscape Planting	Average Time: From Cutting Slopes to Final Shaping	Average Time: From Final Shaping to Seeding
New England	No	50% Yes	3.3 mo	3 wk
Middle Atlantic	No	Yes	7 mo	10 days
Appalachian	80% No	75% Yes	6 mo	2 wk
Southeast	67% No	50% Yes	5 mo	2 wk
Delta	Mostly No	Yes	8 mo	1 wk
Corn Belt	Mostly No	50% Yes	6 mo	3 mo
Lake	No	Yes	3 mo	1 mo
Northern Plains	No	Yes	3 mo	3 wk
Southern Plains	No	67% No	4 mo	6 mo
Northern Mountains	Yes	Yes	3 mo	5 mo
Southern Mountains	Yes	Yes	4 mo	6 mo
Pacific	Yes	Yes	3 mo	1 mo
Hawaii	Yes	Yes		
Puerto Rico	Yes	Yes	Variable	3 mo
Over-all Avg.	22% Yes	73% Yes	4.8 mo	7 wk

operation would be more efficient and more timely if done under separate contracts. Answers in this area indicated a great deal of dissatisfaction with the length of time between final shaping and seeding and that this interval was partly responsible for seeding failures.

One section of the questionnaires covered organization of roadside maintenance. It was hoped that this information would be useful in interpreting actual practices and use of equipment. In checking the average size of the smallest maintenance units used in various State highway divisions and by turnpike authorities, it was found that the average number of miles of road per maintenance unit was 90 mi. The most common range was 20 to 40 mi, and the complete range was 10 to 500 mi. Three-fourths of the highway authorities reported that supervisiors of their smallest maintenance units had a great deal of freedom operating their units. Half the agencies (26) indicated that a supervisor worked under civil service or the equivalent. In 34 of 52 departments, the maintenance supervisor had definite guides to follow maintenance procedure and practices.

Twenty-seven of 48 agencies used specialized roadside equipment on a statewide or authority-wide basis. Examples of equipment so used were mulch blowers, hydraulic seeders, and various tractors, trucks, graders, sod cutters, and brush chippers. This practice of cooperative use would have to be expanded if other specialized equipment were to be developed.

In an attempt to determine whether roadside cover maintenance or establishment cost records were available, several questions on cost were included in the questionnaires. Because it seemed impossible for a highway department to determine roadside maintenance costs accurately unless maintenance funds were kept separate from pavement maintenance funds, this procedure was checked. Thirty-seven of 51 replied that funds for roadside maintenance were not separated from pavement maintenance funds. Thus only 14 were left to form an acceptable basis for determining roadside maintenance costs. Thirty-seven of 50 replied that they kept records of costs of roadside maintenance. In checking on mowing costs, it was found that nearly all of the records were incomplete, being based primarily on costs of repairs and fuel, on operating costs only, or being combined with costs for litter removal, seeding repairs, etc. Thirty-one of 51 indicated that separate maintenance records were kept for each maintenance operation, such as mowing, spraying, and litter removal, but the criticisms mentioned previously were usually found to apply. Ninety percent of the departments indicated that they could release cost information on a confidential basis. In the section on mowing, the replies to requests for cost information are discussed. It appears that the records kept by the smaller tollway authorities or turnpike commissions and by newly formed departments were more accurate and more detailed than those available from the older organizations.

In 98 percent of the cases highway maintenance personnel made seeding repairs instead of contracting them. They made 95 percent of sodding repairs and replaced 94 percent of the eroded earth. When tree removal practices were mentioned, it appeared that maintenance forces also handled this operation.

ROADSIDE COVER ESTABLISHMENT

Tillage Practices and Equipment

Agricultural tools were most commonly used to prepare roadsides for seeding. Table 4 shows the disc harrow was employed in 31 States, the most popular tool for use on fairly level areas. Spring-tooth and spike-tooth harrows were also used on both level areas and cut and fill slopes. The spike-tooth harrow was used slightly more than the spring-tooth harrow (20 users on level areas and 17 on cuts and fills compared with 15 users on level areas and 14 on cuts and fills, Fig. 2). Other fairly commonly used tillage tools on level areas were the simple leveling drag (10 users), rotary tiller (9), roller (9), disc plow (8), culti-mulcher (6), and field cultivator (5).

Besides the spring-tooth and spike-tooth harrows, the implement most commonly used on cuts and fills was the spike-tooth chain. The most popular version of this tool is known as the "Klodbuster." Other tools used on cuts and fills were the tandem disc harrow (12 users), drag (11), disc plow (11), roller (7), field cultivator (4), and limited use of the culti-mulcher, bulldozer, scarifier, and mulch tiller.

Although the disc harrow and the spring- or spike-tooth harrow were used across the entire country, other tools tended to be used in those areas where they were used agriculturally. For instance, the disc plow, used for agricultural puposes in the Southern Plains, Southeastern and Mountain States, and New England, was often used on roadsides in the same areas. Due to its characteristics the disc plow works better than the moldboard plow in the hard and rocky soils found in these areas; it penetrates the hard subsoils found in cutback slopes. The field cultivator was another tool used on roadsides in the areas where it was popular agriculturally. Few special tools (that is, tools used only, or primarily, on roadsides) were mentioned. Some of these few were the York rake, the soil erosion mulch tiller, the grass harrow, the Roseman tiller rake (Fig. 2), the scarifier, the bog disc, and the spike-tooth chain.

Thirty percent of those who replied to the questionnaire considered present tillage equipment either unsatisfactory or marginal in performance, or were experimenting with new types. Others who did not report any general disatisfaction indicated a basic need for tillage equipment to be used on steeper slopes, especially the steeper cut slopes. For instance, the State agronomist in the Oklahoma Department of Highways had found no good implement for tilling soils on steep, clay back slopes. He tried disc plows,

Figure 2. Preparing shoulder with Roseman tiller rake. (Courtesy of Roseman Mower Corporation)

TABLE 4
TILLAGE TOOLS COMMONLY USED[a]

Region	Disk Harrows L	Disk Harrows CF	Spring-Tooth Harrows L	Spring-Tooth Harrows CF	Spike-Tooth Harrows L	Spike-Tooth Harrows CF	Drag L	Drag CF	Roller L	Roller CF	Spike-Tooth Chain L	Spike-Tooth Chain CF	Disk Plow L	Disk Plow CF	Rotary Tiller L	Rotary Tiller CF	Field Cultivator L	Field Cultivator CF	Culti-Mulcher L	Culti-Mulcher CF	Others L	Others CF
New England	x		x		x			x							x							
Middle Atlantic	x		x		x			x				x			x							Bulldozer
Appalachian	x			x		x				x		x					x		x		Scarifier	
Southeast	x		x		x			x	x	x		x		x	x							
Delta	x			x		x		x					x	x					x		Rotary hoe	
Corn Belt	x	x	x	x	x	x	x	x					x				x	x				
Lake	x		x	x	x	x		x			x	x							x			
Northern Plains	x		x	x	x	x		x	x	x												
Southern Plains									x	x			x	x	x	x			x	x		Mulch tiller
Southern Mountains	x		x		x		x	x				x	x							x		
Northern Mountains	x		x	x					x			x										
Pacific			x		x							x					x	x				
Hawaii	b	b																				
Puerto Rico	b	b																				
Summary of Users	31	12	15	14	20	17	10	11	9	7	1	14	8	7	9	1	5	4	6	2		

[a]L = level (up to 4:1 slopes); CF = cuts and fills (over 4:1 slopes).
[b]No data.

scarifiers, and harrows but was not satisifed with their performance. Highway personnel in Louisiana, Missouri, Alabama, and North Carolina felt essentially the same way. About one-half of those who had used the spike-tooth chain were well satisfied with its performance. One drawback mentioned was that the operator must get on top of the slope in order to pull the chain with a tractor or other power unit. Also, the chain was said to cause the soil to move down the slope. On steeper slopes the loose material would not stay on the upper part of the slope but would roll to the bottom. A possible solution would be to pull the chain from the lower side of the slope and use a tractor on the upper side primarily to keep the chain from sliding down the slope.

A tillage practice used in the southernmost highway district in Illinois, District 9, consists of plowing contour furrows about 2 ft apart on the larger cut and fill slopes. These serve the purpose of slowing run-off and allowing soil movement to be from the ridges into the furrows. After making the contour furrows, normal seeding and mulching procedures are followed. This method has given excellent results in an area of relatively poor soils and poor growing conditions.

In summary, the information obtained from the questions on tillage indicates the following: (a) agricultural tillage tools are usually satisfactory on level and flatter slopes, (b) there is considerable interest in finding better tillage tools for steep slopes, especially the steep cut slopes, and (c) the spike-tooth chain seems to work well under some conditions, but it is not satisfactory on the steepest slopes and on the hard soils often found in the cut slopes.

TABLE 5
SEEDING DATES AND RATES

Region	Month Permanent Seeding Made: Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Median Time of Seeding	Amount of Permanent Species Seeded, (lb/acre) Range	Avg.
New England	-	-	1	5	5	4	1	4	6	3	2	-	May 1 & Sept 1	40-130	71
Middle Atlantic	-	-	3	5	5	3	1	3	5	5	3	1	May 1 & Oct 1	45-130	88
Appalachian	-	2	3	5	5	2	1	3	5	4	3	-	May 1 & Oct 1	80-150	97
Southeast	2	2	2	3	3	3	3	3	3	3	3	2	No median time	25-60	46
Delta	2	2	3	3	3	3	2	2	2	2	2	2	No median time	20-60	39
Corn Belt	2	4	5	5	5	2	2	5	5	3	2	2	Apr 15 & Sept 17	10-131	51
Lake	-	-	1	3	3	2	2	3	3	3	2	-	May 1 & Sept 15	23-100	40
Northern Plains	-	1	2	4	3	2	1	4	4	1	-	-	May 1 & Sept 1	25-40	35
Southern Plains	1	1	2	2	2	2	-	1	1	1	-	-	May 1	2-50	30
Southern Mountains	-	1	1	1	1	1	1	1	1	1	1	-	No median time	10-23	18
Northern Mountains	-	-	-	1	-	-	-	-	-	1	1	-	No median time	10	10
Pacific	1	2	3	3	3	3	1	2	2	3	3	1	May 1 & Oct 15	15-60	35
Hawaii	1	1	1	1	1	1	1	1	1	1	1	1	No median time	-	-
Puerto Rico	1	1	1	1	1	1	1	1	1	1	1	1	No median time	-	-
Summary or Avg.	10	17	28	42	40	29	17	33	39	32	24	10	May 1 & Sept 15	2-150	58

Seeding of Roadside Cover

The following section discusses both permanent and temporary seedings, equipment used in various sections of the country, timing of seedings, seeding mixtures, and the relative success of different seedings.

Times of Permanent Seeding.—Individual State and thruway authorities were asked about times of seeding. It was felt this information would be more meaningful if based on regions rather than States. In the summary given in Table 5, the replies are therefore grouped according to regions. The numbers in each column show the number of States making permanent seedings in that month. The median time column indicates the peak seeding season for that region. Except in areas where seeding is done the year round, and in some western areas where not much seeding is done, there are two peaks. The spring season usually starts in February or March, depending on latitude, and continues into May or June. Fall seeding starts in August and lasts until October or November.

Ten States indicated the use of year-round seedings, not all of them were in southern latitudes. Two States in the Corn Belt said they seeded the year round. The Southern Plains and Southern Mountain States, which have a wide range of latitudes as well as altitudes, reported a considerable range in periods of seeding. Colorado seeds from February to April, Arizona from May to August, and Utah from September to November. There is no overlapping among these three States. The spring season for permanent seeding reaches its peak around May 1 in the New England, Middle Atlantic, Appalachian, and Lake States and also in the Northern and Southern Plains and Pacific States. In the Corn Belt, the spring season reaches its peak about mid-April, and in the Southeast, Delta, Southern Mountain, and Northern Mountain regions, Hawaii, and Puerto Rico, there is no definite season for seeding.

The same States that have a definite spring seeding season also have a fall seeding season starting in late summer or early fall, but it is of longer duration. For instance, the New England and Corn Belt regions seem to reach their peak on or about September 1, and the Lake States about September 15. The Middle Atlantic and Appalachian States indicate a seasonal peak on October 1, and the Pacific Coast States seem to have their highest activity about October 15. For the country as a whole, seeding peaks occur about May 1 and again about September 15. However, the summary shows that April and May are seeding months in 42 and 40 of the 45 States replying, and March and June are seeding months in 28 and 29 States. The fall seeding season is more uniform, 33 States seeding in August, 39 in September, 32 in October, and 24 in

TABLE 6

SUMMARY OF SPECIES USED FOR PERMANENT SEEDINGS[a]

Species	New England	Middle Atlantic	Appala-chian	South-east	Delta	Corn Belt	Lake	Northern Plains	Southern Plains	Southern Mountains	Northern Mountains	Pacific	Puerto Rico	Total
Kentucky 31 and alta fescue	2	4	4	1	2	4	1	1	1			1		21
Kentucky bluegrass	2	4	3			4	2	3				1		19
Perennial ryegrass	4	4	3			2	2	1				2		18
Creeping red fescue	4	4	2			2	2					1		15
Redtop	3	3	4			3	1					1		15
Bromegrass						2	2	4	1	2	1	1		13
White Dutch clover and Ladino	1	1	3		2	1	1	1				2		12
Bermudagrass			1	3	3	1			2				1	11
Crested wheatgrass								2			3	2		7
Alsike clover	1	2	2			1	1							7
Lespedeza		1	2	1	1	1								6
Western wheatgrass								3	1		1			5
Pensacola bahia				3	1									4
Carpet grass				1	2								1	4
Crimson clover				1	2									3
Intermediate wheatgrass								2			1			3
Sand dropseed								1	1	1				3
Red clover	1					1						1		3
Weeping lovegrass				1				1	1					3
Chewing fescue			1									2		3
Orchard grass			2											2
Yellow sweet clover						1				1				2
Timothy						1	1							2
Alfalfa						1		1						2
Sand lovegrass								1	1					2
Bluestem								1	1					2
Switch grass								1	1					2
Buffalo grass								1	1					2
Blue gramma									1	1				2
Highland bent												2		2
Crown vetch		2												2
Canada bluegrass	1	1												2
Sudan grass					1									1
Slender wheatgrass								1						1
Modified wheatgrass								1						1
Side oats gramma									1					1
Dallis grass				1										1
St. Augustine grass													1	1
Millet					1									1
No. of species used in region	9	10	11	8	9	14	9	17	12	4	4	11	3	

[a]Number of States in region using the species in permanent seedings.

November. Nine of the 10 agencies indicating seedings in December and January also seeded during the entire year.

Table 5 also gives the range in amounts of seed used per acre in permanent seedings and the average rates of seeding in each region. In general, the seeding rate is lower when one or two species are used than when a larger number of species are sown, hoping that one or two will catch or that a good mixed cover will result. The highest seeding rates occur in the New England, Middle Atlantic, Appalachian, and Corn Belt regions, which tend to use several species. In the Southeastern and Delta States, where no more than one or two subtropical species are used, seeding rates are low. Throughout the Plains and Mountain States, which rely primarily on native grasses, rates are also low, partially because one or two species are seeded rather than several. Another reason is probably the very low rainfall. The seedings are not expected to produce a good stand in one season, but are expected to have scattered emergence and fill in over the years. In the eastern sections of the Pacific States, native grasses are seeded at low rates and in the coastal sections mixtures similar to those used along the eastern seaboard are used, but at a higher rate.

The wide range in season and rates given in the table indicates that the seeding equipment manufacturer needs to produce a machine capable of a wide range of seeding rates, and a hopper with a large volume. Seeding at the rate of 2 lb per acre, as suggested for single species in Texas, would call for an accurate metering system.

Species Used in Permanent Seedings.—In addition to checking on time of seeding, the species used in permanent seedings were also checked. The response to this question was good. Information was obtained from either the State highway deparment or a turnpike authority, or both, in 45 States. Again it appeared more useful to summarize the information on the basis of regions rather than States. Consequently, Table 6 gives the regions, and the States in the region using a certain species is shown by the number in line with the species. The extreme right-hand column gives the total number of States using a certain species.

Table 6 shows several interesting things. For instance, 21 States used Kentucky 31 or alta fescue; only 19 used Kentucky bluegrass. Surprisingly, only 12 species are used in more than 4 States (Kentucky 31 fescue and alta fescue are considered as one species and white Dutch clover and Ladino clover as another). Except for the coastal States where certain grasses are used along the coast and others on inland areas, and the Plains and Mountain States which depend on native grasses, only four or five species were used in a region. For instance, in the entire New England and Middle Atlantic regions only seven species were used by more than one State. In the Southeastern States, only bermudagrass and Pensacola bahia were used by all four States. In the Corn Belt six species were the primary basis for seeding mixtures. In fact, after grouping Kentucky 31 fescue with alta fescue and white Dutch clover with Ladino clover, the table gives only 39 species as being used in normal seeding mixtures in the United States and Puerto Rico. If the wheatgrasses are grouped together, only 35 species are used, 34 of them in the continental United States.

Some species were much more widely distributed than others over the continental United States. For instance, Kentucky 31 and alta fescue, though most common in the Middle West and East, were also used in at least one State in each of the Northern Plains, Southern Plains, and Pacific regions. Perennial ryegrass, Kentucky bluegrass, and bromegrass, as well as redtop and white Dutch clover, were widely used. The

TABLE 7

SUCCESS OF PERMANENT SEEDINGS AND SEEDING SEASONS RESULTING IN FAILURE

Region	Percent of Success in Establishing Cover in First Attempt		Seeding Season Causing Highest Percentage of Failures[a]				Cause of Failure
	Range	Average	Winter	Spring	Summer	Fall	
New England	75-95	87	2		3		Poor soil conditions, drought, erosion, late seedings
Middle Atlantic	80-98	90	1		4		Erosion, soil conditions
Appalachian	75-90	79			6		Drought, heat, erosion
Southeast	80-99	90	3				Summer droughts, erosion, soil conditions
Delta	50-80	65	1		1	2	Erosion, soil conditions
Corn Belt	70-95	82	1	4 (3 late)	1	3 (2 late)	Erosion, drought, soil conditions
Lake	90-95	92		1	2		Erosion, drought
Northern Plains	75-97	82	1		2	1	Drought, erosion
Southern Plains	90	90	1	1		1	Drought, erosion
Southern Mountains	50	50			1		Drought
Northern Mountains	50-80	70	1		2		Drought
Pacific	90	90		1	1		Drought, erosion
Puerto Rico	10	10[b]		1			Erosion
Summary	10-99	80	11	8	23	7	Erosion (11 regions) drought (10 regions)

[a]By number of States

[b]Heavy rains with little mulching.

lespedezas and alsike clover were used primarily in the Middle West and East. Subtropical grasses, such as bermudagrass, Pensacola bahia grass, and carpetgrass, were used primarily in the States along the southern Atlantic and the Gulf of Mexico. The native western grasses such as the wheatgrasses, sand dropseed, sand lovegrass, weeping lovegrass, bluestem, buffalo grass, etc., were seeded only in the Mountains, Plains, and Western Corn Belt regions, and their use was limited to the areas to which they were well adapted. Crown vetch, which has attracted a lot of attention for use on slopes, in some areas surprisingly was listed as being used in the seeding mixture in only two States, both of them in the Middle Atlantic group. It is used, however, for special seedings in several eastern and midwestern States. At best the various legumes have a limited use in roadside seeding mixtures and are used primarily in the more humid areas, such as the East, Middle West, and Pacific coastal regions. The most popular legume by far is white Dutch clover. Alsike clover and lespedeza rank next and are about equal in popularity.

In the Southeastern and Delta States, the subtropical grasses, such as bermudagrass, are often established by sprigging rather than seeding. Often the bermudagrass was established by using mixtures of roots and soil for mulching. One New England State reported that most of its slopes were seeded by applying the seed with the hay mulch.

Success in Establishing Permanent Seedings.—Success in establishing cover with one seeding varied greatly. The Southern Mountain highway agencies estimated only 50 percent success; the Lake State agencies, 92 percent (Table 7). The average success rating was 80 percent, which indicates a need for at least one reseeding on one-fifth of all new highway roadsides. Reseeding usually entails more effort per unit of area than the original seeding, as the failures normally occur on the steepest slopes with the poorest soil. More efficient methods are needed for reseeding. Several States indicated that their reseeding was more thorough than the original seeding, with more topsoiling, fertilizing, tillage, attention to drainage, etc.

The replies indicated a sound basis for timely fall and spring seedings. Most respondees felt that summer seedings failed most often (23 returns) and winter seedings next (11). The causes of failure were almost equally divided between erosion (11 regions) and drought (10 regions), with drought slightly more common in the West.

Temporary Seedings.—About one-half the States used temporary seedings for nurse crops or quick cover. Of this group, seven seeded temporary species alone, the remainder usually seeded them with the permanent seedings.

The most common species for temporary seedings was cereal rye, which was used in 26 States and in all regions except the Northern Mountain (Table 8). Of considerable interest, however, were the frequent comments on the failure of farm rye as a temporary seeding. Several indicated their intention of dropping it completely. Others said they were decreasing the rate because it cast too much shade on the permanent species and was a fire hazard. Some landscape engineers seem to object to it because it appears to establish a good cover but then dies out and leaves the slope poorly protected.

A surprisingly large number listed perennial ryegrass as being used for a nurse crop or temporary seeding. When the number of States using ryegrass as a temporary seeding was added to those using it as

TABLE 8

TEMPORARY SEEDINGS—SPECIES USED AND TIMING

Region	Species Used for Temporary Seedings									Time of Seeding
	Farm Rye	Perennial Ryegrass	Oats	Redtop	Fescue	Sudan Grass	Wheat	Lespedeza	Other	
New England	x	x								Sept. - Oct.
Middle Atlantic	x	x	x	x						Fall
Appalachian	x	x			x	x	x	x		Late fall, June-July, and winter
Southeast	x	x			x			x		Late fall and winter
Delta	x	x	x			x			Millet	Year around (2), Mar.-Sept. (1)
Corn Belt	x	x	x			x				May-July, Oct. - Nov.
Lake	x	x								Aug. - Sept.
Northern Plains	x	x	x	x		x				Year around
Southern Plains	x	x	x			x	x			Spring
Southern Mountains	x								Yellow sweet clover	Spring and fall (7)
Northern Mountains							x			Any time (1), fall (1)
Pacific	x	x							Barley, alfalfa	
Puerto Rico[a]										
No. of users	26	18	8 spring 4 winter	2	2	5	3	2	3	December-May - 10, September -11, October & November - 9, June -8, July - 7, August -6

[a]None used.

TABLE 9

SEEDING IMPLEMENTS AND THIER USE[a]

Region	Hydraulic Seeder		Fertilizer Spreader		Knapsack Seeder		Seed Drill		Tractor Landscape Seeder		Manual Seeding Horn		Hand Spreading		Tractor Rotary Seeder		Air Blast		Heli-copter	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
New England	x	x	x	x	x	x			x				x	x						
Middle Atlantic	x	x	x	x	x	x			x					x			x	x		
Appalachian	x	x	x		x	x	x										x	x		
Southeast		x	x	x	x	x	x													
Delta	x	x	x	x	x	x									x					
Corn Belt	x	x	x	x	x	x	x		x						x					
Lake	x	x	x	x	x	x	x	x			x	x								
Northern Plains	x	x	x	x	x	x	x	x	x	x				x						
Southern Plains	x	x	x	x	x	x	x	x	x	x										
Southern Mountains		x	x		x	x	x					x								
Northern Mountains	x	x	x	x		x	x	x	x											
Pacific	x	x			x	x	x													x
Hawaii[b]																				
Puerto Rico													x	x						
No. of users	20	28	19	13	21	27	20	6	11	5	5	5	3	4	2	0	2	2	0	1

[a]L = level (up to 4:1 slopes); S = slopes (over 4:1 slopes).

[b]No data.

Figure 3. **Applying seed and fertilizer with Finn hydroseeder.** (Courtesy of Virginia Department of Highways)

part of permanent seeding mixtures, perennial ryegrass became the most used species. In addition, there was an indication that those who are veering away from cereal rye are replacing it with perennial ryegrass. Some States listed ryegrass as domestic ryegrass, a mechanical and hybrid mixture of perennial ryegrass and Italian ryegrass that, for our purposes, was classified as perennial ryegrass. Eighteen States used perennial ryegrass for temporary seedings.

Other common species used in temporary seedings were spring oats (8 users), sudan grass (5), and winter oats (4). Redtop, lespedeza, and fescue were each used as temporary seedings in two States.

Reasons given for seeding temporary and permanent seedings together were (a) to serve as nurse crops, (b) to establish quick ground cover for immediate erosion control, and (c) to eliminate competition from weeds. Some reasons for not using temporary seedings were (a) too little rainfall for use of nurse crops, (b) too much competition between temporary and permanent seedings, and (c) the same conditions needed for establishing good temporary seedings also being good for establishing permanent seedings.

Figure 4. Seeding steep slopes with knapsack seeder.

Twenty-four States using temporary seedings listed the timing of temporary seedings as follows: December to May (10), September (11), October and November (9), June (8), July (7), and August (6). Because the majority made temporary seedings with the permanent seedings, these times coincided closely with the times given for permanent seeding. However, a slightly higher number indicated use of temporary seedings in the fall rather than spring. The season for the fall peak was that some States made temporary seedings in the fall to establish a quick cover through the winter until the permanent seedings were made in the spring.

Seeding Implements.—Seeding equipment used in the different regions of the country are given in Table 9. An attempt was made to determine the implements used on level areas (that is, areas no steeper than 4:1), on short slopes steeper than 4:1 but no longer than 20 ft and on slopes steeper than 4:1 and longer than 20 ft. Because little difference was found in the implements used on long slopes and short slopes, the table groups them by use on level areas or slopes.

Several conclusions can be drawn from these data. The hydraulic seeder (Fig. 3), though widely used, was more common in the eastern and central regions of the United States. It was often used on level areas as well as on slopes, as shown by 20 listings for level areas and 28 for slopes.

Somewhat surprising was the fact that knapsack seeders (Fig. 4) are commonly used throughout the country for seeding slopes and level areas. Their use on slopes was reported by 27 highway departments and on level areas by 21. This implement is commonly used for repairing small areas needing reseeding and areas bared as a result of regrading shoulders and ditches.

The seed drill, frequently called a grain drill, was used throughout the United States except in the New England, Middle Atlantic, and Appalachian States. For use on level areas it was as common as the hydraulic seeder or knapsack seeder, having 20 users. Because it is an agricultural drill having a high center of gravity and may not perform satisfactorily in other ways, it was not used to a great extent on slopes, having only six users.

Other implements having fairly widespread use as seeders were the farm-trailer type of fertilizer spreader and the landscape seeder. The fertilizer spreader, which distributes the lighter grass seeds very well, was used more often on level areas than on slopes. It had 19 users on level areas and 13 on slopes. The landscape seeder, which scatters seed and, in some cases, fertilizer on the surface and then, firms the seedbed (thus forcing the fertilizer and seed slightly into the surface), had scattered use throughout the country. Eleven highway departments reported using it on level areas, and 5 mentioned its use on slopes.

Other implements and methods used on level areas to a limited extent were manual seeding horns (5 users), hand spreading (3), tractor rotary seeder (2), and air blast spreading (2). On slopes their use was as follows: manual seeding horn (5), hand spreading (4), air blast spreading (2), tractor rotary seeder (1), and helicopter (1).

The distribution of use shows that on slopes the hydraulic seeder and knapsack seeder were used for the highest percentage of the seedings; fertilizer spreaders and landscape seeders, seed drills, and a few other methods had only a limited amount of use. But on level areas the hydraulic seeder and knapsack seeder were replaced in many departments by the seed drill, the fertilizer spreader, and the landscape seeder. This replacment appears reasonable, because neither the hydraulic seeder nor the knapsack seeder would place the seed in the ground or distribute it as well as the seed drill or landscape seeder. The seed drill can be used to place the seed a reasonable depth in the ground, and the landscape seeder will press it at least into the surface soil. Without mulching, germination is more likely to occur when either of these methods is used than when the seed is merely scattered on the surface. Use of straw or hay mulches usually encourages seedling emergence with all these machines but is most beneficial when seeds are placed on the surface.

In checking with highway departments on the quality of their seeding equipment, it was found that about two-thirds of the present seeding equipment was satisfactory. Twelve percent of the departments felt that performance of seeding equipment was either marginal or unsatisfactory, and 20 percent were experimenting with new types.

Those States using hydraulic seeders, landscape seeders, and air blast spreading equipment, were asked about seeding results and performance of the equipment. Of those reporting the use of the high-speed, low-volume air blast nozzle for spreading seed, only two felt that they had used it enough to comment on its performance. These two rated it good to excellent in performance, medium to high in capacity, quite safe, and not easily damaged.

Those reporting the use of the landscape seeder felt that it gave good to excellent performance on the flatter slopes in level areas and that its capacity was medium (one State rated it low in capacity). They rated it high in need for repairs and routine maintenance and poor in maneuverability. Experience with landscape seeders on this project indicates that they are not entirely satisfactory for steeper slopes because they place the seed too near the surface. Machines that place the fertilizer 2 to 3 in. deep and the seed ½ to 1 in. deep have been more successful. These results have been obtained without the use of straw mulches. Use of a good mulch would probably improve the performance of the landscape seeder on slopes to a satisfactory level.

From the information obtained on species seeded, it can be seen that most seeding mixtures contain grasses having a low density. These grasses require the seeder to pass above the soil, or to carry the seed across the swath in a stream of air or water. They cannot be thrown any distance by a spinning fan or a high-velocity, low-volume air blast that does not move air across the entire distance. Consequently, the only feasible seeders, other than those that cover all of the terrain, appear to be the hydraulic seeders, high-velocity, high-volume air blast nozzles, helicopters, and, perhaps fixed-wing aircraft. All of these have the disadvantage of placing the seed on the surface.

The Oregon Department of Highways reported excellent results from use of helicopters for seeding and fertilizing slopes. They felt that the equipment was reasonable in cost, did a good job of applying seed, was simple to maintain, and had good capacity.

In light of the wide acceptance of hydraulic seeding, the second survey asked about the performance of this machine. Considerable comment was received. In general, the quality of performance was good to excellent and the capacity was usually rated medium. The general feeling was that repairs were negligible and simple, although several persons stated that repairs were needed fairly often but were minor. Hydraulic seeders were considered reasonable in cost for the performance they gave and were believed to be quite safe. The Michigan Highway Department commented that one problem in hydraulic seeding was the large amount of water required. In rural areas the source of water may be so far away as to require a high percentage of work time for transportation thus increasing costs and lowering production. When hydraulic seeders are operated from the pavement they are unable to reach directly to the tops of long slopes. This was not considered a great problem becauses hoses can be used to reach these areas. One State pointed out that this operation required two or three extra men.

The hydraulic seeder has not given consistent results in seeding shoulders. Seedings on shoulders adjoining heavily traveled pavement, even though mulched, have often failed. These failures have been due to air currents created by high-speed traffic. In some areas, experience indicates that it is more satisfactory to drill the seed above a band of fertilizer and then cover both seed and fertilizer. In cooperative work with the Illinois Division of Highways, encouraging results have been obtained from both spring and fall applications with a "once-over" machine. This machine prepares the seedbed by penetrating the soil with either a boot or a spring tooth, places fertilizer either in the furrow or on the surface and in the furrow, and then places the seed either in the furrow or on the surface and in the furrow. Two years of trials under varying conditions of slope, soil, and weather have been very successful (Figs. 5 and 6).

From this work and from comments received in the questionnaire, it appears desirable to use more than one type of machine on a given contract. Using a seed drill or landscape seeder to place seed and fertilizer in the ground on flat and gently sloping areas should give consistently better results than placing the seed and fertilizer on the surface. On slopes, the hydraulic seeder with a proper application of straw mulch has been successful.

Fertilization Practices and Equipment

A check was made of use of fertilizers with seedings and for maintaining seedings after they had been established. Tables 10 and 11 give some of the results. Use of fertilizer with permanent seedings can be considered almost standard procedure in the continental United States, Hawaii, and Puerto Rico. In fact,

Figure 5. Seeding and fertilizing unprepared roadside with pasture dream seeder.

Figure 6. Unmodified John Deere MLF-6 used for "once-over" seeding trials.

34 out of 46 midwestern and western States said that all seedings were fertilized, and another 11 indicated occasional or frequent fertilization.

Because many States do not use temporary seedings, fertilizing them is not so common a practice as fertilizing permanent seedings. Fourteen of the 15 replied that it was either a standard practice or an occasional one.

The amount of fertilizer used on roadsides ranged from 80 to 2,000 lb per acre. The higher amounts, used primarily east of the Mississippi, exceed an average of 1,000 lb per acre. The rates used in the Plains and Mountain States are much lower, and several States use no fertilizer at all. For the country as a whole, the average rate is about 800 lb per acre. A typical analysis runs about 20 or 25 lb of actual nutrients per 100 lb. In general, a mixed or balanced fertilizer containing nitrogen, phosphorus, and potassium was used, although some States relied on nitrogen alone.

TABLE 10

FERTILIZATION PRACTICES IN CONJUNCTION WITH SEEDING ESTABLISHMENT

Region	Degree of Use[a]		Amount Used (lb/acre)		Time of Application in Reference to Seeding		
	Permanent Seedings	Temporary Seedings	Range	Avg.	% Before	% During	% After
New England	SP	-	400-1,500	930	30	70	-
Middle Atlantic	SP	SP (2), O (1)	450-1,750	1,000	18	73	9
Appalachian	SP	SP (2)	900-1,500	1,100	0	90	10
Southeast	SP	SP (1)	400-2,000	1,300	33	33	33
Delta	SP (2), F (1)	SP (1)	800-1,000	900	33	67	0
Corn Belt	SP (4), O (2)	SP (1), O (1)	500-960	700	50	50	0
Lake	SP (2), O (1)	R (1)	430-800	615	42	58	0
Northern Plains	SP (1), O (2) R (1)	O (1), R (1)	80-350	210	33	67	0
Southern Plains	SP	SP (1)	200-300	235	10	90	0
Southern Mountains	SP (1)	O (1)	250-375	300	100	0	0
Northern Mountains	F (1)	-	100-200	150	0	85	15
Pacific	SP	SP (1)	300-850	490	0	100	0
Hawaii	SP	-	1,000	1,000	0	0	100
Puerto Rico	SP	-	-	-	75	25	0
Summary	SP (34), O (9)	SP (10), O (4)	80-2,000	800	30	58	12

[a]SP = standard practice; O = occasional; R = rare; N = never; F = frequent; number of highway departments in region giving indicated reply in parentheses.

TABLE 11

MAINTENANCE FERTILIZER PRACTICES

Region	Degree of Use of Maintenance Fertilizer[a]	Type Used (%)		Time of Year Applied (No. of States)				
		Dry	Liquid	Any	Winter	Spring	Summer	Fall
New England	F (1), 0 (1), R (3)	98	2	1	0	2	1	1
Middle Atlantic	0 (6)	99	17	0	1	6	0	3
Appalachian	F (1), 0 (2), R (2)	100	0	0	0	4	0	4
Southeast	F (1), 0 (1), R (1)	100	0	1	0	2	1	2
Delta	F (2), R (1)	100	0	0	0	2	1	2
Corn Belt	R (4), N (1)	65	35	0	0	2	0	3
Lake	0 (2), N (1)	95	5	0	0	1	1	1
Northern Plains	0 (2), R (1)	100	0	1	0	2	1	1
Southern Plains	0 (2), N (1)	100	0	1	0	1	0	0
Southern Mountains	R (4)	100	0	1	0	2	0	3
Northern Mountains	0 (1)	0	100	0	0	0	0	1
Pacific	0 (3)	67	33	0	1	2	1	1
Hawaii	0	10	90	0	0	1	0	1
Puerto Rico	0	50	50	1	0	0	0	0
Summary	F (5), 0 (21), R (16)	77	23	6	2	27	6	21

[a]0 = occasional; R = rare; N = never; F = frequent; number of States using practice in parentheses.

Fifty-eight percent of the States applied the fertilizer during the seeding operation, 30 percent before seeding, and 12 percent after seeding.

Twenty-six of 42 States reported the use of maintenance fertilizers occasionally or frequently (Table 11). The remainder used them only rarely. Three of four applications of maintenance fertilizers were in the dry form, but the trend seemed to be toward liquid application. Most maintenance fertilizer goes on in the spring and fall, but spring is the favorite season in almost 70 percent of the States.

The hydraulic seeder is the popular implement for applying fertilizers, being used by 26 States (Table 12). Twenty-one States still use hand or knapsack spreading. In line with the use of farm implements, 21 States listed farm trailer fertilizer spreaders for this purpose; 7 listed lawn spreaders; 4 high speed air blast nozzles; 4 liquid sprayers; and 2 bulk fertilizer spreading trucks. Two States mentioned using the seed drill; several more probably use it but did not mention it because its primary purpose is to apply seed. One State mentioned the successful use of a salt spreader, and Oregon used the helicopter to good advantage on long slopes.

Hand spreading was used primarily on steep slopes or on small areas. Indications were that the hydraulic seeder was used to cover the most area and that its use will increase for both fertilizing and seeding. The use of sprayers to apply liquid fertilizers is increasing, especially in areas that have started using maintenance fertilizers. In addition to the States using the high-speed air-blast nozzle to apply fertilizer, Virginia is using a large fan to provide a high-velocity, medium-volume air blast to spread seed and fertilizer (Fig. 7). The New Jersey Highway Authority had promising results with the experimental use of a commercial machine having a high velocity and medium-volume air blast to apply granular fertilizers. The Oregon Highway Department reports using air blast nozzles to apply 90 percent of its fertilizer.

TABLE 12

FERTILIZING EQUIPMENT USED

Region	Number of States Using							
	Hydraulic Seeder	Hand Spreading or Knapsack	Farm Trailer Spreaders	Lawn Spreaders	Air Blast Nozzles	Sprayers	Bulk Spreader Trucks	Other
New England	3	3	0	1	0	0	0	0
Middle Atlantic	4	2	2	1	1	0	1	0
Appalachian	4	3	2	1	1	0	0	Seed drill
Southeast	1	1	3	0	0	0	0	0
Delta	2	2	2	0	1	0	1	0
Corn Belt	4	3	4	2	0	1	0	0
Lake	2	0	3	3	0	0	1	0
Northern Plains	1	0	1	0	0	0	0	Seed drill
Southern Plains	1	2	2	0	0	0	0	0
Southern Mountains	0	2	0	1	0	1	0	Salt spreader
Northern Mountains	1	1	1	1	0	0	0	0
Pacific	2	1	0	0	1	0	0	Helicopter
Hawaii	0	0	1	0	0	0	1	0
Puerto Rico	1	1	0	0	0	0	0	0
Summary	26	21	21	7	4	2	4	4

Figure 7. Applying seed and fertilizer with machine developed by Lynchburg District Shop. (Courtesy of Virginia Department of Highways)

Figure 8. Experimental three-gun assembly for applying dry fertilizer to wide rights-of-way.

The Illinois Division of Highways, in using the high-speed, low-volume air blast nozzle to spread fertilizer, indicated that it has a limited capacity for use on wide rights-of-way (Fig. 8). There was a high corrosive rate in the nozzle, causing an increase in maintenance costs and maintenance repair time. This corrosion tends to occur in the nozzle where the changes in air pressure cause cooling and condensation. This trouble may not be encountered in areas of low humidity.

The hydraulic seeder should continue to gain favor for applying fertilizer to seedings. However, where degree of slope permits, it seems desirable to place the fertilizer a few inches below the soil surface. An implement capable of working on 3:1 slopes, placing fertilizer at desired depths, and positioning the seed above it in one operation should find widespread acceptance.

Truck-mounted or trailed high-capacity dry and liquid fertilizer applicators are needed for applying

TABLE 13

MULCHING PRACTICES

Region	Mulching								Minimum Slopes Mulched	
	Degree[a]		Amount (tons/acre)		Mulching Anchored with[b]					
	Permanent	Temporary	Range	Avg.	Asphalt	Netting	Twine	Other	Range	Typical
New England	SP	SP (1)	1½ - 4	2¼	3	1	-	Brush	Flat to 2:1	Flat
Middle Atlantic	SP	SP (1), 0 (2)	2 - 3	2½	6	-	-	Soil, brush	Flat to 2:1	Flat
Appalachian	SP (3), cut slopes (1)	SP (1), R (1)	1½ - 3	2	5	-	2	-	Flat to 1:1	1½:1
Southeast	SP (2), R (1)	SP (1)	-	2	2	1	-	-	Flat to 1½:1	2:1
Delta	SP (1), 0 (2)	SP (1)	-	2	3	-	-	-	Flat to 4:1	4:1
Corn Belt	SP (3), 0 (2)	SP (1), 0 (1)	1½ - 4	2	3	3	2	Rotary mixer and mulch tiller	Flat to 2½:1	Flat
Lake	SP (1), 0 (2)	SP (1)	2 - 3	2½	3	-	2	Disking in 2	4:1	4:1
Northern Plains	SP (2), 0 (2)	-	2 - 2½	2¼	4	-	-	Mulching tiller	2:1 to 4:1	3:1
Southern Plains	SP (2), R (1)	R (2)	2	2	2	-	-	Mulching tiller	Flat to 4:1	Flat
Southern Mountains	0 (2)	0 (1)	2	2	2	-	-	-	2:1, 2½:1, 3:1	2½:1
Northern Mountains	SP (1)	-	-	-	1	1	-	Sheepsfoot roller	3:1 to 80% of area	-
Pacific	SP (3)	SP (1)	4 - 6	4	2	1	-	Sheepsfoot roller	1½:1 to 4:1	2:1
Hawaii	-	-	-	-	-	-	-	-	-	-
Puerto Rico	SP	-	-	-	-	-	-	-	Flat	Flat
Summary	SP (29), 0 (10)	SP (8) 0 (4) R (3)	1½ - 6	2	36	7	6	Mulching tiller in 4 Brush 2 Sheepsfoot roller 2	Flat to 1:1	4:1

[a] SP = standard practice; 0 = occasional; R = rarely; number of States using practice in parentheses.

[b] Number of States.

maintenance fertilizer, especially to Interstate rights-of-way. By increasing tank, pump, and nozzle capacity and using proper materials to prevent corrosion, present weed and brush control spray equipment may be converted for spraying liquid fertilizer.

A high-velocity, medium-to-high-volume air blast offers the best possibility for complete right-of-way coverage, even distribution, and high capacity in applying granular or pelleted fertilizers. In this project, good capacity and distance have been obtained with a single large outlet fan. Present and future tests will attempt to improve distribution through the use of multiple outlets and other devices.

Mulching Equipment and Practices

Twenty-nine States apply straw or hay mulch to permanent seedings as a standard practice (Table 13).

TABLE 14

MULCHING EQUIPMENT USED

Region	Number of States Using			
	Straw Mulcher	Hand Spreading	Forage Chopper	Other
New England	3	3	-	-
Middle Atlantic	5	2	1	-
Appalachian	4	3	-	-
Southeast	3	2	1	-
Delta	3	1	-	Motor patrol
Corn Belt	5	3	3	Mulching tiller
Lake	3	3	-	-
Northern Plains	2	4	1	Mulching tiller (2)
Southern Plains	1	1	-	Mulching tiller
Southern Mountains	1	2	-	Bulldozer, motor patrol
Northern Mountains	1	-	-	-
Pacific	2	1	-	-
Hawaii	-	-	-	-
Puerto Rico	-	1	-	-
Summary of Users	33	27	6	Mulching tiller (4)

Figure 9. Applying straw sprayed with asphalt with mulch blower. (Courtesy of Virginia Department of Highways)

Ten States apply mulch occasionally. Of those States using temporary seedings, 8 indicated that the use of mulch on the seeding was standard practice, and 4 said that it was an occasional practice. The amount per acre ranged from $1\frac{1}{2}$ to 6 tons. Inasmuch as a large number of States indicated the use of about 2 tons per acre; 2 tons per acre may be considered standard practice for most areas.

Varied practices are followed in mulching. In areas where bermudagrass is used on roadsides, some States use a sod mulch containing bermudagrass roots, especially on the steeper slopes. The North Dakota Highway Department has successfully used barnyard manures as mulch. It consists primarily of straw and animal manure which anchors the soil in place and adds some vital nutrients, including chelates. At least one State has been successful in mixing the seed with the mulch as it is applied.

Thirty-six States said they used asphalt to anchor the mulch, 7 used netting, 6 used twine and pegs, and 4 used the mulching tiller to push the mulch into the soil and hold it. Two used brush and 2 used the sheepsfoot roller. One State used a rotary mixer to mix the soil and mulch; another used soil thrown onto the straw.

A high percentage of States used mulch on nearly all areas, sloping or level. This was especially true east of the Mississippi except for the Lake States. Of the States not using the mulch on flat areas, many started using it on slopes as shallow as 4:1 and a few on slopes that were 2:1 or $1\frac{1}{2}$:1.

Table 14 gives by regions the equipment for applying these mulches. Thirty-three States used the mulch blower or straw mulcher (Figs. 9 and 10). Spreading mulch by hand is still done in 27 States. Six States reported using forage choppers to apply mulch. Other equipment included the mulching tiller, used by four States; the motor patrol, by two States; and the bulldozer, by one State.

The response to queries on the performance of mulch blowers was good. In general, the mulch blower is considered to be good to excellent in quality of performance, to have a medium capacity, to be fairly re-

Figure 10. Using canvas extensions on mulch blower. (Courtesy of Virginia Department of Highways)

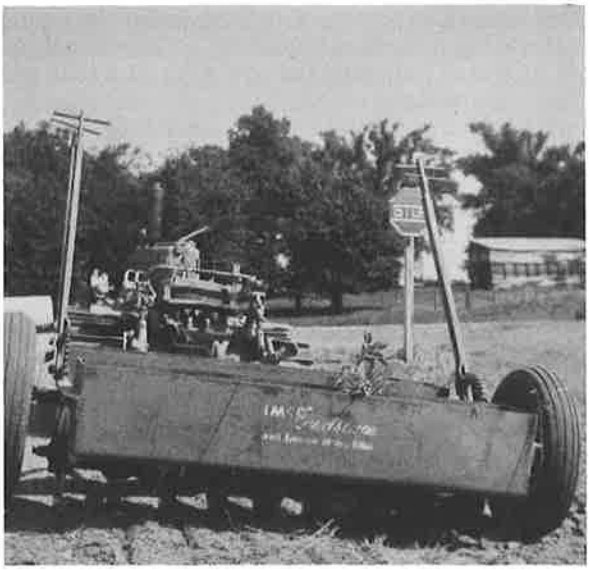

Figure 11. Anchoring straw mulch with Imco soil erosion mulch tiller. (Courtesy of Iowa State Highway Commission)

liable, and not to be easily damaged. For quality of performance, it is considered reasonable in cost and safe from the standpoint of stability. In general, repairs were reported to be negligible and routine maintenance simple. Some criticisms were that (a) it is dependent on the operator for even application and for proper rate of application; (b) the machine breaks the straw into too many small pieces, making it difficult to hold in place and thus less effective; (c) performance is mediocre, capacity is medium for cost, and repairs and maintenance are time consuming; (d) the method of feeding the baled straw or hay into the blower needs improving; (e) length of throw should be greater (Fig. 10); and (f) the strands of straw or hay are not separated as completely as they should be and fall into irregular clumps that smother the grass.

At least two States have tried the farm forage chopper for spreading mulch. One found that it gave a longer throw and more even distribution than the commercial mulch blower but cut the mulch too short. The other reported that the machine gave mediocre performance, was dangerous to operate, and needed too much time for repair and routine maintenance. In general, the majority of users were satisfied with the mulch blower type of machine, although some felt that it should be improved to provide a longer throw, a better feeding mechanism, and a mulch of individual strands rather than short pieces.

Other machines were used primarily to anchor the mulch after it was spread. The most common machine of this type was a mulching tiller (Fig. 11). Four States using the mulching tiller indicated its performance to be good to excellent. One State requires all mulch to be anchored by this method, reporting that the mulch was well anchored, and that the seedings emerged along the lines of penetration of the disk in such fashion as to give good erosion resistance. The users have found this mulching tiller to be a medium-capacity machine that is both reliable and safe. It is not easily damaged, and repairs and maintenance have been simple.

Modifying the sheepsfoot roller so that it leaves depressions along the slopes similar to those left by the mulching tiller has made it more satisfactory than the original. The modification has been accomplished by welding heavy plates to the circumference of the roller in staggered fashion, with the plates always perpendicular to the axis of the roller. Two farm implement manufacturers produce a mulch treader that has been used successfully in heavy wheat straw to shred, spread, and mix the straw with the topsoil.

In areas where heavy runoff occurs, interest is high in replacing straw mulch with something better and cheaper. Although straw mulches have been satisfactory on slopes in most areas, there is the problem of procuring adequate quantities and providing proper storage so that the mulch will spread well. Another reason for interest in other methods or materials is the frequent contamination of the straw or hay with weed seed. The mulch often introduces new weeds into an area, with resultant complaints from adjacent land owners.

Various materials have been tried with varying degrees of success. Materials undergoing tests at this time include a wood pulp product, various petroleum derivatives, other chemical compounds, fiber mattings of both organic material and glass fibers, wood chips, and corn cobs. Many of these materials have worked satisfactorily under certain conditions and will certainly find expanded use as knowledge of their performance grows and costs are lowered.

Sodding and Topsoiling

The States were questioned concerning their use of sodding (Table 15). Although some agencies listed use of sod as standard practice, in most cases it was considered to indicate a practice of sodding areas where needed rather than of sodding all roadside areas. The use of sod is most general in the Corn Belt, 4 States using it on drainage areas, 2 in front of residences, and 2 for other purposes. The drier western States used little sod. Six States listed sodding as standard practice, 8 reported it as an occasional practice, 10 used it in drainage areas, 6 used it in urban areas, and 7 rarely used it.

Several highway departments indicated their interest in decreasing the use of sod for reasons of cost and availability. One State hopes to replace sod almost completely with fiber matting. With proper seeding

TABLE 15
SODDING AND TOPSOILING PRACTICES

Regions	Degree of Sodding[a]	Extent of Topsoil Use (No. of States)						Depth of Application (in.)		No. of States Using Fertilization of Topsoil	
		Cuts and Fills	Medians	Shoulders	Residential Areas	All	None	Range	Avg.	Yes	No
New England	0 (1), R (2), D (1)	2	5	1	3	1	0	2 - 6	4	5	1
Middle Atlantic	R (4), D (3)	1	3	0	1	2	0	2 - 6	4	6	0
Appalachian	U (2) R (1)	Slopes less than 1½:1 (1)	1	0	1		2	1 - 2	2	4	0
Southeast	U (1), 0 (1)	1	1	0	1	0	1	3 - 4	4	2	0
Delta	0 (2), SM (1)	1	0	Fore-slopes (1)	0	0	2	4	4	1	0
Corn Belt	D (4), RE (2), 0 (2)	Poor soils (1)	0	0	1	Sandy areas (2)	2	4 - 8	6	4	1
Lake	SP (2), D (1)	Cuts and fills and poor soils (1)	0	0		2		4 - 6	4.3	2	1
Northern Plains	SP (1), U (1), D (1), 0 (1)	Sandy cuts and fills (1)	0	0		All (1) 50% (1)	1	2 - 6	3.7	1	2
Southern Plains	SP (1), A (1), 0 (1)	1	0	0			1		4	1	0
Southern Mountains	None	2	0	0		Some (1)	2	2 - 6	3	2	1
Northern Mountains	None	0	0	0		0	1		4	0	1
Pacific	None	2	0	0	1	0	Rarely	2 - 6	4	3	0
Hawaii	SP		1	1					4	1	0
Puerto Rico[b]	SP										
Summary of use	SP (6), 0 (8), R (7), D (10), U (6)	14	12	3	8	6	13	1 - 8	4	33	9

[a]SP = standard practice; O = occasional; R = rare; D = ditches; U = urban areas; RE = residences; SM = sod mulch; A = all slopes; number of States using practice in parentheses.

[b]Medians and intersections.

and fertilizing under the matting, a good sod will replace the matting by the time it rots. This is merely growing the sod in place rather than placing it there from another source.

Several States indicated a need for improving equipment for cutting and placing the sod. Sod cutters could be improved by reducing tearing along the edges of the cut strip to provide more usable sod. Sod cutters are needed that will provide more precise control of the cutting depth, as thickness of sod affects rate of survival under adverse conditions and speed of rerooting in the new location.

The other area of concern was for equipment to place sod on slopes. An Illinois contractor has developed a conveyor belt mounted on a boom that can be varied to a length of 100 ft. The boom is counterbalanced and placed on a heavy truck. The boom-carrying truck is about 11 ft wide, allowing pallets of sod to be winched on it from a supply truck. One man then places the sod on the conveyor belt, which runs up the center of the boom. The boom, hydraulically controlled in swing and lift, moves up and down the slope as needed and delivers the sod to the point of placement. This equipment eliminates the eight or ten men normally used to carry sod up the slope. One of the disadvantages of using manpower to carry sod is loss of condition resulting from numerous handlings before the sod is laid. It arrives in much better condition when delivered by conveyor.

Table 15 also summarizes the replies on topsoiling practices. In the New England and Middle Atlantic States, the major reason for topsoiling seems to be to establish good cover quickly on the medians, intersections, and shoulders to provide a good appearance. For this purpose, residential and urban areas are usually topsoiled. In other States, the main reason for topsoiling is to obtain quicker cover to control erosion. Hence, most topsoiling is on cuts and fills, sandy areas, and poor soils.

Depth of topsoil varied from 1 to 8 in., but was surprisingly uniform, 22 of the 40 States applying it 4 in. deep. Application depth tended to be less in the Appalachian, Mountain, and Plains regions. Use of topsoil was most frequent east of the Mississippi River. Most of the eastern States fertilized the topsoil. A high percentage in the Midwest and West did not fertilize topsoil.

The construction industry has developed adequate equipment and methods for applying topsoil to roadsides. One commercial machine for stockpiling loose materials (such as coal, gravel, and dirt) is capable of throwing these materials approximately 100 ft. With the proper deflectors or nozzles, this machine might be adapted for trailing behind trucks or for picking up previously windrowed topsoil and spreading it uniformly and rapidly on long slopes.

From the experience of highway personnel in Illinois, there is a need for equipment to help anchor topsoil in place after it is applied. Often the topsoil is applied to a previously well-smoothed surface. When the slope is steep and heavy or prolonged rains occur, the topsoil often slides down the slope along the plane between it and the surface to which it was applied. Certain equipment might be useful in developing a bond between the original surface and the topsoil: (a) equipment to roughen the original surface so that the topsoil will blend with it, and (b) equipment to travel the contour of the slope and blend the topsoil with the original soil either on the entire slope or in contour strips.

Roadside Stabilization Materials Other Than Turf

Thirty-five of the 52 State and thruway authorities replying to the questionnaire said they used materials other than turf to stabilize some roadside areas. Such areas include cuts and steep slopes, bridges and slide areas, drainage areas, and areas of wind erosion or sandy soils. Commonly mentioned were roadside shoulders, which were stabilized for traffic purposes with concrete or asphalt, so this purpose was considered outside the area of roadside cover stabilization.

The common roadside stabilization materials were shrubs and vines: 12 departments used vines and 9 used shrubbery. Two used trees and evergreens, and a significant number (8) used aggregates.

The plant materials were usually installed by hand on fairly steep slopes. The aggregate materials were usually applied with construction equipment. In general, the highway departments were satisfied with the results obtained from the use of plant materials but were not satisfied with the methods of installing the materials on the slopes. The main deterrent to greater use of vines, shrubs, and woody ground cover is the high cost of placing them on slopes rather than the cost of the materials themselves. In this regard, two operations need to be mechanized: (a) digging the holes or trenches in the proper places with the proper spacing, and (b) planting the materials. The most urgent need from a labor-saving standpoint is mechanized digging of holes or trenches.

ROADSIDE MAINTENANCE PRACTICES AND EQUIPMENT

Mowing of Roadsides

In the supplemental questionnaire, a check was made of the amount of mowing and the types and numbers of mowers. In all 12 regions, replies were sufficient to permit a projection of the mileage mowed, the acreage mowed, and the number of different types of mowers used in the entire region. This information was either tabulated or computed where projections were needed and is given in Table 16.

Much of the yearly mileages and acreages mowed were concentrated in the regions eastward from the Great Plains. The Corn Belt had the highest yearly acreage mowed, and the largest number of mowing units. The Northern Plains region, mowing a larger acreage than the Appalachian States, used fewer units to do the job. Almost one-half of the mowing units were concentrated in the Middle Atlantic, Appalachian, and Corn Belt regions. A good share of the remainder were in the Southeast and Lake regions. The total of more than 3,500,000 acres mowed per year equals the acreage of forage crops grown in some of the larger agricultural States. The total number of mowers, almost 18,000, is as many as are owned by farmers in some of these States. These figures indicate that roadside mowing is a good-size industry that will increase with completion of the Interstate system. In many cases, when new highways replace old ones, the

TABLE 16
NUMBERS AND USES OF TRACTOR MOWERS

Region	Yearly Mileage Mowed	Yearly Acreage Mowed	Percentage of Mowers State Owned	Number of Sickle Bar Mowers	Number of Rotary Mowers	Number of Other Tractor Mowers
New England	18,400[a]	64,000[a]	52	536[a]	75[a]	80[a]
Middle Atlantic	59,134	155,520	90.5	1,953[a]	540[a]	420[a]
Appalachian	94,430[a]	386,750[a]	100	2,071[a]	541[a]	0[a]
Southeast	61,000[a]	257,900[a]	100	736[a]	1,056[a]	96[a]
Delta	32,800	337,200[a]	99.7	791	632	6[a]
Corn Belt	84,200	815,500	98	2,364	1,178	268
Lake	31,500	384,400	33	1,060	166	86
Northern Plains	31,390	499,000	100	970	358	78
Southern Plains	51,000	479,000	42	233[a]	650[a]	60[a]
Southern Mountains	15,000[a]	30,000[a]	100	210[a]	103[a]	0[a]
Northern Mountains	14,700[a]	34,500[a]	100	148	16	0
Pacific	25,800	84,000	97	206	84	15
Hawaii	-	1,090	100	4	25	11
Puerto Rico	-	-	100	16	44	28
Total: Projected or averages	519,354	3,527,770	90.8[b]	11,279[b]	5,399[b]	1,109[b]
Actually submitted	449,353[c]	2,698,191[c]	90.8[c]	9,901[c]	4,319[c]	1,097[c]

[a]Projected for region on basis of replies, road mileage, and area.

[b]Projected totals or averages for continental United States.

[c]Totals or averages based on replies to questionnaire.

old ones do not revert back to their original land use but are used for local roads. Consequently, the new highways add directly to the total roadside acreage. Four-lane highways with 300-ft rights-of-way and frequent interchanges add about 30 acres of roadside per mile. When the Interstate system is completed, another million acres of roadside will require mowing and other maintenance operations.

From Table 17, it is shown that each mower mowed an average of 29.2 mi or 198 acres per year. An average production figure of 0.7 acre per hour (obtained from replies on rotary and sickle bar mower capacities), revealed an average yearly use of 270 hr per mower.

The total number of sickle bar mowers calculated to be in use from 41 replies to this question was 11,278. The total number of rotary mowers calculated from 39 replies was 5,399. The total number of other mower types estimated to be in use was 1,109. Two States using rotary mowers indicated dissatisfaction with their tendency to throw objects. Hammer-knife and reel-type mowers were in a minority, 317 hammer-type units and 234 reel-type being reported.

Highway agencies were asked what percentage of mowing was done by different types of mowers in their States or on their tollways (Table 18). Replies showed that most of the mowing was done by the tractor sickle bar and rotary mowers (60.5 and 28.5 percent, respectively). The amount of mowing indicated with rotary mowers is 47.1 percent of that with the sickle bar mowers. The number of rotary mowers projected for the continental United States is 47.9 percent of the number of sickle bar mowers, so the two ratios are quite close. Tractor reel-type mowers did 4.7 percent of the mowing in the eastern half of the United States and on the turnpikes and super highways. Almost 5 percent was done with walking power mowers. Five percent of the more than 3.5 million acres reported would be about 175,000 acres, which is a large acreage to mow with this type of mower with its slow speed and narrow cut. The agencies indicated that about 1 percent of their mowing was done with hand tools. It is estimated that, including areas around bridges and guardrails with the steeper slopes, the figure for hand mowing may be as high as 3 percent, or more than 108,000 acres per year.

In all but three regions, State or other highway agencies owned almost 100 percent of the mowers they used. These three regions were the New England, Lake, and Southern Plains States.

The hammer-type mower, indicated by two States as the most desirable, was used on only 0.6 percent of the total acreage.

With regard to the relative stability of the sickle bar and rotary mower on slopes, a definite difference

TABLE 17

SUMMARY OF MOWING INFORMATION

Item	No. of Replies	Value
Amount of Mowing, Mower Numbers, and Capacity:		
Total mileage mowed per year (projected)		519,354
Total acreage mowed per year (projected)		3,527,770
Average acreage mowed per mile		6.8
Total number of tractor mowers (projected)		17,786
Miles mowed per mower per year		29.2
Acreage mowed per mower per year		198
Total number of tractor sickle bar mowers (projected)		11,278
Total number of tractor rotary mowers (projected)		5,399
Total number of hammer type (reported)		317
Total number of reel type (reported)		234
Sickle bar mower use per year (hr)	13	341
Sickle bar mower (acres/hr)	11	0.67
Rotary mower use per year (hr)	10	519
Rotary mower (acres/hr)	9	0.75
Hammer mower (acres/hr)	3	0.65
Reel mower (acres/hr)	2	2.7
Mowing Costs (dollars):		
Sickle bar mower, operating costs per acre	6	3.32
Sickle bar mower, repair and maintenance costs per acre	7	1.67
Sickle bar mower, total operating, repair and maintenance costs per acre	6	4.61
Rotary mower, operating costs per acre	6	2.37
Rotary mower, repair and maintenance costs per acre	5	1.32
Rotary mower, total operating, repair and maintenance costs per acre	9	3.92
Total mowing costs per acre	4	10.21

TABLE 18
MOWING PRACTICES

Region	Percentage of Mowing Done by Different Mower Types: Tractor Sickle-bar	Tractor Rotary	Tractor Reel	Tractor Hammer Knife	Walking Power	Hand	Mowings per Year	Most Satisfactory Mower Type	Steepest Slopes Mowed: Tractor Sicklebar	Tractor Rotary
New England	75	12	5	0	2.2	5.8	2	Sickle, hammer knife	2:1	2:1
Middle Atlantic	59	16	12	4	9.0	0	3	Reel, rotary	2.5:1	2.5:1
Appalachian	85	14	0	0	0	1	3	Combined sickle and rotary	2.5:1	4:1
Southeast	54	42.4	0.3	0	3.3	0	3	Rotary, combined sickle and rotary	2:1	3:1
Delta	60	33.3	3.3	0	3.4	0	3+	Rotary, sicklebar	2:1	3:1
Corn Belt	53	36.8	4.2	4	1	1	2+	Rotary, sicklebar, and combinations	2.5:1	3.5:1
Lake	75	15	3.3	-	5	1.7	2	Rotary, sicklebar on some areas	3:1	3:1
Northern Plains	56	38.5	0	0	5.5	0	2	Rotary, sicklebar on some areas	3:1	3:1
Southern Plains	20	67	5	0	5	3	2+	Rotary	3:1	3:1
Southern Mountains	77	22	0	0	0	1	1+	Rotary	3:1	3:1
Northern Mountains	91	9	0	0	0	0	2	Rotary, sicklebar	3:1	3:1
Pacific	63	32	3	0	2	0	2+	Rotary, sicklebar, hammer knife	2.5:1	3:1
Hawaii	30	10	30	0	30	0		All have place	2:1	3:1
Puerto Rico	50	50	0	0	0	0		Sicklebar	4:1	-
Avg. for U.S.	60.5	28.5	4.7	0.6	4.8	1.0	2.5	Rotary (10), sicklebar (8), combination sickle and rotary (3), hammer knife (2), and reel (1)	2.6:1	3.3:1

was found. For the entire country, the average for the steepest slopes mowed with the tractor sickle bar mower was 2.6:1, whereas the average with the tractor rotary was 3.3:1, a marked difference in the degree of slope the two types of mowers can traverse.

The number of mowings per year varied from none on roadsides in the most arid western States to 12 or 15 on some of the highly maintained eastern expressways. The average for the different regions was only 1+ mowings per year to 3+ mowings per year. The average for the entire country was 2.5.

When asked whether all areas were mowed each time mowing was done, 14 agencies replied affirmatively and 30 replied negatively. Of the areas skipped, 11 were steep cut and fill slopes, 6 were those not needing mowing, 6 were outsides of shoulders, 4 were backs of ditches, and 2 were back slopes.

Thirty-six agencies reported that they hand-mowed weeds and grass around hand rails and bridges, 12 indicated that they did not, 28 said they used soil sterilants to control weeds and grass, and 21 used both hand mowing and soil sterilants.

Thirty-nine States reported using hand tools to control vegetation on steep slopes. Many tried herbicides to reduce the need for mowing the steeper slopes. Some used low-growing ground covers to eliminate the need for mowing. Six used small, self-propelled walking mowers on the steeper slopes. One of the six used a dual-wheel sickle bar mower which had good traction and performed well.

A check of the height of the roadside cover before and after mowing showed a wide range in the amount of growth permitted before cutting in certain regions. The amount of growth permitted on different roads in any one State also varied considerably. Cover height permitted before cutting ranged from 6 to 36 in., with an average of 13 in. After mowing there was more uniformity, the height ranging from 2 to 6 in. Cutting height was greater in the western regions than in the eastern area, and the average for the entire United States was 3.6 in.

Table 17 also gives average cost figures based on mower performance and mowing costs.

The sickle bar mower was used on an average of 341 hr per year and its capacity was 0.68 acre per hour. The rotary mower was used 519 hr per year and had a capacity of 0.75 acre per hour. The hammer-type mower had a capacity of 0.65 acre per hour; and the reel-type mower, 2.7 acres per hour. The higher capacity for the reel-type mower is due to its use in wide-gang units on flat, easy-to-mow median strips and other flat areas.

The operating costs for the sickle bar mower were $3.32 per acre; repair and maintenance costs were $1.67 per acre. Total operating, repair, and maintenance costs for the sickle bar mower were $4.61 per acre. Operating costs for the rotary mower were $2.37 per acre, repair and maintenance costs were $1.32 per acre. Total operating, repair and maintenance costs for rotary mowers were $3.92 per acre compared with $4.61 per acre for the sickle bar mower.

Four States reported a total mowing cost per acre; the average of these four figures was $10.21 per acre. To compare the figure for total mowing costs, the total per acre cost for each type of mower was computed on the basis of capacity and percentage of mowing done. With this weighting, a figure of $6.02 per acre was obtained as operating, repair, and maintenance costs of mowing. Adding to this figure a reasonable charge for labor, depreciation, insurance and interest gave a total mowing cost of $10.21 per acre.

One State provided figures for the fiscal year 1958-59. The cost per mile for removing and burning weeds, removing debris, planting trees and shrubs, seeding, sodding, and mowing was $102, or 11.15 percent of the total maintenance budget.

Eighteen States indicated that they had no cover destruction from mowing, 17 indicated some destruction, 8 said it was fairly common, 6 indicated they had some, and 3 indicated a minor amount. Twelve States said the sickle bar mower was responsible, 7 said the rotary. Inasmuch as the sickle bar is used in hard-to-mow areas where the mowing is less frequent and growth is heavier and taller, it is understandable why it is listed more often.

With the increasing use of rotary mowers and expanded herbicide programs in most States, interest in changing mowing practices is evident. The Michigan Highway Department has inaugurated a type of mowing called "contour mowing" which is done on the wider rights-of-way along rural truckline highways (Fig. 12). Mowing is limited to areas within an average of 5 ft above and 5 ft below the pavement grade. If any portion of a cut slope exceeds the vertical dimension in excess of 5 ft, it is left completely unmowed. The mowing limit is the toe of the cut slope. Likewise, if any portion of the fill slope is more than 5 ft in vertical depth below the pavement grade, it also is left unmowed, except that a mowing limit is established down the slope to a line paralleling the highway which conforms to the toe of a cut slope normally 20 ft from the edge of the pavement. Transitions from mowing areas within this 10-ft range of plus or minus 5 ft are made by long sweeping mowing curves following the roadside contours. The Michigan Highway Department feels that this type of mowing will reduce costs, keep the appearance of the roadside presentable, and is more adaptable to use of the rotary-type mower. This attitude reflects the increased recognition of all the agencies of mounting costs of roadside mowing, the increased effectiveness of spraying, and the need for revising past mowing practices.

Several general statements can be made about the different types of mowers. In general, a rotary mower is less expensive to operate and has a higher hourly capacity than a sickle bar mower. The rotary mower does not operate on steep slopes so well as a sickle-type mower, but it operates at a faster speed in areas where mowings are more frequent or the grass is not thick. It has the disadvantages of throwing

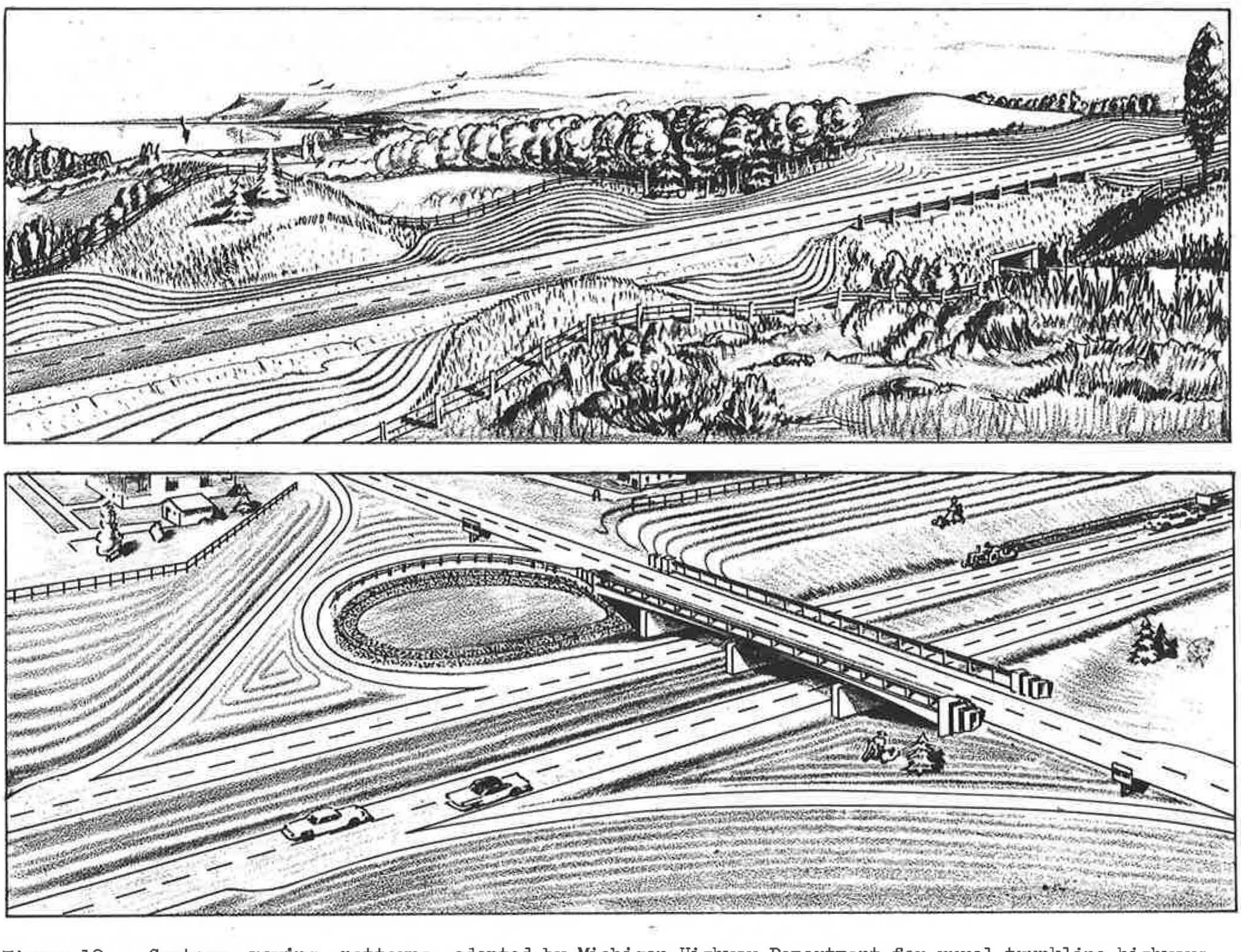

Figure 12. Contour mowing patterns adopted by Michigan Highway Department for rural trunkline highways. (Courtesy of Michigan Highway Department)

objects which may be dangerous to highway personnel and to motorists, of scalping the sod where abrupt changes in contour occur, and of causing the ends of the grass to appear burnt when mowing is done with dull blades.

A sickle bar mower operates better on steeper slopes because the side-mounted sickle bar can be placed up the slope, transferring weight to the upper wheels (Fig. 13). Because it has a lower power requirement than other types of mowers, it uses less fuel per acre. It is better than other types for use on older narrower highways and on steep, short slopes. Its disadvantages are lower capacity, higher repair and maintenance costs than the rotary, and frequent need to operate from the pavement in cutting shoulders.

A hammer knife mower (Fig. 14), which uses small, light knives, does not throw objects as the horizontal rotary mower does. In tall, heavy growth, however, it requires more power than either the sickle bar or the rotary mower. Its repair and maintenance requirements are higher than the horizontal rotary and perhaps as high as the sickle bar mower.

The number of knives on a new hammer knife mower developed by a major farm implement company has been reduced 75 percent through the use of larger, heavier knives (Fig. 15). Tests have shown that this type is equal in performance to the light knife mower, and has the advantages of faster knife replacement and more flywheel energy for handling heavy vegetation.

A reel-type mower can be used only where the ground is relatively flat and mowings are frequent. In such areas the use of a gang of several mowers provides high capacity with low power requirement and fairly low repair and maintenance costs (Fig. 16).

On wider rights-of-way, several States have had excellent results with center-mounted and pull-type rotary mowers having as wide a cut as 15 ft. Experience with hydraulically driven sickle bar mowers has been excellent, and most of those using sickle bar mowers plan to change to this type of drive (Fig. 17). The hydraulic drive costs more originally but has lower repair and maintenance costs due to its tendency to stop when clogged rather than to break parts. On steeper slopes and around guardrails where hand mowing has been required in the past, several States have successfully used small self-propelled walking sickle bar mowers. In Illinois and several other States, the use of side- or front-mounted rotary mowers on tractors with low-pressure, high-flotation tires has shown them to be excellent for mowing slopes as steep as 2:1 (Fig. 14). One company has designed a side-mounted hammer knife mower for use on a small garden tractor. It has a special transmission for slow speeds and a low center of gravity for use on steep slopes. Trials with this machine have shown it to give fair performance but to be slightly underpowered under some conditions.

Side-mounted rotary mowers used with modern tractors having quick reverse gears make it possible for them to be the equal of sickle bar mowers on steep slopes. They have the additional advantage of being capable of mowing in either direction, which is not the case with the sickle bar. The rear-mounted and center-mounted rotaries have been satisfactory for most rights-of-way except the steep slopes (Fig. 18).

Figure 13. Low-center-of-gravity dual-wheel tractor with sicklebar. (Courtesy of Jacobsen Manufacturing Company)

With the increasing number of expressways and Interstate highways, more roadsides are being maintained at the parkway level. In such areas, which must be mowed frequently, gang-type reel mower units have worked well and are increasing in use. Experience with the hammer-type mower in either single or gang units has been fair and their use is likely to increase as the design is improved.

Manufacturers and highway agencies have rapidly improved both mowing equipment and practices in recent years. Several new machines and special tractors to drive them have been developed. The main needs now are for higher capacity tractor-driven mowers for use on steep slopes and for satisfactory equipment for mowing around guardrails, signs, and other obstacles. A number of States and agencies indicated the need for several types of mowers for use on slopes. The most commonly expressed need was for tractor-mounted mowers, but there was also a demand for self-propelled, engine-powered walking mowers and shoulder-operated mowers for slope use. In conjunction with this is a high demand for tractors for use on side slopes. One company in Michigan is now making a mower attachment for tractors which is designed for mowing around guardrails. The

Figure 14. Hammer knife mower on tractor with low-pressure tires. (Courtesy of Topeka Hiway Mower Inc.)

Michigan Highway Department was interested in its performance when demonstrated and has purchased six units for use on a trial basis.

In summary, much improvement has been made in equipment and tractors for mowing standard rights-of-way. There is a need for improvement in tractor-mounted mowers and tractors for use on steeper, hard-to-mow slopes. There is also a need for development of mowers for mowing around guardrails, signs, and other obstacles. One mowing method that has been tested on steeper slopes by at least one State is to take the operator off and operate the machine by remote control. This would make it possible to build a lighter machine with a lower center of gravity which could operate on steeper slopes without the drive wheels tearing the sod.

Chemical Roadside Cover Control

The use of chemicals to control weeds and brush on roadsides has become common, and indications are that the practice will increase. In 1960, 39 States were using herbicides in roadside spray programs. Thirty-two said they were using chemicals to supplement mowing (Table 19); 3 said they were using them only to kill weeds, with no relation to mowing. Twelve States using spray programs reported that spraying had not reduced mowing. Fifteen States, or about 50 percent of those reporting, felt that their spray programs

Figure 15. Hammer knife mower with larger and fewer knives (Courtesy of Deere & Company).

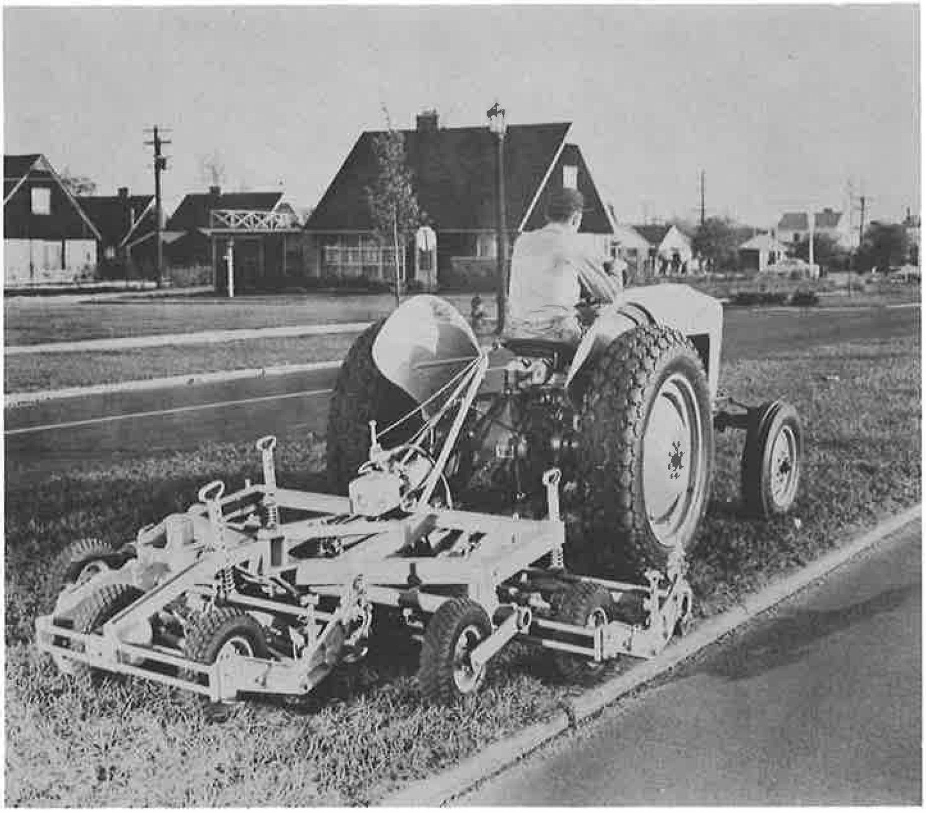

Figure 16. Gang-type reel mower used on flatter roadside areas. (Courtesy of Roseman Mower Corporation)

had eliminated one mowing. Five said it had eliminated two mowings, and 1 said that it had eliminated three. Sixty-eight percent of those reporting believed that spraying had eliminated one or more mowings.

Nineteen States using definite spray programs were spraying only once a season, 10 sprayed twice each season, and 4 sprayed three times. Six indicated they sprayed when required to do so by weed growth.

Regions using spray programs to the greatest extent were the New England, Middle Atlantic, Corn Belt, Lake, Southern Mountain, and Pacific.

The use of soil sterilants around such obstacles as signs and guardrails paralleled the use of post-emergence weed and brush sprays. The same regions using weed sprays reported the highest use of soil sterilants. Inquiries about weed control around these obstacles showed that 37 States still used hand mowing, 32 used soil sterilants, and 4 used weed sprays. Many States used a combination of two or three

TABLE 19

HERBICIDE PRACTICES BY NUMBER OF STATES

Region	Herbicidal Spraying to Supplement Mowing		Mowings Eliminated by Spraying				Number of Roadside Sprayings per Year					Weed Control Around Obstacles		
	Yes	No	None	One	Two	Three	None	One	Two	Three	AR[a]	By Hand Mowing	By Soil Sterilants	By Selective Herbicides
New England	5	1	1	4	0	0	2	2	2	0		3	2	0
Middle Atlantic	4	1	3	2	2	1	1	4	0	2		5	4	2
Appalachian	2	3	4	0	1	0	3	1	0	1		5	3	1
Southeast	1	2	2	0	0	0	2	0	0	0	1	3	1	0
Delta	0	3	3	0	0	0	2	1	0	0		2	2	0
Corn Belt	5	0	2	3	0	0	0	2	4	1		5	2	0
Lake	3	0	1	2	0	0	0	0	2	0	1	3	3	0
Northern Plains	2	2	4	0	0	0	2	0	2	0	2	3	3	0
Southern Plains	0	2	2	0	0	0	1	1	0	0		2	2	0
Southern Mountains	5	0	3	2	0	0	0	3	0	0	2	3	4	1
Northern Mountains	1	1	1	1	0	0	0	2	0	0		1	2	0
Pacific	3	0	1	1	1	0		2	0	0	1	0	3	0
Hawaii	1	-	0	0	1	0	<--------Year-round program------->					1	1	0
Puerto Rico	-	1	1	0	0	0	0	1	0	0		1	0	0
Summary	32	16	28[b]	15	5	1	13	19	10	4	7	37	32	4

[a]As required.

[b]Includes 16 States not spraying.

Figure 17. Hydraulically driven sicklebar mower. (Courtesy of New Jersey Highway Department)

methods; 13 relied on hand mowing alone, 10 on use of soil sterilants alone, and none on weed sprays alone. Of those using soil sterilants, 10 felt that results were good to excellent; 16, mediocre; and none, poor.

Because of the high cost of mowing, many States have become interested in the possible use of growth inhibitors to decrease the number of mowings. Growth inhibitors have been developed to the point where a few States along the eastern seaboard have used them to a limited extent for several seasons with encouraging results. Several midwestern States, including Illinois, experimented with their use during the 1961 season. Growth inhibitors, if successful, appear to have two promising areas of use. One is where slopes are steep or the presence of many obstacles cause mowing costs to be high because of the need to use small-power equipment or hand mowing. Eliminating even one mowing in such an area would justify a sizable expenditure for growth inhibitor application. The other area of use is in high-maintenance areas, such as the medians and outer shoulders of expressways and Interstate highways, and the fringe areas of large cities. An effective growth inhibitor might decrease the number of mowings from 10 or 12 a year to 2 or 3, again justifying a sizable application cost.

The increasing use of post-emergence weed and brush sprays has attracted a sizable contract spray business. These contractors, as well as many State maintenance forces, have in large measure developed their own roadside spray booms (Fig. 19). They started with basic spray rigs and made their own modifications. Unfortunately, many of the accessories on the market were designed for agricultural spraying, under

Figure 18. Small center-mounted rotary mower. (Courtesy of New Jersey Highway Department)

conditions different from those on roadsides. For example, broadcast-type nozzles are usually used in spraying roadsides, and, due to the speed of spraying desired, are relatively high capacity. With varying roadside widths due to changes in rights-of-way and cuts and fills, one or more of the broadcast nozzles will be turned on and off. The result is a higher flow rate than in agricultural spraying. Pressure regulators have been used which were satisfactory for agricultural spraying but which permit too much variation in pressure for roadside spraying. These variations tend to vary the particle sizes and causes more drift than is desirable. Mistakes have been made in designing and constructing booms. Use of too small fittings and hoses has contributed to a wide variation in pressures when flow rates were changed. Pressure gages have been placed where they were easily damaged when valves were closed, making it impossible for the operator to know the true spraying pressure. Frequently the major portion of the cost of the spray rig has been for a high-pressure pump and a large engine to power it. For roadside spraying it is desirable to maintain nozzle pressures well under 40 psi, which requires only a single cylinder engine producing five or six horsepower, even at the higher volumes used in roadside spraying. The saving incurred by using the proper size of pump and engine can be used for larger fittings, reduction-type pressure regulators, and other accessories to maintain proper pressures during variations in flow rates.

An encouraging development has been the increasing interest of established sprayer manufacturers in developing roadside spray equipment (Figs. 20 to 22). At least one "long-time" farm equipment manufacturer who produces agricultural-type sprayers has become interested enough to develop a roadside sprayer using some of the principles previously mentioned. At present this company has incorporated an adjustable swath-width nozzle assembly in its roadside spray boom design. This adjustable nozzle assembly replaces the broadcast-type nozzle at the boom end and enables the operator to vary the outer reach of the nozzle in 4-ft increments over a 20-ft swath from the boom end to the edge of the rights-of-way (Fig. 23).

The main problem in the field of roadside spray equipment is to develop sprayers specifically for roadside use and a readily available parts supply system for them. There will be a need to develop sprayers not only to spray weed control chemicals accurately, but also to apply liquid fertilizers for maintenance purposes. That will necessitate the use of non-corrosive materials in the sprayer and will require pumping more gallons than are used in spraying weeds. If the use of growth inhibitors develops, these same sprayers will need to apply more gallons for that purpose and will probably need to apply the chemical more evenly across the swath than is required in weed spraying. Another need is to develop sprayers for use on extremely wide rights-of-way, interchanges, and other areas where spraying cannot be done from the road.

With the increased use of soil sterilants to control weeds around obstacles, there is a need to develop both granular and liquid applicators that will apply the chemical to these areas with little escape of chemical to adjacent areas. A definite erosion problem occurs if the chemical is allowed to drift to areas outside the guardrail at the top of fill slopes. Equipment has been developed on a custom basis that appears to do a satisfactory job, but it is not widely available. When sprayer manufacturers recognize the need and the market potential for different equipment for roadside spraying this development can be expected to progress rapidly.

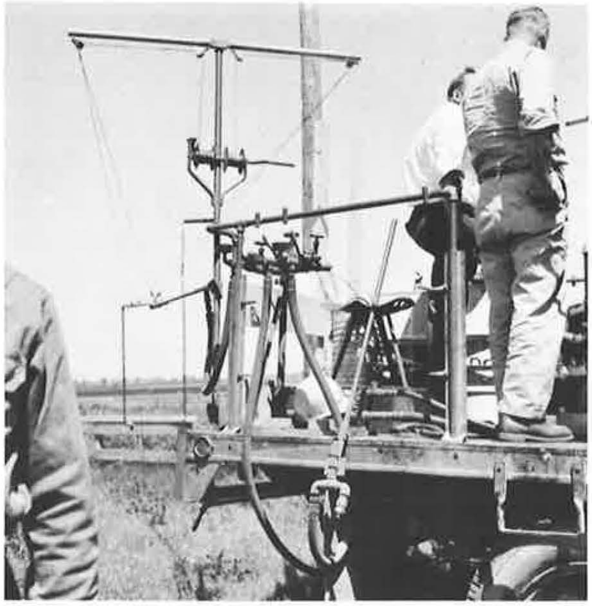

Figure 19. Spray controls and boom developed by pest control company.

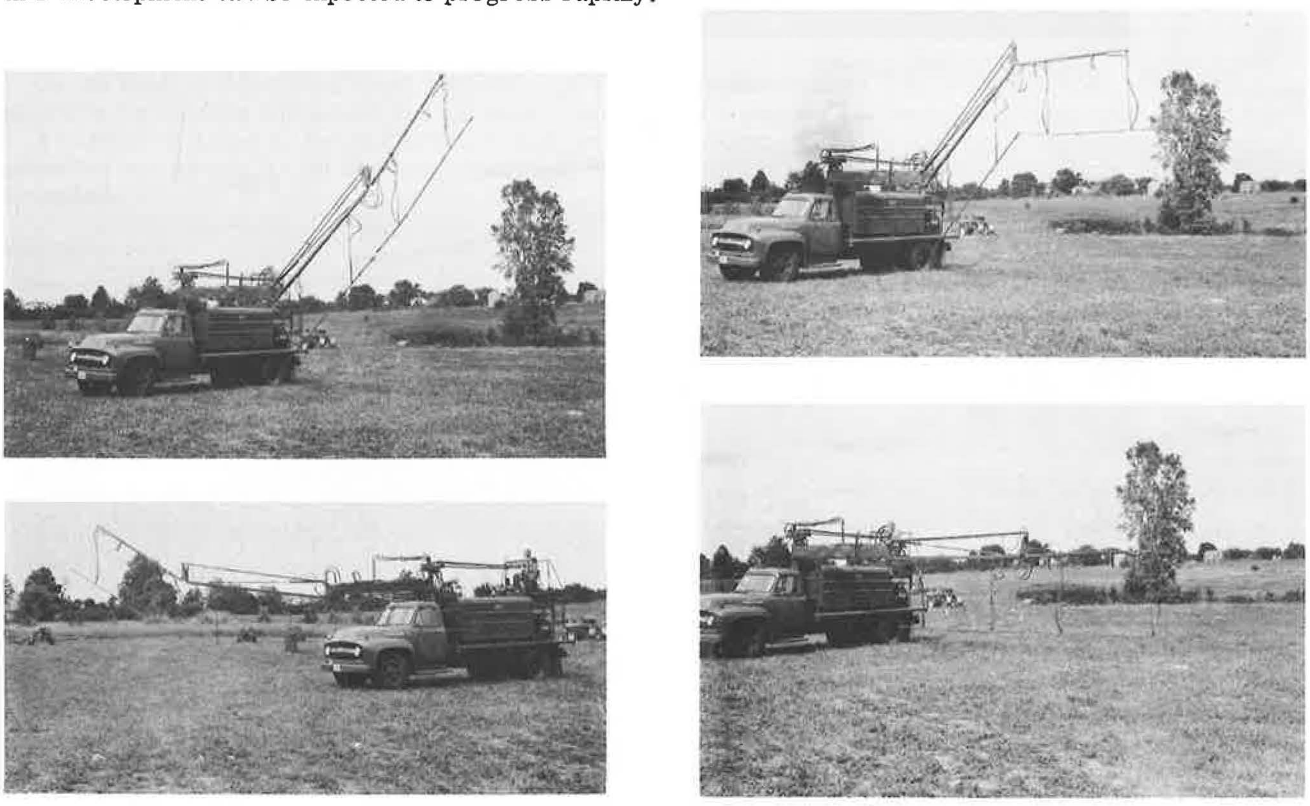

Figure 20. Newly developed roadside sprayer having spanner section. (Courtesy of John Bean Division, FMC)

Figure 21. Hydraulically controlled roadside spray boom. (Courtesy of John Bean Division, FMC)

Figure 22. Hydraulically controlled roadside spray boom. (Courtesy of Tarrant Mfg. Co., and New York Thruway Authority)

Figure 23. Adjustable swath-width nozzle assembly controlled by push-pull cable from truck.

Roadside Litter Removal

Thirty-five States indicated that they removed litter as often as once a week to as seldom as once a year. Thirteen States indicated that they did this job as required. For the 35 indicating time intervals, the average was two and one-half times a year.

Only a few States had used litter removal equipment even experimentally. Four have indicated the use of side delivery rakes, homemade rakes, or other rake-type devices. Five had used mechanical litter removal equipment either in roadside parks or in municipal areas or have tried it on roadsides. In general, it was considered too expensive to use on rural roadsides even if it worked satisfactorily. All types tested have had some difficulty in handling one class of roadside debris or another. Usually the trouble occurs in picking up larger items, such as tail pipes, large pieces of tire, etc. One type did not satisfactorily pick up bottles; another lacked capacity in general. No type has been developed that appears to be economically feasible for rural roadside use.

Nearly all States rely on hand labor and trucks to handle their roadside debris. A large number of States have indicated interest in mechanizing this operation but had no suggestions for the type of mechanisms needed to accomplish it. Arizona indicated that it has used a magnet truck to remove metallic objects from roadsides. Where rotary mowers are used, it might be satisfactory to remove metal objects only as the rotary mower tends to disintegrate paper and glass into the grass cuttings. Most litter removal machines are designed to pick up all loose material. On roadsides, the machine would pick up mowed clippings along with the trash, causing an excessive amount of material to be handled. This would necessitate either a great deal of hauling or burning or baling on the site.

There is a definite need for the development of equipment for the removal of roadside litter.

Equipment for Establishing and Maintaining Steep Slope Cover.—It was apparent from the first questionnaire and from the work of project personnel of the Illinois Division of Highways that one of the major problems was to get equipment that would operate on steep side slopes. Consequently, the follow-up questionnaire attempted to determine how various State highway departments and tollway and thruway officials felt about the need for equipment for this purpose. All agencies were asked to indicate their feelings about the need for several different types of equipment, including tractor-mounted, self-propelled, engine-powered walking, and shoulder-operated. Along with indications of need by types, they were asked to indicate needs by operations performed. The different operations were tillage, seeding, mulching, fertilizing, mowing, and spraying. It was evident that some who replied were influenced by what they knew to be available and that for others the idea of need was mainly financial.

The greatest indicated need was for tractor-powered equipment with primary emphais on mowing equipment (Table 20). Tillage and fertilizing equipment ranked second in priority, and seeding and spraying equipment was next. No great need was shown for tractor-powered mulching equipment. With the need shown for tractor-powered mowing equipment came an equal need for tractors designed to operate on side slopes, 14 agencies indicating an urgent need for such a tractor and 21 feeling some need.

On the basis of equipment type, shoulder-operated equipment ranked next to tractor-powered. The highest need was for mowing equipment and spraying equipment with seeding and fertilizing equipment ranked next.

A number of agencies listed a need for self-propelled equipment. Fourteen expressed a need for self-propelled equipment, 14 for shoulder-operated, and 14 for tractor-mounted. The main need was for self-propelled mowers, 16 indicating such a need.

In engine-powered walking equipment, the only apparent need was for mowing equipment, 11 States reporting a need.

On the basis of operations performed, regardless of equipment type, the greatest need was for equipment for mowing, 20 listing a strong need and 47 expressing some need. Next urgent was fertilizing equipment, 9 showing a strong need and 27 showing some need. Third was tillage equipment, 7 indicating a strong need and 24 showing some need.

TABLE 20
NUMBER OF AGENCIES EXPRESSING NEED FOR MORE STABLE EQUIPMENT FOR USE ON SIDE SLOPES

Operation Performed	Tractor-Mounted		Self-Propelled		Engine-Powered Walking		Shoulder-Operated		Operation Totals	
	Strong Need	Some Need	Strong Need	Some Need	Strong Need	Some Need	Strong Need	Some Need	Strong Need	Some Need
Tillage	3	11	1	6	1	3	2	4	7	24
Seeding	1	10	1	3	0	4	3	9	5	26
Mulching		8	1	3	0	3	2	10	3	24
Fertilizing	3	11	2	2	1	5	3	9	9	27
Mowing	6	21	8	8	3	8	3	10	20	47
Spraying	1	10	1	5	0	4	1	14	3	33
Total by equipment type	14	71	14	27	5	27	14	56		
Tractor for side slopes	14	21								

TABLE 21

NEED FOR MORE STABLE EQUIPMENT FOR USE ON SIDE SLOPES, BY OPERATION AND EQUIPMENT TYPE

Items	Priority						
	First	Second	Third	Fourth	Fifth	Sixth	Avg.
Operation performed:							
Tillage	2	5	1	0	0	2	2.8
Seeding	2	4	1	0	1	1	2.7
Mulching	0	0	2	1	2	0	4.0
Fertilizing	1	1	4	4	0	0	3.1
Mowing	9	3	2	0	1	0	1.7
Spraying	2	2	0	1	0	1	2.7
Tractor for side slopes	2	1	0	0	0	0	1.3
Equipment type:							
Tractor-mounted	4	1	1	1	0	0	1.9
Self-propelled	1	2	0	0	0	0	1.7
Engine-powered walking	0	2	0	0	0	0	2.0
Shoulder-operated	5	0	1	0	0	0	1.3

From these data it may be concluded that the greatest need is for the development of tractor-powered equipment for side slopes. Along with it a side-slope tractor should be developed. Mowing, tillage, and fertilizing machines are the main types of tractor-powered equipment needed. The need for work on seeding equipment was little less than for fertilizing, but the need for mulching and spraying equipment was considerably less. So far as tractor-powered equipment is concerned, the first need is to develop a tractor with a low center of gravity which will operate on steep slopes without damaging the sod and without tipping. After development of the tractor, the development of the equipment should be fairly simple.

The various highway agencies were asked to give a priority of need for more stable equipment for side slopes. The results are given in Table 21. This tabulation shows essentially the same relationships as the previous table, with the emphasis again on mowing equipment. The other operations given priority were tillage and seeding equipment and tractors.

When the priorities were given by type of equipment, the variation was not too great on the basis of averages, but the shoulder-operated equipment was given first priority five times and the tractor-mounted four times. The priorities given in this table do not alter the conclusions made from the data in Table 20.

Other Means of Controlling Steep Side Slopes. —Highway agencies are continuously searching for new methods to establish cover, control erosion, and lower maintenance costs on steep slopes. Tests have been and are being made with many different compounds sprayed or placed on slopes either to control erosion directly or to aid in establishing sod cover to control it. Results have ranged from very poor to very good. No particular compound has proved definitely superior. Various kinds of nettings and blankets have been tried with about equal results. Costs may run high for these materials on all slopes. However, for very steep slopes in problem areas, some of them are replacing paved ditches and sodding. Compared with concrete, their cost is reasonable and they may compete with sodding if performance is equally satisfactory. The use of low ground covers requiring little or no maintenance is a definite possibility, especially if methods and equipment can be developed to lower establishment costs.

SUMMARY

From this report, several observations can be made about the present situation and future trends in equipment and practices for establishing and maintaining roadside cover.

With the construction of the Interstate system and expressways, more acres of roadside cover are being established and maintained. With the increasing acreage of wide rights-of-way and the continued use of nearly all older rights-of-way, there appears to be a need for two types of equipment, one with high capacity for operation on the wide, flat areas of the Interstate system and expressways and another for operation on the steeper slopes of older roads and new rights-of-way in high-value areas near metropolitan centers. Although the trend is definitely toward flatter side slopes, in some areas the cost of land and construction may necessitate steep slopes that will be difficult to maintain.

Hydraulic seeders and straw mulchers are widely accepted as the most satisfactory equipment now available for seeding slopes. Although certain species of plants have proved best in certain regions, only 14 are used in standard mixtures in four or more States. Farm grains for temporary seedings are becoming less popular and there are indications that temporary seedings themselves are being used less each year.

Highway officials are cognizant of increasing maintenance costs and will increase the demand to mechanize roadside maintenance. Private industry, in cooperation with highway agencies is developing equipment to operate on the flatter terrain of new highways. It is also making progress in developing equipment for the steep slopes on old rights-of-way and on some areas of new rights-of-way.

This report has established the need to develop tractors and associated equipment for use on side slopes. Such a large percentage of costs for roadside cover maintenance goes into mowing that not only tractor-mounted but also self-propelled, shoulder-operated, and engine-powered walking types of mowing equipment are needed. The engine-powered walking mowers are desirable for extremely steep slopes where present tractors cannot operate and for areas that contain many obstacles.

Although sickle bar mowers are still used on more acreage, the percentage of mowing by rotary mowers has increased rapidly and will continue to increase. Hammer knife mowers and gang-type reel mowers are in limited use, but their use will increase as more superhighways are built. Sickle bar mowers will still be used on difficult areas but will be hydraulically driven.

A large amount of hand labor is still being used, especially in mowing and removing litter. State highway officials seem willing to use hand labor in repairing seeding failures and erosion damage because the repair can be done in a single operation. In mowing and litter removal, however, which are often done three or four times a season, they are eager to replace hand labor with mechanized equipment. Use of chemicals for weed control and soil sterilization is expected to expand. Growth inhibitors, if practical, should have wide acceptance.

This report shows that highway agencies recognize the problems and are trying to mechanize their operations. They have communicated their needs to private industry, and industry is working to supply these needs. With recognition of this by small manufacturers and by large equipment producers, it is believed that development of special roadside equipment will accelerate.

Along with better highways, the public is demanding and getting better roadside appearance through improved maintenance. Expected continuation of this trend will involve (a) better roadside cover control through use of chemicals, maintenance fertilizers, and modern equipment; (b) more frequent removal of litter; (c) more roadside landscaping; and (d) more roadside parks. Roadside practices and equipment will need to be efficient to keep maintenance costs from becoming burdensome. Highway planners and designers will need to continue to design and plan with maintenance in mind to avoid excessive channeling of tax dollars from new construction to maintenance.

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