SCHOOL OF
CIVIL ENGINEERING

INDIANA

DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

Executive Summary

FHWA/IN/JHRP-88/2 - 2

COST REDUCTION AND INCREASED
EFFICACY OF GROWTH RETARDANT
MIXTURES FOR VEGETATION MANAGE-
MENT ALONG INDIANA ROADSIDES

D. James Morre

PURDUE UNIVERSITY

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Executive Summary
Final Report

COST REDUCTION AND INCREASED EFFICACY OF GROWTH RETARDANT MIXTURES FOR
VEGETATION MANAGEMENT ALONG INDIANA ROADSIDES

TO: H. L. Michael, Director
Joint Highway Research Project

December 31, 1987

FROM: D. J. Morré

Project: C-36-53K

File: 9-5-11

Attached is a Final Report of the HPR Part II study titled "Cost Reduction and Increased Efficacy of Growth Retardant Mixtures for Vegetation Management Along Indiana Roadsides." I served as the Principal Investigator on this study, directed the project and have authored the report.

The research results include recommendations for a single spray application that will control weeds, retard grass growth and prevent formation of seedheads in bluegrass and fescue. For control of both bluegrass and fescue, no further herbicide applications or mechanical mowings are required for the year of treatment. The recommendations are based on new combinations of materials developed under the project where cost-effectiveness has been increased to the point that the cost of the spray application is competitive with a single mechanical mowing cycle.

In early stages of implementation evaluation is a combination of materials developed specifically for use on secondary and narrow right-of-way highways. It includes materials effective in suppression of seed heads in smooth brome and late-germinating annual grasses such as foxtails and barn-yard grass that invade from adjacent agricultural lands. Failure to control both these types of grass have in the past have largely limited chemical mowing to the Interstate System. Removal of this limitation is expected to increase greatly potential cost savings from substantial reductions in force-account mowings and reduced necessity for purchase of costly mowing equipment.

The results of these studies have been recommended for implementation in the State of Indiana and plans to begin the implementation phase have been initiated. These and other findings with potential for further development are expected to point the way to even greater cost saving modifications in the program of chemical mowing for future years.

Sincerely

D. James Morré
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16. Abstract A cost-effective program of chemical mowing for use on Indiana roadsides has been developed. A single spring application of a combination of new materials gives season-long control of seedheads in bluegrass and fescue as well as control of broad-leaf weeds and suppression of grass growth. The cost of materials and application are equal to or less than the cost of a single mowing cycle. The treatment is environmentally safe when applied in early spring before most agricultural crops have been planted. Problems of carry over with repeated applications to the same area have been reduced or eliminated by low overall application rates recommended. The effectiveness and low cost of the combination is based on the ability of certain growth regulatory materials, referred to as additives, that may be only weakly effective as growth retardants themselves, to interact in a synergistic fashion with mefluidide to increase overall efficacy and to reduce the required application rates sufficiently to make chemical mowing an economically sound practice. The combination has been field tested for five years under actual use conditions, and was found to be effective for full season management of mixed bluegrass-tall fescue turf to permit considerable cost savings when compared to 2-cycle or 3-cycle mechanical mowing. On secondary and narrow right-of-way roadsides, seedheads from smooth brome and from later-germinating annual grasses such as foxtails and barnyard grass cause additional problems. For use on such roads, a new combination has been developed that includes trichlopyr (Garlon) plus an agent for pre-emergence control of annual grasses. Implementation is expected to increase potential cost-savings even further through reductions in force-account mowing and in reduced necessity to purchase costly mowing equipment.		
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EXECUTIVE SUMMARY

Final Report

COST REDUCTION AND INCREASED EFFICACY OF GROWTH RETARDANT MIXTURES FOR
VEGETATION MANAGEMENT ALONG INDIANA ROADSIDES

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and the

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The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

Purdue University
West Lafayette, Indiana

December 31, 1987

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Abstract

The research results include recommendations for single spray applications that will control weeds, retard grass growth and prevent formation of seedheads in bluegrass and fescue. For control of both bluegrass and fescue, no further herbicide applications or mechanical mowings are required for the year of treatment. The recommendations are based on new combinations of materials developed under the project where cost-effectiveness has been increased to the point that the cost of the spray applications are competitive with a single mechanical mowing cycle.

In early stages of implementation is a combination of materials developed specifically for use on secondary and narrow right-of-way highways. It includes materials effective in suppression of seedheads in smooth brome and late-germinating annual grasses such as foxtails and barnyard grass that invade from adjacent agricultural lands. Failure to control both these types of grass have in the past largely limited chemical mowing to the Interstate System. Removal of this limitation is expected to increase greatly potential cost savings from substantial reductions in force-account mowings and reduced necessity for purchase of costly mowing equipment.

The results of these studies have been recommended for implementation in the State of Indiana and plans to begin the implementation phase have been initiated. These and other findings with potential for further development are expected to point the way to even great cost saving modifications in the program of chemical mowing for future years.

Introduction

Mechanical mowing of roadsides as required to meet current safety and esthetic standards is a substantial budget item in any program of roadside maintenance. At current costs of \$20-25 per acre per mowing cycle, 3-cycle mowing to maintain adequate site distances and visual appearances would cost between \$60 and \$75 per acre annually. In Indiana, where approximately 70,000 acres of roadside are mowed each year, the annual costs may well exceed \$5,000,000. The present program of chemical mowing detailed by this report, if implemented, is expected to reduce present mowing costs by 50% or more.

The research described was initiated with a view to develop a growth retardant mixture that would reduce or prevent the formation of grass seed-heads and control tall weeds so that the need for mechanical mowing along roadsides could be eliminated or reduced. The treatment, to consist of a single spray application, was to be effective against both fescue and blue-grass as well as to give control of broadleaf weeds and brush. Maximum grass height was not to exceed acceptable mowing limits at any time during the growing season. In addition, the treatment was to have been safe for the environment. There was to be no permanent weakening of the root system of established turf, no injury to desirable species and no carry over that would limit repeated use on an annual basis. A healthy lawn-type appearance to the turf was a desirable characteristic. The cost should be sufficiently low to make the treatment competitive at least with 3-cycle mechanical mowing.

Method of Approach

The approach followed was to first identify the most cost-effective primary growth retardant available for elimination of seedheads in fescue

and then to employ various additives in different combinations to simultaneously increase efficacy and reduce treatment costs. 2,4-D, amine salt, was included for control of both broadleaf weeds and of brush species. The research program undertaken combined laboratory and greenhouse studies with field investigations. Growth retardant combinations, once identified, were perfected and modified on the basis of greenhouse as well as laboratory studies and then verified in the field. Field studies involved both large and small plots as well as large-scale tests under actual use conditions using truck-mounted equipment in collaboration with District highway personnel. Close liaison was maintained with both State and District highway personnel both in the planning and evaluation of new combinations and in determining the most effective implementation strategies.

Results

This research project was to reduce costs and increase efficacy of vegetation management along Indiana roadsides through a program of chemical mowing. The findings will show how low-cost additives can be used together with an effective primary growth retardant material to reduce application rates, eliminate unfavorable herbicide-retardant interactions and make chemical mowing cost-competitive and even less expensive than standard mechanical mowing.

Selection of the Primary Retardant

The primary retardant utilized in these studies, Embark (Mefluidide), was selected from a group of approximately 12 materials including Sustar, MH and Eptam that were available as potential growth retardants when the present investigation was initiated. Although the material was expensive and tended to cause some discoloration of turf, its strong features were effectiveness as a seedhead suppressant with fescue, overall environmental safety and lack

of carry over from one season to the next. In subsequent investigations, Embark was adopted as the standard to which other primary retardants were compared as they became available for evaluation. These comparisons were extended to Manage, ACP 1900, EL 107, Mon 4625 and Mon 4529, to list a few, during the last two years of the project. While these evaluations are still incomplete, none of the other primary retardants tested has exhibited a clear superiority over Embark.

The initial difficulty with Embark was the high rates required to control seedheads in fescue (Fig. 1). With Embark alone, on the order of 3/4 lb/A was required. At a cost of more than \$30/lb, this amount would have been prohibitive. Toxicity to native bluegrass was also noted as these high rates of application.

A second difficulty with Embark was an antagonism with 2,4-D herbicides (Table 1). Embark does not kill broadleaf weeds. Therefore, the retardant must be mixed with a weed control herbicide. 2,4-D, because of its low cost (\$1.70/lb) and broad-spectrum effectiveness would be the material of choice.

To overcome antagonism with 2,4-D (Table 1) and to reduce the required application rates (Fig. 1), a surfactant was added to the mixture. This low-cost (\$10.00/gallon) additive provided the first major breakthrough in the development of a cost-effective program of chemical mowing for Indiana roadsides.

Effect of surfactant

Surfactants greatly enhanced the effectiveness of Embark. The overall effect with seedhead suppression in fescue was to double the effectiveness of the primary retardant materials, so that 90% control of fescue seedheads could be achieved at rates of Embark starting at 1/2 lb/A. This is illustrated in Table 1 where the three-combination of Embark + Surfactant + 2,4-D

Fig. 1. Influence of application amount of Embark on seedhead formation in fescue. Experiment was in 1983 and 1984 with WK surfactant and in 1985, 1986 and 1987 with X-77 surfactant

Fig. 2. Effect of rate of application of surfactant XM-12 in the presence of 1/2 lb/A Embark plus 2 lb/A 2,4-D amine on the growth of bluegrass

Fig. 3. Influence of application amount of Telar on seedhead formation in fescue. Experiment was in 1983 and 1984 with WK surfactant and in 1985, 1986 and 1987 with X-77 surfactant

Fig. 4. Influence of application amount of Oust on seedhead formation in fescue. Experiment was in 1983 and 1984 with WK surfactant and in 1985, 1986 and 1987 with X-77 surfactant.

Table 1. Fescue seedhead suppression from Embark and antagonism between Embark and 2,4-D amine. Surfactant increases the effectiveness of Embark alone (see also Fig. 1) and largely eliminates the antagonism with 2,4-D.

Treatment (Rate per acre)	Seedheads per ft ²	Suppression %
None (Check)	18	0
Embark (1/2 lb/A)	9	50
Embark (1/2 lb/A) + 2,4-D amine (2 lb/A)	13	28
Embark (1/2 lb/A) + X-77 Surfactant (1%)	4	75
Embark (1/2 lb/A) + X-77 Surfactant (1%) + 2,4-D amine (2 lb/A)	2	89

Table 2. Comparison of WK, XM-12 and X-77 surfactants on seedhead formation and vegetative growth of tall fescue and bluegrass. Miami County adjacent to US 31. Applied April 12, 1983 using flood tip nozzles (F3) at 20 gpa. Evaluations were on June 16, 1983.

Treatment*	Fescue			Bluegrass		
	Seedhead No./10 ft ²	Ht.	Blade Ht.	Seedheads No./10 ft ²	Ht.	Blade Ht.
None (Check)	22	36	23	7	25	20
Embark (1/2 lb/A)	12	30	21	6	18	16
Embark (1/2 lb/A) + WK (0.25%)	9	29	20	5	19	17
Embark (1/2 lb/A) + XM-12 (0.25%)	10	29	20	4	19	17
Embark (1/2 lb/A) + X-77 (0.25%)	7	28	19	5	18	17

* All treatments included 2 lb/A 2,4-D amine except for the check which was untreated.

amine resulted in 89% suppression of seedheads in fescue under roadside conditions.

Initially, the manufacturers recommended rates of 0.5 or 1% surfactant (as percent of total in the spray mixture) were followed. Careful field studies conducted in 1982 demonstrated that 0.25% surfactant was just as effective as 0.5% surfactant at 40 gpa of total spray mixture (Fig. 2). This resulted in a cost saving of approximately \$1.00/acre in material costs compared to the 1% surfactant rate utilized initially.

While some surfactants tended to be more effective than others, these differences in the field tended to be minimized with time from date of treatment so that in the end the choice of surfactant was not critical. Among the three most effective surfactant materials tested were, WK (Fig. 1), XM-12 (Fig. 2) and X-77 (Table 2). X-77 was ultimately selected on the basis of ready commercial availability and environmental safety.

Effect of additives

A second way to increase effectiveness of the primary retardant was through synergistic interaction with other materials. While a synergistic interaction is possible with a number of different herbicides (examples include pactlobutrazol, fluroprimodol, bentazon, acifluorefen, sethoxydim, naptalam and various thiocarbamates such as Eptam), one of the most effective was with the DuPont products, Telar (chlorsulfuron) and Oust where just fractions of an ounce of the additive reduced the amount of primary retardant required by a factor of 2 or more (Table 3). An additional factor in the selection of Telar as the additive of choice to combine with Embark, surfactant and 2,4-D was the ability of Telar to control some 2,4-D resistant weed species such as wild carrot (Table 4).

Table 3. Comparison of different rates of Embark alone and in combination with the additive Telar on seedhead suppression in fescue comparing 14 different dates of application between April 7 and May 16 1984 under roadside conditions.

Schedule	Treatment and amount*				Control of fescue seedheads, %
	Embark	X-77	Telar	2,4-D Amine	
A	1/2 lb/A	0.25%	-	2 lb/A	79 $\pm$ 15
B	1/4 lb/A	0.25%	1/4 oz/A	2 lb/A	88 $\pm$ 11
C	1/8 lb/A	0.25%	1/8 oz/A	2 lb/A	90 $\pm$ 11

Table 4. Control of wild carrot by Telar at varying rates under roadside conditions. Applications were on May 19, 1983 with evaluations on June 28.

Telar (oz/A)	Wild Carrot (plants/50 ft ²)
-	37
1/16	24
1/8	2
3/16	4
1/4	8
1/2	2
3/4	4
1	1

*Rates are lb/A of mefluidide for Embark, oz/A of chlorsulfuron for Telar and lb/A acid equivalent for 2,4-D amine. X-77 surfactant was as % of the total spray mixture applied at 40 gpa and 40 psi.

Setting the rate of Telar

Rates of Telar of 1/2 oz per acre or greater were not considered due to phytotoxicity. There was a tendency for Telar alone to give 25 to 50% suppression of seedheads with rates in the range of 1/8 to 1 oz/A but with no obvious strict dose dependency (Fig. 3). Maximum effectiveness of Telar in the combination was obtained with 1/4 oz/A. In all five years of the study, 1/4 oz/A of Telar plus 1/4 lb/A of Embark were equivalent to 1/2 lb/A of Embark alone (Table 5). At \$12/oz for Telar, a treatment costing \$16/A for Embark alone was reduced to \$8/A for Embark plus \$3 per acre for Telar, an overall cost reduction of \$5/A in material costs. Further refinements in the rate of Telar may lead to even greater cost reductions.

Addition of 2,4-D to the basic Embark + Telar combination

While giving excellent control of wild carrot and some other species, Telar is ineffective in the control of plantain, for example, a dominant turf weed species. Therefore, it was considered desirable to include a broadleaf herbicide such as 2,4-D amine in the chemical mowing mixture. Maximum weed control was achieved in the range of 1.5 to 2 lb/A acid equivalent. The antagonism between Embark and 2,4-D also was less at the higher 2,4-D rates. Only the environmentally safe, amine formulations of 2,4-D have been recommended for general roadside uses.

Alternatives to Telar as the additive

Oust, a chemical relative of Telar, has been under test as an alternative to Telar since 1983. In contrast to Telar, Oust showed a strong surfactant response (Fig. 4) and in the presence of surfactant was approximately twice as effective overall as Telar (Compare Fig. 4 with Fig. 3). Similarly, in combination with Embark, Oust is also more effective than Telar, about twice. Its phytotoxicity is also about twice that of Telar but pound for

Table 5. Embark in combination with surfactant and 2,4-D as influenced by the addition of Telar at early and late dates of application. 1983 test results under roadside conditions.

Date of Application	Amount/A				Fescue seedheads		Weeds per 100 ft ² <u>b/</u>	Cost per acre <u>c/</u>
	Embark	Surfactant ^{a/}	Telar 2,4-D		Per ft ²	Height (inches)		
March 18	-	-	-	-	12	47	160	
	1/2 lb	0.25%		2 lb	3	31	25	\$22.00
	1/4 lb	0.25%	1/4 oz	2 lb	2	29	25	\$17.00
May 3	-	-	-	-	17	46	124	
	1/2 lb	0.25%	-	2 lb	5	5	10	
	1/4 lb	0.25%	1/4 oz	2 lb	1	22	10	
May 9	-	-	-	-	17	46	64	
	1/2 lb	0.25%	-	2 lb	7	24	2	
	1/4 lb	0.25%	1/4 oz	2 lb	0	14	0	

a/ X-77 as percent by volume of the total spray mixture applied at 40 gpa and 40 psi

b/ Exclusive of common milkweed

c/ Based on Telar \$12/oz; Embark \$32/lb; 2,4-D \$1.60/lb; Surfactant \$10/gal.

pound it is less expensive than Telar. The only advantage of Telar over Oust in the mixture may be environmental safety.

Environmental Safety

Turf remained healthy and vigorous in a series of test plots receiving Embark applications (1/2 lb/A annually) for 10 years since the spring of 1977. Neither Embark alone nor Telar alone resulted in any permanent inhibition of root growth with fescue or bluegrass. Repeat applications of high rates of Embark (e.g. 1 or 2 lb/A) reduce or eliminate some strains of native bluegrass but fescue continues to grow vigorously even in those plots. Similarly, continuous Telar and Oust plots (since the spring of 1977) have not caused any permanent deterioration of either bluegrass or fescue turf.

Any of the treatments may display some initial discoloration (yellowing) of grass foliage in the second or third week post treatment. This discoloration is temporary and is usually gone when the vegetative growth of the grass resumes in 3 to 4 weeks after application.

No problems have been encountered from injury to nontarget species either due to drift or to inadvertent direct overspraying under normal roadside use conditions. All of the materials included in mixtures recommended for implementation have been determined to be safe to man, domestic animals, fish, aquatic food-chain organisms, and nontarget vegetation both by the manufacturer and in independent tests conducted as part of the environmental safety evaluations (mutagenicity and carcinogenicity assays, animal studies, toxicity to fish and algae, etc.) included among the project's objectives. The margin of safety for the Embark + Telar + 2,4-D + Surfactant combination is sufficiently high that an overdose of 2- to 4-times the recommended rates would not present an environmental hazard nor result in permanent turf damage.

Implementation tests, 1983-1987

In 1983, 1/2 lb/A Embark + 0.5% surfactant + 2 lb/A 2,4-D amine were tested successfully using commercial applicators and application equipment with seedhead suppression in fescue averaging about 80%. In 1984 through 1987, a spring application of 1/4 lb/A Embark + 1/4 oz Telar + 2 lb/A 2,4-D amine and 0.25% surfactant was tested and gave 90% control of seedheads of both fescue and bluegrass and of broadleaf weeds. These tests were on I-70 and the Illinois State Line. For most of the growing season, the area would not have required mowing. Its appearance was equivalent to adjacent road segments that had received 2 cycles of mechanical mowing. Only in the fall when native prairie species such as purple top formed seedheads was a clear need for mowing indicated.

Similar trials on secondary roads in Miami County in 1983 and in the Crawfordsville subdistrict in 1984 through 1987 were less encouraging. The treatments were effective in controlling seedheads in fescue and bluegrass as on the Interstates and dual lane roads. However, the treatments were much less effective on smooth brome that is frequently present along secondary roads in scattered patches and becomes unsightly as seedheads are formed. Also growth of later germinating weeds (such as velvetleaf) and annual grasses (such as giant foxtail and barnyard grass) tended to dominate narrow rights-of-way adjacent to cropped fields late in the growing season.

Both the problem with the smooth brome and the late germinating annual weeds and grasses received extensive study during the final two years of the project. To overcome the late germinating annual weeds, an appropriate pre-emergence material was added to the spray mixture. For control of smooth brome, a new mixture containing Garlon-4 was developed. Both these mixtures may be ready for early implementation testing in 1988.

Manage as a primary grass retardant

Manage (Glyphosate, Monsanto) was introduced in 1986 as an industrial turf growth regulator in Indiana. Evaluation of the initial test sites suggested effectiveness in the control of seedheads in fescue and bluegrass at rates of about 6 oz/A in combination with 1/4 oz/A of Telar or 1/8 oz/A of Oust. Testing was continued in 1987 with confirmation of major findings.

On 21 different dates, Manage alone or in combination with Telar or with Oust was applied at different rates and ratios together with 2,4-D amine at 2 lb/A and 0.25% by volume of X-77 surfactant in the total mixture. Manage at 3, 4 or 6 oz per acre gave essentially equivalent results with about 50% control of fescue seedheads and a 40% reduction in seedhead elongation. Rates of Manage at 6 oz/A or above could not be used practically in a roadside program due to toxicity to bluegrass. Rates of Manage of 2 oz/A or less were largely ineffective.

Addition of Telar to the combination with Manage increased effectiveness somewhat and was most effective at low rates of Manage. The effectiveness of Telar was maximal between 1/16 and 3/32 oz/A. Increasing the amount of Telar to 3/8 oz/A had no additional effect.

At a near optimum rate of Manage of 4 oz/A, fescue seedhead control was 50%. Addition of 1/4 oz/A Telar to the mixture increased seedhead control to 65% comparing 8 different dates of application.

Manage was most effective in 1987 during a very narrow window in the first week of May. Applications before May 1 and after May 5 were less effective.

Addition of Oust to the combination with Manage also increased effectiveness. With Oust, 1/8 oz/A appeared to give optimal results. In side-by-side comparisons, Manage + Telar and Manage + Oust combinations gave

Fig. 5. Seedhead suppression in fescue comparing different dates of application in 1986. Schedule B (1/4 lb Embark + 1/4 oz Telar + 2 lb 2,4-D amine + surfactant) (closed symbols) and schedule C (1/8 lb Embark + 1/8 oz Telar + 2 lb 2,4-D amine + surfactant) (open symbols) are compared. The application window for the Embark + Telar combination extends from the beginning of April to about the end of the first week of May when seed-heads first begin to form.

Fig. 6. Seedhead suppression in fescue comparing different dates of application of Manage (3-6 oz/A) plus Telar (1/4 oz/A) in a mixture containing 2 lb/A of 2,4-D amine and surfactant X-77 (0.25% by volume of the total spray mixture) in 1987. A very narrow application window of about 1 week was observed.

similar results although the combination with Oust was consistently more effective.

Side-by-side comparisons of the Manage (4 oz/A) + Telar (1/4 oz/A) and of the Embark (1/4 lb/A) + Telar (1/4 oz/A) according to Schedule B in combination with 2,4-D amine and surfactant also were carried out in 8 trials (2 early, 4 mid-season and 2 late). Overall the Embark + Telar + 2,4-D + Surfactant gave 90% control of fescue seedheads in these trials as in past years. In contrast, the combination of Manage + Telar + 2,4-D + Surfactant gave only 70% control of fescue seedheads which was very near the overall average of 65% control. Only with the two mid-season applications were the treatments equivalent. Both early and late, the Embark combination was decidedly superior in inhibition of fescue seedheads.

While the Embark + Telar combination provides better control of fescue seedheads, the appearance of the plots treated with Manage + Telar was often acceptable since those seedheads that formed were short. Only in about 4 of approximately 20 trials (20% of the time) did the Manage + Telar combination fail to reduce seedhead height.

While the date of emergence of seedheads determines one end of the application window for the Embark + Telar combination, the beginning of rapid growth marks the other (Fig. 5). When percent seedhead suppression in fescue is graphed at different times of application of the combination of 1/4 lb/A Embark + 1/4 oz/A Telar + 2 lb/A 2,4-D amine + surfactant (Schedule B), maximum effectiveness of the treatment is reached at the beginning of April and extends through the first week of May (solid symbols in Figure 5). Similar results were obtained with 1/8 lb/A Embark + 1/8 oz/A Telar + 2 lb/A 2,4-D amine + surfactant (Schedule C) except that seedhead control was about 90% (open symbols in Figure 5) compared to nearly 100% for schedule B.

The relatively extended window for the Embark + Telar combinations of approximately 5 weeks contrasts with the relatively narrow window for the Manage + Telar combination determined in 1987 to be on the order of one week in duration (Fig. 6). This window coincided approximately with the successful application times for Manage in 1986.

Discussion

This study demonstrates the practical use of combinations of chemicals to reduce or prevent growth of grass and weeds along roadsides so that the need for mechanical mowing is reduced. Embark remains the most reliable and effective primary retardant for the mixture and with the greatest margin of safety. Among its several advantages are no appreciable inhibition of root growth.

By mixing Embark with various additives, effectiveness is increased and costs are reduced. Among the most effective of the additives is Telar. At just fractions of an ounce per acre, this material when mixed with Embark reduces or eliminates seedheads in fescue using amounts of chemicals whose costs may be less than that of a single conventional mowing cycle.

The effect of the surfactant is to increase effectiveness of both the Embark and of the 2,4-D amine. This effect is due to enhanced penetration of these materials through the foliage of the treated vegetation. However, foliar uptake is not the only route of entry of plant growth regulators into vegetation. It is apparent, as well, that these materials can enter through the root system. Root uptake via the soil would not be expected to be influenced by the presence or absence of surfactants, however.

Several spraying schedules developed are given in Tables 6-8. Schedule A (Table 6) is useful but no longer recommended due to its high cost. Schedule B (Table 6), with the addition of Telar as additive to the Embark +

Surfactant + 2,4-D mixture, is much more cost effective and has proven very effective in the control of seedheads in fescue and in general vegetation management on improved dual lane and interstate highways. Control of fescue seedheads is nearly complete. For most species, weed control is also better than 90% and due to the inclusion of Telar in the mixture is very effective for control of wild carrot. Schedule B has been thoroughly tested in the field for four years under actual use conditions in several locations and is the proven reliable standard against which other treatments must now be judged. Cost is comparable to one mowing cycle.

Schedule C (Table 6) or some variation of schedule C (Table 7) is expected to be even more cost effective than schedule B. However, with schedule C, field experience is much more limited and additional testing will be required. Small plot results have been most encouraging. Schedule C has given results comparable or superior to 4 oz of Manage + 1/4 oz Telar (in combination with 2,4-D and surfactant). However, material costs for the Manage + Telar combination would be of the order of \$18.00/A compared to about \$9.00/A for schedule C.

With either schedule B or schedule C, spring applications only are recommended. The materials can be applied in the fall for seedhead control the following spring but much higher rates are required and the fall applications have not proven to be economical. With both schedules B and C, the seedheads and grass remain after spraying essentially the way they were at the time of application. Vegetative growth will resume after a time but seedheads once suppressed will not reform until the following spring. Thus, with both schedules B and C, the materials may be applied at any time from green-up until the seedheads just emerge from the boot. This constitutes an application "window" of about 5 weeks.

A large segment of work was involved with the development of a new mixture of materials for use on secondary roads (Table 8). The approach taken was to screen for some combination that would control seedhead formation in smooth brome, a problem on secondary roads not encountered on Interstates. Additionally, the material was to have pre-emergence activity against late-germinating weeds and annual grasses. Among the most effective materials selected initially were compounds that by themselves were phytotoxic but without true growth retardant action. One of the most effective was the addition of Poast with or without crop oil to Schedule B. The margin of safety of the mixture, however, was quite narrow and potential toxicity remains as a major concern. Field testing of this material, however, is expected to continue.

A major important new finding was that a combination of Embark plus Garlon in combination with Telar was very effective in suppression of seed-heads in smooth brome and orchard grass without apparent toxicity to blue-grass or to other turf species. It may not be necessary to add 2,4-D to this mixture as the Garlon + Telar combination may provide sufficient weed control by themselves. This combination is expected to enter initial testing for implementation in 1988.

Laboratory studies were equally rewarding. Significant progress was recorded in efforts of long standing to identify the specific plant molecules that combine with growth retardants and herbicides. These findings have facilitated development of new assays for growth regulators and have aided in evaluations of environmental safety. Perhaps the greatest utility of the new findings has been the rapid development of better and more effective combinations of plant growth regulating materials. Since it is now possible to combine agents in a test tube, much larger numbers of

combinations can be evaluated in a much shorter time and at lower cost than afforded by applications in the field.

Recommendations

In 1983, 1/2 lb/A Embark + 0.5% surfactant + 2 lb/A 2,4-D amine were tested successfully using commercial applicators and application equipment (Schedule A, Table 6). In 1984-1987, a spring application of 1/4 lb/A Embark + 1/4 oz/A Telar + 2 lb/A 2,4-D amine and 0.25% surfactant were tested and gave 90% control of seedheads of both fescue and bluegrass and of broadleaf weeds (Schedule B, Table 6) at a cost of \$5.00 per acre less than Schedule A. Even greater cost savings may be possible with Schedule C (material costs of less than \$10.00/A). When used on Interstates or dual lane roads, the sprayed areas do not require mowing until late in the season when native prairie species such as purple top form seedheads.

On secondary roads, the treatments were much less effective due to smooth brome seedheads which were not controlled and the growth of late-germinating weeds (such as velvet leaf) and annual grasses which tended to dominate such narrow right-of-way roads adjacent to cropped fields late in the growing season. For use on these roads, a series of alternative treatments have been developed (Table 8) for implementation testing. Each of these treatments will require considerable further testing, to include environmental impact assessments, before definite recommendations will be possible. These schedules may also be combined with pre-emergence herbicides such as Balan or Surflan to enhance control of the late-germinating annual weeds and grasses.

Additionally, a series of alternative treatments for use on Interstates and dual lane roads has been developed as well (Table 7). Each of these schedules has received limited testing under use conditions as well but

further testing is recommended before definite recommendations are made. Again, testing should include environmental assessments. Whether or not any of these treatments will prove more cost effective than either Schedule B or C (Table 6) must await further testing.

Materials costs for comparisons of the various programs of chemical mowing for vegetation management on both secondary roads and the Interstate/dual lane roads are given in Table 9. Schedules D and E, if proven safe and effective on implementation, would be considerably less expensive than the comparable schedules B and C which they would replace. Recommended application dates determined experimentally are provided in Table 10.

Table 6. Recommended program of chemical mowing for roadside vegetation management in Indiana. Each of the following schedules has been tested in at least three successive years in at least 3 different locations within the state under actual use conditions with consistent and reproducible results. The 3 schedules normally give equivalent results. Schedule A is the most costly but has the greatest safety margin. Schedule C is the least costly but seedhead control in fescue may drop below 90% with some early applications. Schedule B is, at present, considered as the most cost-effective compromise for general highway use.

Materials: Embark (mefluidide) Plant Growth Regulator containing 2 lb active mefluidide per gallon. Telar (chlorsulfuron) concentrate containing 75% active material. 2,4-D amine form concentrate containing 4 lb/gallon acid equivalent (Ester formulations of 2,4-D are not recommended due to possible environmental hazards). X-77 or WK Surfactant concentrate.

Rate:

Schedule A: 1/2 lb/A Embark (as mefluidide) + 0.25% X-77 + 2 lb/A of 2,4-D amine.

Materials are mixed at the rate of approximately 2.3 gallons of Embark plus 1/4 gallon of X-77 plus 1 1/2 gallons of 2,4-D amine in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule B: 1/4 lb/A Embark (as mefluidide) = 1 pint/A + 1/4 oz/A Telar + 0.25% X-77 + 2 lb/A 2,4-D amine.

Materials are mixed at the rate of approximately 2 1/2 pints of Embark plus 5/8 oz Telar (reduction to 1/2 oz would seem feasible on the basis of 1986 and 1987 test results) plus 1/4 gallon of X-77 plus 1 1/2 gallons of 2,4-D amine in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule C: 1/8 lb/A Embark (as mefluidide) = 1/2 pint/A + 1/8 oz/A Telar + 0.25% X-77 + 2 lb/A 2,4-D amine.

Materials are mixed at the rate of approximately 1 1/4 pints of Embark plus 5/16 oz of Telar (reduction of 1/4 oz would seem feasible on the basis of 1986 and 1987 test results) plus 1/4 gallon of X-77 plus 1 1/2 gallons of 2,4-D amine in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule of Application: Recommended for application the spring only. For schedules A and B, apply as the grass begins to green and grow at the beginning of April until just before the emergence of seedheads from the boot at the end of the first week of May. Application of schedule C should begin approximately 10 days later on or about April 10 with termination the same as schedule B. With schedule A, termination should be about 1 week earlier at the beginning of May. These dates are for the central 1/3 of the state. For the Northern 1/3, one week may be added. For the Southern 1/3, one week may be subtracted. These dates are summarized in tabular form in Table 10. Comparable cost of materials comparisons are summarized in Table 9.

Table 7. Program of alternative treatments for use on Interstates and dual lane roads. Each of the following schedules has received limited testing under use conditions. However, further testing is recommended before definite recommendations will be possible to include a detailed environmental impact assessment.

Schedule D. 1/4 lb/A Embark (as mefluidide) = 1 pint/A + 1/8 oz/A Oust + 0.25% X-77 + 2 lb/A 2,4-D amine.

Materials are mixed at the rate of approximately 2 1/2 pints of Embark plus 5/16 oz of Oust (or even as low as 1/4 oz) plus 1/4 gallon of X-77 plus 1 1/2 gallons of 2,4-D amine in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule E. 1/8 lb/A Embark (as mefluidide) = 1 pint/A + 1/16 oz/A Oust + 0.25% X-77 + 2 lb/A 2,4-D amine

Materials are mixed at the rate of approximately 2 1/2 pints of Embark plus 5/32 oz of Oust (1/8 oz of Oust) plus 1/4 gallon of X-77 plus 1 1/2 gallons of 2,4-D amine in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule F. 4 oz/A Manage + 1/4 oz/A Telar + 0.25% X-77 2 lb/A 2,4-D amine.

Materials are mixed at the rate of approximately 1/4 lb (4 oz) of Manage plus 5/8 oz (1/2 oz) Telar plus 1/4 gallon X-77 plus 1 1/2 gallons of 2,4-D amine in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule G. 4 oz/A Manage + 1/8 oz/A Oust + 0.25% X-77 + 2 lb/A 2,4-D amine.

Materials are mixed at the rate of approximately 1/4 lb (4 oz) Manage plus 5/8 oz (1/2 oz) Telar plus 1/4 gallon X-77 plus 1 1/2 gallons of 2,4-D amine in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule of Application: Recommended for application in the spring only. For Schedule D, apply as the grass begins to green and grow at the beginning of April until just before the emergence of seedheads from the boot at the end of the first week of May. Application of schedule E should begin approximately 10 days later on or about April 10 with termination the same as schedule D. With schedules F and G, application should be delayed until the 3rd week of April for best results. For the Northern 1/3 of the state, applications may be delayed for one week longer than the dates given above while in the Southern 1/3 of the state, the applications may be begun and ended one week earlier.

Table 8. Program of alternative treatments for use on secondary roads. While each of the following schedules has received limited testing under actual use conditions, further testing is required before definite recommendations will be possible.

Schedule SR-1. 1/4 lb/A Embark (as mefluidide) + 1/4 oz/A Telar + 1/2 lb/A Garlon-4 + 0.25% surfactant (to be tested with or without the inclusion of 1/2 lb/A 2,4-D amine)

Materials are mixed at the rate of approximately 2 1/2 pints of Embark plus 5/8 oz (1/2 oz) Telar plus 5/16 gallons (2 1/2 pints) Garlon-4 plus 1/4 gallon X-77 (with or without 3/8 gallon (3 pints) of 2,4-D amine) in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule SR-2. 1/4 lb/A Embark (as mefluidide) + 1/4 oz/A Telar + 1/2 lb/A Poast (down to 0.3 lb/A) with or without 1 gallon/A of crop oil + 0.25% surfactant + 2 lb/A 2,4-D amine.

Materials are mixed at the rate of approximately 2 1/2 pints of Embark plus 5/8 oz (1/2 oz) Telar plus 2 1/2 quarts of Poast concentrate (down to 1 1/2 quarts) with or without 2 1/2 gallons crop oil + 1/4 gallon X-77 + 1 1/2 gallons of 2,4-D amine in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule SR-3. 4 oz/A Manage + 1/4 oz/A Telar + 1/2 lb/A Garlon-4 + 0.25% surfactant (to be tested with or without the inclusion of 1/2 lb/A 2,4-D amine).

Materials are mixed at the rate of approximately 1/4 lb (4 oz) Manage plus 5/8 oz (1/2 oz) Telar plus 5/16 gallon (2 1/2 pints) Garlon-4 plus 1/4 gallon X-77 (with or without 3/8 gallon (3 pints) of 2,4-D amine) in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule SR-4. 4 oz/A Manage + 1/8 oz/A Oust + 1/2 lb/A Garlon-4 + 0.25% surfactant (to be tested with or without the inclusion of 1/2 lb/A 2,4-D amine).

Materials are mixed at the rate of approximately 1/4 lb (4 oz) Manage plus 5/16 oz (1/4 oz) Oust plus 5/16 gallon (2 1/2 pints) Garlon-4 plus 1/4 gallon X-77 (with or without 3/8 gallon (3 pints) of 2,4-D amine) in 100 gallons of water. The mixture is applied at the rate of 40 gallons per acre.

Schedule of Application. Schedule SR-1 and Sr-2 should follow the same dates of application as Schedule B of Table 27 and can be applied any time between greenup and the beginning of growth until the seedheads are formed in the boot. Schedule SR-3 and Sr-4 should be delayed in its application until the 3rd week of April for Central Indiana. For the Northern 1/3 of the state, applications may be delayed for one week longer while in the Southern 1/3 of the state, the applications may be begun and ended one week earlier.

Pre-emergence herbicides (Balan, 3 lb/A; Surflan, 2 quarts/A) may be added to each of the above schedules to enhance control of late-germinating annual weeds and grasses.

Table 9. Approximate costs of materials for comparisons for the various recommended and alternate programs of chemical mowing for vegetation management along Indiana roadsides.

Based on: Embark \$32.00/lb; Telar \$14.50s/oz; Oust \$8.75/oz; Poast \$25.00/lb; Crop Oil \$3.00/gallon; Manage \$44.00/lb; Garlon-4 \$15.00/lb; 2,4-D amine \$1.70/lb; X-77 surfactant \$10.00/gallon.

Material Cost per acre											
Schedule	Embark	Manage	Telar	Oust	Garlon-4	Poast	Crop Oil	X-77	2,4-D Amine	Total	
Recommended Interstate/Dual Lane											
A	\$16.00							\$1.00	\$3.40	\$20.40	
B	8.00							1.00	3.40	15.40	
C	4.00							1.00	3.40	9.90	
Alternative Interstate Dual Lane											
D	8.00			\$1.20				1.00	3.40	13.50	
E	4.00			0.55				1.00	3.40	8.95	
F		\$11.00	\$3.00					1.00	3.40	18.40	
G		11.00		1.10				1.00	3.40	16.50	
Alternative Single Lane											
SR-1	8.00		3.00		\$7.50			1.00		19.50	
SR-2	8.00		3.00			\$12.50	\$3.00	1.00	3.40	30.90*	
SR-3		11.00	3.00		7.50			1.00		22.50	
SR-4		11.00		1.10	7.50			1.00		20.60	

* Costs could drop as low as \$21.00 depending on final rates of Poast and 2,4-D.

Table 10. Approximate dates of application for the recommended program of chemical mowing for vegetation management along Indiana roadsides.

Schedule	Southern 1/3		Central 1/3		Northern 1/3	
	Begin	End	Begin	End	Begin	End
A	March 25	April 24	April 1	May 1	April 8	May 8
B	March 25	May 1	April 1	May 8	April 8	May 15
C	April 3	May 1	April 10	May 8	April 17	May 15

D	March 25	May 1	April 1	May 8	April 8	May 15
E	April 3	May 1	April 10	May 8	April 17	May 15
F	April 17	April 24	April 24	May 1	May 1	May 8
G	April 17	April 24	April 24	May 1	May 1	May 8

SR-1	March 25	May 1	April 1	May 8	April 8	May 15
SR-2	March 25	May 1	April 1	May 8	April 8	May 15
SR-3	April 17	April 24	April 24	May 1	May 1	May 8
SR-4	April 17	April 24	April 24	May 1	May 1	May 8

These dates should be regarded as approximate and the application window may vary as much as 7 to 10 days in length depending upon the season and particular weather conditions of any given year.

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