will increase. It is anticipated that foresters and landscape architects will blend their professional backgrounds to develop ROW maintenance practices that will be aesthetically appealing, safe, and productive of many thousands of tons of woody material that can be used. Just as landscaping Interstate highways is not identical with landscaping estates, forestry on ROWs will not be identical with forest management of farm woodlots or large tracts.

We are convinced that there is little to be gained from more studies similar to those cited earlier. The next logical step is for one or more state transportation departments to try a combination of forestry and landscape architecture. For those so engaged this will be a new venture in which everyone will learn by trial and error. Results cannot be assessed after only 1 or 2 yr, for markets must be developed, contractors encouraged to participate in this new venture, and both field and safety methods determined. The potential decrease in maintenance costs as well as the potential contribution of an enormous amount of biomass to the nation's economy encourage a positive dynamic approach to developing ROW maintenance from a widely expanded point of view.

REFERENCES

1. A. Toffler. The Third Wave. Morrow, New York, 1980.
2. H.E. Young. Bibliography of the Complete Tree Institute. 1982, 10 pp.
3. H.E. Young. Woody Fiber Farming: An Ecologically Sound and Productive Use of Right-of-Ways. HRB, Highway Research Record 411, 1972, pp. 15-23.
4. H.E. Young. Management of Forest Stands on Highway Right-of-Ways. Research in the Life Sciences, Vol. 12, 1973, pp. 12-21.
5. D.B. Hatton. A Proposal of Forest Management Alternatives to the Present Method of Vegetation Control of a Section of Interstate 95, Bangor to Newport, Maine. College of Forest Resources, Univ. of Maine, Orono, and Maine Department of Transportation, Augusta, 1982 (available from the Maine Department of Transportation).

Publication of this paper sponsored by Committee on Landscape and Environmental Design.

New Program of Chemical Mowing Along Indiana Roadsides

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The objective of this research project—full-season vegetation control along Indiana roadsides through a single spray application with no need for additional herbicide application and the complete elimination of mechanical mowing—has been realized. A combination of materials is used that consists of a grass growth retardant, a primary agent to control broadleaf weeds, and various additives that potentiate the mixture. The application is made during a 1-month period in early spring by using standard commercial spray equipment. Formation of grass seedheads is prevented and by frost, in the fall, total grass height is still less than 12 in., well within the normal mowing limits specified by the state. Thus, the feasibility of chemical mowing has been demonstrated. In addition, by means of low-cost potentiating additives, the economics are such that the cost of the treatment is substantially less than current costs of three-cycle mechanical mowing with a herbicide treatment. Additional cost-reduction approaches are under investigation. The program has immediate application for difficult-to-mow areas or narrow medians, guard rails, bridge approaches, and so forth, where both cost and safety considerations favor complete elimination of conventional mechanical mowing.

Chemical mowing is the outcome of a program of research in roadside vegetation management initiated for the state of Indiana in 1966 under the auspices of the Joint Highway Research Project of the Department of Civil Engineering of Purdue University. The research was structured to include four phases (Table 1).

The first research phase, from 1966 to 1970, was largely one of problem identification in which surveys were conducted to evaluate existing vegetation management practices and to identify specific needs that, if met, would result in significant cost savings to the state.

The second phase, development of a herbicide program, was the first to be implemented. The program began in 1971 and was fully implemented in 1972-1973. A fall application of an environmentally safe amine formulation of 2,4-D was followed by a second application in early spring on a 3-yr rotation. This program was presented in 1975 (1) and has been very successful.

Research on phase 3, reduced mechanical mowing, was initiated in 1971 and first implemented in 1974. A report on this phase was made in 1978 (2) and remains the basis for current mechanical mowing practices in Indiana.

The project has now entered the implementation of phase 4, or chemical mowing. The objective was to develop and test materials that would eliminate or reduce the need for mechanical mowing and provide

Table 1. Indiana program of roadside vegetation management.

Phase	Designation	Begin	End	Total Study Cost ($)	First-Year Cost Savings ($)
1	Problem identification	1966	1970	25,000	None
2	Herbicide program	1971	1973	30,000	300,000
3	Reduced mechanical mowing	1974	1976	45,000	1,100,000
4	Chemical mowing	1977	1983	125,000	2,000,000[a]

[a]Projected.

efficient total vegetation management at reduced costs to the state.

CONCEPT OF CHEMICAL MOWING

As the name implies, chemical mowing is the use of chemicals to prevent or reduce the growth of vegetation so that the need for mechanical mowing is either eliminated or reduced. Some of the characteristics of the desired treatment are summarized below:

1. Single spray application;
2. Control of broadleaf weeds, brush, and annual grasses;
3. No seedheads formed in turf species;
4. Maximum grass height below acceptable mowing limits;
5. No mechanical mowing necessary;
6. No weakening of root system, no adverse effects to desirable species, repeated annual use possible;
7. Healthy, lawn-type appearance;
8. Low cost; and
9. Environmental safety.

Ideally, a single spray application would prevent seedhead formation and maintain maximum grass height below acceptable mowing limits. For use in Indiana, it must be effective against both fescue and bluegrass, the dominant turf species in the state, as well as give control of broadleaf weeds and brush. Annual grasses, such as giant foxtail, also must be controlled; a preemergence action that prevents the germination of annual grass seeds in the spring is one approach that offers considerable promise. The most important performance criterion, however, is to suppress seedhead formation. Most roadsides require mowing to control seedheads, especially with tall fescue. If even a few seedheads form, the roadside will appear unsightly. For whatever treatment is used, the elimination of seedheads is essential.

In addition to the above criteria, it is important that the treatment be environmentally safe. There should be no weakening of the grass root system, no injury to desirable species, and no carryover that would limit repeated annual use. A healthy, lawn-type appearance to the turf would be ideal.

Finally, the treatment must be economical. The total cost of a single spray application must not exceed the current maintenance costs. For Indiana this consists of a fall-spring spraying rotation and limited three-cycle mowing. If possible, the treatment should not only be cost-effective but also provide substantial cost savings.

EXPERIMENTAL APPROACH

Independently and through the assistance of the industry, a large number of commercially available and experimental materials were screened for plant-growth-regulator (PGR) activity in a series of laboratory, greenhouse, and field studies. More than 500 materials were screened. From these, about 20 materials were selected for detailed study.

Finally a series of test plots was established under roadside conditions to begin the evaluation of the materials selected from the preliminary laboratory, greenhouse, and field trials. More than 2,000 test plots were evaluated. Included in the grass evaluations were degree of growth regulation; effects on seedhead suppression, color, vigor, and root growth; and mode of action. Measurements of individual plant parts were taken at weekly or biweekly intervals to help understand how grass growth was being affected. Emphasis was on evaluating how growth was regulated, for how long, and to what extent. Any material showing promise on one species was tested on other species as well. Five materials, effective on both bluegrass and fescue, were selected for detailed evaluation in combination with a primary agent to control broadleaf weeds.

The five materials were tested in large plots, primarily along the Interstate highway system, for optimum rate of application at a fixed date and for optimum date of application at a fixed rate. Date studies were initiated about once every 2 weeks from early March to mid-September in the first years and from early March to early June in the 3 succeeding years. Rate studies were conducted in early, mid-, and late spring; midsummer; and early fall in the first year and in early, mid-, and late spring in the 3 succeeding years. Several potentiating additives were also evaluated.

RESEARCH FINDINGS

Effective Three-Way Mixture of PGR plus Herbicide plus Additive

One of the mixtures tested over the past 4 yr consistently gave the desired results. This mixture consisted of three different materials: mefluidide (1 lb/acre) plus an experimental additive (1 lb/acre) plus the lithium salt of 2,4-D lithate (2.5 lb/acre). A single spray application of this combination in early spring (March 20 to May 1) gave complete suppression of both tall fescue and bluegrass seedheads, and the roadsides maintained a healthy lawn-type appearance, well within current mowing standards, for the entire growing season without the need for mechanical mowing. The inclusion of 2,4-D in the mixture gave control of broadleaf weeds and, through preemergence action, most annual grasses. There was no weakening of the root system of the turf grasses, and no visible carryover effects were observed the next season. Repeated applications of this material have been made to the same site for 5 yr with no evidence of adverse effects. All materials have been judged to be environmentally safe.

Mefluidide, the active ingredient in Embark 2S PGR, is the primary grass regulator in the mixture. Its advantages are effectiveness, safety, and no appreciable inhibition of root growth. A disadvantage is that a high rate of application is required to control seedheads in fescue. These high rates may injure native bluegrass. The material is also relatively costly.

The additive was included in the mixture as a means of decreasing cost by reducing the rate of Embark required for seedhead suppression in fescue. This material also had the additional potential of reducing phytotoxicity and improving grass color and appearance. As a single agent, the additive was ineffective.

Neither Embark nor additive alone or in combination gave significant control of broadleaf weeds, so a third component was necessary for this purpose. Amine formulations of 2,4-D or related phenoxy-type herbicides, especially at lower rates of application, sometimes showed an antagonism with low application rates of Embark. For this reason, a lithium formulation of 2,4-D was chosen initially. The lithium 2,4-D was safe, effective, nonvolatile, and sold commercially as a water-soluble powder (lithate). The main disadvantage of lithium 2,4-D over 2,4-D amine was its greater cost. Other materials, dicamba or picloram, could be substituted for 2,4-D, but cost remained the primary consideration in selecting 2,4-D.

Table 2. Seedhead suppression and growth inhibition from Embark alone and Embark plus additive applied to tall fescue and Kentucky bluegrass.

Embark[a] (lb/acre)	Additive	Seedheads per Square Foot		Height (in.)	
		Fescue	Bluegrass	Fescue	Bluegrass
None	None	17 ± 3	8 ± 4	31 ± 4	18 ± 1
0.125		3 ± 1	5 ± 2	22 ± 1	11 ± 3
0.375		4 ± 1	3 ± 0	23 ± 2	13 ± 3
0.50		2 ± 1	1 ± 1	17 ± 2	11 ± 1
0.125	XM-12S 1 percent	1 ± 1	4 ± 1	17 ± 3	9 ± 2
0.375		1 ± 0	5 ± 4	13 ± 4	9 ± 2
0.50		0 ± 0	1 ± 1	10 ± 1	8 ± 3

Note: applied April 27; evaluated May 27; initial height of fescue = 10 in.; initial height of bluegrass = 7 in.
[a]As mefluidide.

The results obtained with the Embark-additive-lithium 2,4-D combination established the feasibility of chemical mowing. One chemical treatment, applied in the spring, suppressed seedhead formation in all grass species. The treated grass maintained a uniform height and a healthy lawn-type appearance. The appearance was judged to be superior to that of a mowed roadside. Results were consistent in three consecutive years at several locations within Indiana.

The major disadvantage of the Embark-additive-lithium 2,4-D mixture was its cost. Based on results obtained during the 1980 season, a modified combination was developed for application in the spring of 1981. This combination consisted of 0.50 lb/acre of mefluidide plus 0.06 lb/acre of the additive and 2.2 lb/acre of lithium 2,4-D. The estimated cost of materials was $65/acre, the approximate break-even point compared with the cost of three-cycle mowing. This cost estimate unfortunately could not be realized in practice due to the unavailability of the additive, and the next 2 yr were spent in developing a practical alternative to the original three-part mixture.

New Additives to Enhance Growth-Retardant Action and Reduce Material Costs

In 1982 two new additives to replace the original one in the mixture were field tested. They were designated XM-12S and IN-IIA. Both materials were inactive when used alone but when combined with Embark reduced the effective rate required by approximately half (Table 2). The additives are inexpensive, costing no more than $3.00 to $6.00/acre.

Additive XM-12S was especially effective and enhanced not only the action of the Embark but also that of the 2,4-D. This effect is summarized below (species present included wild carrot, dandelion, red clover, black medic, goldenrod, aster, common plantain, buckhorn plantain, milkweed, and thistle; XM-12S is given as percent by volume of the total spray mixture; the active ingredient in Embark is mefluidide):

Treatment	Amount (lb/acre)	Weeds per 10 ft²	Control (%)
Unsprayed check	--	19	0
Embark + 2,4-D	0.5 + 2	15	21
Embark + 2,4-D + XM-12S	0.5 + 2 + 1	1	95

As a result, the XM-12S overcame any 2,4-D antagonism in the mixture with Embark. Although some reduction in the rate of 2,4-D was indicated from the results, it may still be wise to retain the high rate of at least 2 lb/acre in order to achieve good control of resistant broadleaf weeds such as wild carrot and red clover, which, if not fully controlled, quickly become unsightly.

Additional cost savings may be possible by using a combination of the two new additives, SM-12S plus IN-IIA. Preliminary results obtained during the 1982 growing season were encouraging but additional tests will be required to complete evaluation.

Due to the effectiveness of XM-12S, it will be possible to use the amine formulation of 2,4-D in the mixture rather than the more expensive lithium formulation. This in itself will result in considerable cost savings compared with that of the original mixture.

RECOMMENDATIONS

The treatment schedule for implementation in Indiana in the spring of 1983 is summarized below. The cost will be competitive with three-cycle mowing plus the usual 2,4-D herbicide treatment.

1. Materials: Embark PGR containing 2 lb/gal active ingredient (mefluidide) plus 2,4-D amine from concentrate containing at least 4 lb acid equivalent/gal plus additive XM-12S.
2. Rate: Material is mixed at the rate of 0.66 gal of Embark (2 lb/gal active ingredient) plus 1.25 gal of 2,4-D amine (4 lb/gal active ingredient) plus 1 gal of XM-12S in 100 gal of water. The mixture is applied at the rate of 40 gal/acre.
3. Application schedule: Recommended for spring application only. Apply as soon as the grass begins to green up until well before emergence of seedheads from the boot (end of March to the end of April in Indiana).

It is clear from our experience that Embark alone at the rate of 0.375 lb/acre of mefluidide or less is insufficient to control seedhead formation in tall fescue in the tough spots along roadsides (medians, adjacent to pavement, adjacent to fence). The 0.375-lb/acre rate may be sufficient for interchanges but not for the bulk of the roadside. At best, only 50 to 60 percent control of seedheads in fescue has been achieved. However, by employing additives, the effectiveness of the Embark has been increased and any 2,4-D antagonism overcome.

The recommended treatment, Embark at 0.5 lb/acre of mefluidide plus 1 percent XM-12S plus 2 lb/acre of 2,4-D amine, should be applied before seedheads form between the end of March and the end of April. It can be applied to already-mowed roadsides, but this partly reduces the cost-effectiveness and defeats the purpose. Commercial spray equipment can be used in making the application. Although an error factor of 2 can be tolerated (either underdosing by half or overdosing by twice) without complete loss of effectiveness or adverse effects, uniformity of application is considered critical and spray coverage is essential.

REFERENCES

1. D.J. Morré. A Minimum-Cost, Environmentally Safe Program of Herbicide Maintainance for Indiana Roadsides. TRB, Transportation Research Record 506, 1975, pp. 85-93.
2. D.J. Morré. Five-Year Evaluation of Highway Mowing Practices in Indiana. TRB, Transportation Research Record 674, 1978, pp. 47-53.

Publication of this paper sponsored by Committee on Landscape and Environmental Design and Committee on Roadside Maintenance.