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Biological Control of Carduus Thistles Along Roadsides in Northeastern States

SUZANNE W.T. BATRA

The host-specific European seed-destroying weevil, Rhinocyllus conicus, has been released at 72 sites in Maryland and Pennsylvania for the biological control of Carduus thistles in crown vetch. Established populations along roadsides are spreading into adjacent thistle-infested pastures. Another host-specific European beetle, Trichosirocalus horridus, which attacks rosettes, will be released along roadsides in 1981.

The northeastern region includes West Virginia, Maryland, Pennsylvania, New York, Delaware, New Jersey, and the six New England States. Carduus species occurring in this region are C. acanthoides (plumeless thistle), C. crispus (curled or welted thistle), and C. nutans and C. thoermeri (nodding or musk thistle).

Carduus crispus is an economic problem only in West Virginia, where the host-specific European weevil Rhinocyllus conicus has been established by the West Virginia Department of Agriculture in Monroe County for its control (1). This thistle has been present in the general area since about 1920 (2).

Carduus nutans was first recorded in the United States in 1853 at Harrisburg, Pennsylvania (3), where musk thistle still remains a serious pest. Other early northeastern introductions were in ballast dumped at Hoboken (1893) and Camden, New Jersey (1880); at Providence harbor, Rhode Island (1890); and at Washington, D.C. (1897). Carduus acanthoides similarly appeared first at ballast dumps at Camden (1878) and Hoboken (1880), and at Providence harbor (1893); it was found in Ohio in 1878.

Carduus nutans, C. thoermeri and C. acanthoides in the northeast often occupy the same habitats, such as overgrazed pastures and roadsides, sometimes occurring as mixed stands. These plants are troublesome primarily in the Great Valley region, which is a northeastward extension of the Shenandoah Valley of Virginia and located between two long, parallel mountain ridges. Serious infestations are found from northern West Virginia to near Hagerstown and Frederick, Maryland, to Harrisburg, and eastward past Allentown, Pennsylvania, into western New Jersey. As noted in Ohio by Stuckey and Forsyth (3) and in Virginia by Hensley (4), these thistles in the northeast create economic infestations primarily when growing in shallow soil over limestone. Scattered plants or patches may be found elsewhere and, due to their conspicuousness, these may be relatively well represented in herbaria. However, the early introductions outside the limestone zone apparently did not create major infestations there.

For example, as one progresses from east to west across Maryland, four zones are encountered:

1. Eastern shore (Delmarva Peninsula)--sandy soils,
2. Piedmont plateau (area around Washington, D.C.)--primarily poor red clay or mica-schist soils,
3. Great Valley--well-drained fertile soils developed over limestone, and
4. Western Maryland beyond Hancock--shale, sandstone, or schist.

Bull thistle (Cirsium vulgare) is the predominant thistle in the coastal eastern region (zones 1 and 2) on the red clay or sandy soils; Carduus thistles occupy the same ecological niche in zone 3 (limestone soils), and Canada thistle (Cirsium arvense) becomes predominant in western Maryland as well as in other areas north and west of the Great valley.

The distribution of C. acanthoides and C. nutans is positively correlated with the location of fertile soils developed over limestone in three contiguous counties, Franklin (Pennsylvania) and Frederick and Washington (Maryland). In Franklin County (5), this valley soil, referred to as the Hagerstown-Duffield association, occupies 32 percent of the county, where nearly all is cleared for crops, orchards, hay, and pasture. Carduus thistles in Franklin County also extend their range to somewhat overlap adjacent areas of thicker valley soils overlying limestone (Murrill-Laiding formation) or shale and sandstone (Weikert-Becks-Bedington association). The reddish to yellowish soils of the Hagerstown-Duffield-Frankston association occupy 46 percent of the total area of Washington County, Maryland. Although cultivation may be hindered by the numerous limestone ledge outcrops, this most fertile soil in the county provides high yields in corn, small grains, hay, and pasture (6). About 10 percent of Frederick County is occupied by the well-drained Duffield-Hagerstown-Sasquatchie-Athol valley soils developed from limestone and shale over limestone rocks much less acidic than surrounding areas (7). Although there may be massive outcrops of hard limestone, excellent yields support numerous farms and productive dairying. Although Carduus is most prevalent on these soils, some thistles grow in adjacent poorer micaschist-derived soils of the Piedmont plateau where underlaid by marble or limestone. These plants are rarely found to the west or north on stony, steep mountain soils or on the shallow soils of red shale and sandstone in the valleys. As may be seen from the above data, Carduus thistles are a particularly serious economic pest because they interfere with agriculture on the most productive soils of the region.

The geographic distribution of economic infestations of Carduus thistles in the northeast appears to be long-standing and related to the availability of soils formed over limestone. This does not seem to be the case with the recent and rapidly spreading infestations occurring in the central Midwestern and Mountain States in various soils (8-10). According to Doing and others (11), C. nutans in Australia grows in moist, neutral, well-drained soils over basalt or granite; fertile and calcareous soils are rare in climatic zones suitable for this plant.

An introduced European weevil, Rhinocyllus conicus, was released on C. nutans, C. acanthoides, and C. thoermeri in Maryland and Pennsylvania in 1975 at 10 sites, in 1976 at 19 sites, in 1977 at 9 sites, in 1978 at 12 sites, in 1979 at 7 sites, and in 1980 at 15 sites. These releases of R. conicus were made in heavily infested pastures, in vacant land, and also along highways where Carduus thistles have crowded out crown vetch (Coronilla varia) planted on steep banks for erosion control. The beetles were collected at White Hall, Frederick

County, Virginia, and released during the above years at sites in the following counties: Prince George's, Frederick, Washington, and Baltimore in Maryland and York, Cumberland, Franklin, Lancaster, Berks, Centre, and Dauphin in Pennsylvania. As a result, populations have become established since 1978 and are spreading of C. nutans of 7 of 11 locations checked in 1979: Beltsville, Maryland (100 percent plants infested); junction of I-70 and Appalachian Trail, Maryland (50 percent plants infested); Fort Detrick, Maryland (9 percent infestation); Pinola, Pennsylvania (10 percent infestation); I-81 at Greencastle, Pennsylvania (93 percent infestation); at Scotland, Pennsylvania (30 percent infestation); and at Shippensburg, Pennsylvania (75 percent infestation); and of C. acanthoides at State College, Pennsylvania. This insect has proven effective in controlling Carduus nutans in other regions (12,13).

In the northeast, it has also been released in Hunterdon, Warren, and Burlington Counties, New Jersey, and Monroe, Jefferson, Berkeley, Pendleton, Grant, and Hardy Counties, West Virginia (1,14). The spread and impact of these first population establishments along roadsides in the northeastern states will continue to be evaluated; and new releases of R. conicus will be made as needed.

Cassida rubiginosa, an accidentally introduced chrysomelid beetle, is abundant on C. nutans and C. acanthoides in Maryland and Pennsylvania. This defoliator, which also attacks Canada thistle, Cirsium arvense (15), does not seem to significantly reduce the vigor of Carduus thistles, although leaves may be extensively damaged in some areas.

A newly imported European thistle rosette-destroying weevil, Trichosirocalus horridus, will be distributed in April 1981 along roadsides in the northeastern states to augment the seed-destroying action of R. conicus. As soon as additional biological control organisms are tested and approved, they will also be distributed and released in the northeastern states (16).

Carduus thistles are important weed pests in relatively inaccessible pastures as well as long roadsides. Biological control agents released along roadsides subsequently spread into adjacent thistle-infested fields. This program thus benefits both agriculture and roadside management.

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Lead Compounds in Mule Deer and Vegetation Along I-80, Southeastern Wyoming

LARRY L. IRWIN, MARK L. MASON, AND A. LORIN WARD

The levels of lead compounds from automotive emissions were determined for organs of mule deer (Odocoileus hemionus) and for annual growth of two important forage species collected near Interstate-80 and a control area. Levels of lead in big sagebrush (Artemisia tridentata) up to 90 m from the highway were significantly higher than in those from an area 6.5 km north of the highway. Values ranged from 20.0 μg/g dry weight at 15 m to background levels (2.0 ± 1.8) at 90 m. Levels of lead compounds in true mountain mahogany (Cercopcarpus montanus) were not significant and were much lower than those in big sagebrush. Organs of three mule deer collected near the highway contained higher lead levels in each of 52 comparisons with organs of four deer collected from the control area, ranging from trace amounts in muscle to 10.8 μg/g in the antlers of a young male. Bones, kidneys, and livers accumulated most of the lead burden, and the deer were not hazardous for consumption by humans. Composite samples of fetuses from highway deer contained amounts equivalent to those in livers of their mothers, indicating that transplacental movement of lead occurred. Chronic lead poisoning is possible, particularly in fawns. Population indicators were adequate, but lead poisoning could be a significant problem in other populations in areas with higher traffic.

Studies of lead compounds from motor vehicle exhaust along major highways have shown significant levels in vegetation up to 91 m away (1-3), in small mammals (4,5), and in domestic livestock (6,7). However, little is known about levels in wild ungulates, such as pronghorn antelope (Antilocapra americana) or mule deer, which may use foraging and resting areas adjacent to highways. In national parks they appear less likely to avoid highways (8), and in other areas they spend significant time during winter within a few hundred meters from major highways.

Mule deer in the Telephone Canyon area of southeastern Wyoming spend about two-thirds of their time annually within 300 m of I-80, where radio-tagged deer rested in timber stands and fed in brushy openings, often inside the right-of-way fence (9, 10). Because lead is a cumulative poison and the highway has been at its present location for more than 50 years, there was concern for the welfare of deer that may inhale motor vehicle exhaust and ingest vegetation that may contain lead (Pb) compounds as dust on leaves or as constituents of internal tissues. In addition, those deer are subject to human consumption; hence, there was concern for human health.

This paper reports the incidence of Pb compounds in various organs of mule deer and important forage vegetation collected near I-80 and a control area some distance from I-80.

An area of known mule deer use along I-80 in Telephone Canyon was selected 12 km east of Laramie, Wyoming. A comparable, unroaded canyon was selected for a control 6.5 km north of I-80 and 7.5 km northeast of Laramie. The control area received only occasional seasonal use by off-road vehicles. Vegetational composition of the higher elevations in the study areas was dominated by conifers. At somewhat lower elevations and/or drier sites, a shrub-steppe vegetational type prevailed. In that type true mountain mahogany was most abundant, but concave slopes produced large amounts of basin big sagebrush. Both of the latter plants are important forage for mule deer in the area (11). In winter, prevailing west winds average about 35 km/h and combine with long periods of cold weather to pose serious obstacles for survival of mule deer. Domestic sheep graze on private lands along the highway in the canyon. Traffic averages about 5000 vehicles/day, according to the State of Wyoming Highway Department.

METHODS

Three transects 165 m in length were located: two were perpendicular to each side of I-80 and one was located in the control area. Ten collection stations were established at 15-m intervals on each transect. South of the highway a deep rocky ravine precluded samples closer than 45 m. All of the current annual growth of twigs from big sagebrush and mountain mahogany was collected at each station during July 1979. Ten plants per station were necessary for representation. Terminal shoots collected during each sample were dried in a forced-draft electrical oven at 62°C for 48 h and ground through a Wiley mill with a 20-mesh screen. A preliminary analysis of washed and unwashed sagebrush samples resulted in no significant differences in Pb compounds, so plant samples were not washed.

A collection permit was obtained to collect five mule deer. Three had histories from previous studies of being residents of Telephone Canyon and their range included very little area beyond 400 m of I-80. A 6-year-old doe carrying an inoperable heart-rate-monitoring telemetry system from another study (10) was collected within an hour after it was killed by a vehicle on I-80 on January 16, 1979. It was labeled D-1 and frozen until laboratory analysis. In spring 1979, a second adult female (D-2) and a two-year-old male (D-3) were collected 400 m and 100 m north of I-80, respectively. Doe (D-2) carried twin fetuses. The twin embryos found in the vehicle-killed doe (D-1) in January were too small for analysis.

In spring 1980, a two-year-old doe (D-4) carrying a fetus and a yearling buck (D-5) were collected from the control area. Also, parts of two adult males (D-6, D-7), collected at some distance from major roads by the Wyoming Game and Fish Department, were used as additional control animals. All deer (except for the vehicle kill) were shot with a high-powered rifle, usually in the neck region.

Whole deer organs and fetuses were dried in a forced-draft electrical oven at 70°C for one week, and ground through a Wiley mill with a 2-mm screen. Samples of plant and animal tissue were ashed in a muffle furnace at 490°C for 4 h, dissolved in 10 mL of 50 percent (V/V) nitric acid and 10 mL of 3 percent (V/V) hydrogen peroxide, filtered through Whatman No. 40 filter paper, rinsed with hot distilled deionized water, and brought to 10-mL volume with distilled deionized water. Lead content of 3-g samples of plant and animal tissue was determined by using atomic absorption spectrophotometry (Perkin-Elmer Model 403) and common procedures (12-14). Each sample was assayed three to five times. Lead content of collected and prepared samples was checked by using the standard addition test (dried orchard leaves from the National Bureau of Standards) and blanks. Concentrations of lead compounds in randomly selected samples were also verified by the Wyoming State Chemistry Laboratory. A paired difference test and paired t-tests (16) were used to statistically compare lead in deer and plant tissues, respectively. Statistical significance in this paper denotes comparisons at the 0.05 level of probability.

RESULTS

Levels of Pb in sagebrush up to 90 m from I-80 were significantly higher than in plants grown in an area 6.5 km north of the highway. Values ranged from a high of 20 µg/g dry weight 15 m from the Interstate, and decreased to control values at 90 m from the highway (Table 1). Baseline levels of lead in shrubs have been reported to be 1-4 µg/g (15). Other researchers (16) found 1-2 µg/g Pb in deer forage in an unroaded area in Montana. Perhaps the high winds contribute to lead being deposited further than 50 m, which is the figure most often given in the literature. There were no significant differences in levels of Pb in sagebrush plants growing on either side of the highway.

Levels of Pb in true mountain mahogany near I-80 were not significantly different from those found in plants from the control area, but they were much lower than those found in big sagebrush growing in similar sites. The finely pubescent leaves of big sagebrush possibly entrapped more Pb particulate matter than mountain mahogany.

It was found that deer from the I-80 area contained significantly more Pb than deer from the control area (Table 2). Levels of Pb in deer from the I-80 area ranged from trace amounts in hip muscle to 10.8 µg/g dry weight in the antlers of the young male. Bones, kidneys, and livers contained more Pb than other organs. Composite samples of the near-term fetuses contained amounts equivalent to those found in the livers of the adult deer. Thus, transplacental transfer of Pb appears probable.

Although the levels of Pb for deer in the I-80 area were significantly higher than in deer from the control area and in livers and kidneys from deer in an unroaded area in Montana (16), they were lower than levels that produced no signs of lead toxicosis in an experiment with domestic sheep (17). However, the length of exposure and relative ability of forage plants to entrap or absorb Pb would be factors for long-lived ungulates living near major highways. Lead is a cumulative poison, building up in bones and taking the place of calcium (18). Thus, the relatively higher levels found in the antlers of one of the deer in this study was not unexpected. Antler shedding could possibly be a pathway to rid the body of some of the lead burden. In bone salt form it is not toxic, but during high calcium metabolism, as probably occurs in growth of antlers or in development of deer fawns, skeletal Pb may be mobilized and acute lead toxicity may result.

Symptoms of acute plumbism were not observed in this study, but these data suggest the possibility for chronic effects, compared with domestic sheep (19). The concept of a threshold value for chronic symptoms has been criticized (20,21), but high-normal values for livers of small mammals are accepted to be 3-6 µg/g (22). The data from mule deer in this study were within those values.

The data for fetuses (see Table 2) suggest an even stronger possibility for toxicity to mule deer

Table 1. Levels of lead compounds in unwashed mule deer forage plants along I-80, southeastern Wyoming.

Plant Type and Location	Distance from Highway (m) 15	30	45	60	75	90	105	120	135	150	165	180	Control Area[b] ($\bar{x}$ ± 95 percent C.I.)
Sagebrush													
North of highway	20.3	11.3	8.2	6.3	6.3	4.7	4.0	4.0	4.0	3.3			2.0 ± 1.8
South of highway[a]			7.0	8.3	5.7	3.3	2.7	3.3	2.7	2.0	1.0	1.7	
Mountain mahogany													
North of highway	2.7	2.3	1.7	1.3	0.0	0.0	0.0	0.0	0.0	0.0			1.0 ± 0.7
South of highway[a]			3.0	2.0	1.7	1.3	1.3	1.3	1.0	1.0	0.0	0.0	

Note: All data given in µg/g dry weight.
[a]South of highway no samples could be collected closer than 45 m.
[b]6500 m north of I-80.

Table 2. Levels of lead compounds in mule deer tissues, southeastern Wyoming.

Part	I-80 Area: Deer number, sex, and age D-3 (♂) 2	D-1 (♀) 6	D-2 (♀) 3-4	Comparison Area: Deer number, sex, and age D-4 (♀) 2	D-5 (♂)[a] 1	D-6 (♂)[b] <4	D-7 (♂)[b] <4
Hip muscle	1.0	1.0	0.2	0.0	0.0		
Brain	0.7		1.2	0.0	0.1		
Spleen	1.0	1.3	1.2	0.2	0.4		
Heart	0.8		1.6	0.2			
Lung	1.3	1.3	2.4	0.4			
Hair	2.4			1.6			
Fetus-1			2.0	0.3			
Fetus-2			2.3				
Rib	3.3			1.0	1.3		
Loin	3.0			0.0	0.0		
Liver	3.0	3.0	3.2	0.2		0.7	0.7
Kidney		4.0	2.2	0.2	0.7	1.0	1.7
Femur	4.4	9.7	4.9	0.0	0.5		
Antler	10.8				1.2		

Note: All data given in µg/g dry weight.
[a]Liver, heart, and lungs of D-5 contaminated by bullet.
[b]Kidneys and livers were only parts available and were provided by the Wyoming Game and Fish Department.

fawns, which apparently absorb lead across the placenta during fetal development. Transplacental transfer of Pb has also been observed in other mammals (20). In addition, a considerable part of the maternal dose can be transmitted via milk to suckling rate and mice (21), in which subclinically dosed mothers may give birth to chronically poisoned offspring.

Because lead is a cumulative poison, the possibility may exist for chronic Pb poisoning in deer fawns in the study area. The manifestations of such a problem for a wild ungulate population would likely go unnoticed because of the confounding effects of mortality due to other causes. However, data for population composition (9), which show doe-fawn ratios to be adequate, indicate that possible chronic effects of Pb may not be serious for deer populations along I-80. Also, the levels in deer tissue are not considered a threat for human consumption. However, the possibility may exist for lead poisoning of other wild ungulates in areas with higher levels of traffic.

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Proceedings

(Symposium on Roadside Vegetation Management and Manipulation Program, August 3-8, 1980, San Antonio, Texas, sponsored by Committee on Roadside Maintenance and Committee on Landscape and Environmental Design.)

Preface

The Texas Department of Highways and Public Transportation hosted the combined summer meeting of the Committee on Roadside Maintenance and the Committee on Landscape and Environmental Design. The meeting was a unique symposium on Roadside Vegetation Management and Manipulation, held at the Marriott Hotel in San Antonio, Texas, with approximately 120 people in attendance.

Members of the joint committee sponsored a special award for outstanding achievement of beauty along the roadsides of highways in the United States. This award went to Mrs. Lyndon Baines Johnson. The presentation was made by Tom Taylor, Director of Travel and Information, Texas Department of Highways and Public Transportation; Roy White, architect and builder, accepted the award on behalf of Mrs. Johnson at a special luncheon.

A field trip to view urban landscape projects in the San Antonio area included the McAllister Freeway, which received special recognition for achievement in this category. The field trip extended to rural areas and included a review of a rest area.

This publication of the proceedings does not include the full manuscript of the presentations. The abstracts presented were either presented by the authors or condensed by the Committee on Roadside Maintenance for purposes of publication. More details may be obtained from the authors.

I wish to thank all of the individuals who worked hard to formulate the program and the authors for their excellent product.

Charles T. Edson, Chairman
Committee on Roadside Maintenance

Notice: The Transportation Research Board does not endorse products or manufacturers. Trade and manufacturers' names appear in these proceedings because they are considered essential to its object.

Abstracts

PRESENTATION AND PROPAGATION OF NATIVE PLANT MATERIALS
Tom Allen

(Allen's presentation was not available for publication.)

RELICT BIOMES IN TEXAS
Joseph W. Tyson, Jr.

Transportation agencies are entering areas not entered before. Although there are several different changes that have been made in the East Texas piney wood region, the major agent of change has been forestry. In the coastal zone and extending up into the prairie area, it has been urbanization. Along the Rio Grande River in Texas, agriculture has been the major change. In the Central Texas region, urbanization is the key; in the high plains area, range use and grazing have been inhibiting factors.

However, even in these areas where man has introduced himself to the greatest degree, areas still remain where no evidence exists of man's impact on the plant and animal environment. These are called relict areas--areas that have remained substantially unchanged since before the advent of modern man. The early native inhabitants altered the environment by cutting, slashing, burning, overgrazing, or overharvesting. There is no tractless wilderness outside of the Arctic and Antarctic. Men have always been on the move and have made well-traveled pathways from one point to another. We are still making such paths either because of safety, convenience, or other social pressures. The earliest descriptions then formed the base for a determination of whether or not an area is a relict area. There are records of several kinds on first visitors to a whole host of different kinds of areas (in the full text of this presentation, there are many examples of how individuals or groups of individuals affected the environment in Texas).

What's happening in these relict areas? There is a food chain, and the plants that are found in relict areas are the bottom of this food chain. They are the food producers on whom primary consumers first feed. Those primary consumers are in turn eaten by secondary consumers, such as meat-eating animals, and they ultimately die. The materials of which their bodies are composed are either eaten by others or they return to the soil so they combine with the soil and reenter the food chain. This same thing is happening on our rights-of-way; except now as a general rule, we exclude the grazing population. As a consequence, our mowing programs and other roadside vegetation control programs fill that biological nitch and we, in effect, are the grazing community.

Without this grazing activity, the plant community changes and can no longer be considered a climax community developed under optimum conditions. When creating a transportation corridor, we preempt further encroachment into that particular area and, as a consequence, we tend to preserve what was there. It is this preservation aspect that becomes very important.

Relict areas are of scientific interest and they are of some aesthetic interest. The transportation agency, as a general rule, has preserved a great number of these areas, and it requires no new policy or no new effort by such agencies to ensure that such relict areas continue to exist.

WILDFLOWER WORKS
Chapman Kelley

When discussing the arts, it is important to realize that, at their highest and most meaningful level, they are a language of philosophical communication through abstract means. The profundity of the idea/concept along with the uniqueness of the aesthetic eventually determines its ultimate value to future generations. Those few whose accomplishments survive their time and earn them the distinction of "artist," are those who define or substantially redefine what a work of art may be. As both Leonardo da Vinci and Robert Henri said, Art is invention.

The arts have to change from being elitist to populist in order to have relevance and meaning in today's world. We design paintings and sculptures. We also design buildings; furnishings; governmental, educational, and economic systems; assembly lines;

machinery; our time; and, in fact, our entire lives and living environments. Because man is an intelligent, inventive, acquisitive, ambitious, and--all too often--a greedy creature, by his very existence, he scratches the surface of the earth much more deeply than any other animal. It is for this reason that he should both understand and cooperate technologically and spiritually with nature.

The monotonous conformity of concrete forms combined with man's answer to nature, uniform grass, seemed to be a totally inadequate solution aesthetically and economically. This juxtaposition of concrete and grass does little to challenge the human spirit. I voiced the idea of transposing both the appearance and significance of the flat man-made areas of my paintings with similar shapes or roadway and airport runways and, in addition, planting the otherwise grass-covered areas with color: wildflowers arranged according to my design. The concept amounted to an actualization of what I had been painting only on somewhat of a grandiose scale in a three-dimensional context. The aesthetic would be the same, but the opportunities for human participation would be greatly enhanced. The contract between slabs of austere concrete designed by airport engineers for traffic pattern purposes and shapes of color defined with waving fields of wildflowers might stir individuals to consider that opposites can coexist for the benefit of both. The lyricism and beauty of wildflowers would be a challenge to our sense of design.

In working with the administration of the Dallas-Fort Worth Airport, phase one of the Dallas-Fort Worth Wildflower Works was launched. Literally tons or hundreds of millions of seeds have been planted along the International Parkway as part of this project. In endeavoring to cover thousands of acres of land, with 12- to 15-in leafy material, there are bound to be ecological and economic impacts. We are continually seeking answers to such diverse questions as, What kind of impact would wildflowers have on modifying or cushioning sound? Which plants would require less water? and How can native materials be planted with root systems at different levels, thereby better using soil nutrients, eliminating the need for costly fertilizers, and aiding soil erosion?

A big advantage of native materials is their economic saving in mowing. Through the use of chemicals applied by the ropewick system, taller competitors can be virtually eliminated without the expense of mowing. Findings indicate that it would cost from two to three times as much energy to plant and maintain the average suburban lawn as it would a comparable-sized food crop. If I could start with this aesthetic challenge, foresee ecological benefits, and wind up with a savings in the cost, how could parks, highways, transportation corridors, other airports, and public places afford not to be composed into wildflower works of art?

REHABILITATION OF INTERSTATE SAFETY REST AREAS IN IOWA
Harold Dolling

Four pairs of safety rest areas on Iowa's Interstate Highway System were constructed and available for public use during 1966. These rest areas were built before a design guide was available. In upgrading these facilities, they had to be completely accessible to the handicapped and, in addition, were to provide additional parking, ground lighting, waste water dump for recreational vehicles, waste water pond or lagoon improvements, sidewalks to tables, rest room upgradings, additional landscaping, and general upgrading of outdated items.

In the first contract, the design guide indicated that an additional parking facility was needed for 52 cars and 22 trucks at each site. This was not practical based on existing topography. The final design provided for 36 cars, 10 recreational vehicles, and 16 trucks at each site. The parking was less than desirable because of the topography. The high price tag of $1 000 000 for modifications was high compared with the original $250 000 to construct the entire complex. The lagoons needed to be improved as part of the total contract, which originally cost $14 500 to build. Due to changes in the environmental requirements, the refurbished lagoons cost $199 000.

In subsequent improvements, it was noted that the lagoons would require enlargement and appropriate arrangements would have to be made. An alternate solution considered was the replacement of the five conventional water closets with microphor low-water-volume toilet fixtures in each building. This was done in subsequent rest areas and water use has been reduced 45 percent or more. Rest area rehabilitation is a challenge, particularly when total costs are considered. For future rest area rehabilitation, I recommend the Federal Highway Administration Technical Advisory Publication T-5140.8 (August 10, 1979), Rest Area Design Charts, which is based on data developed by Minnesota officials. This is an excellent planning and design tool.

DEVELOPMENT OF THE McALLISTER FREEWAY--SAN ANTONIO
Mel Steinberg

Steinberg made a presentation on the development of the McAllister Freeway as it relates to the roadside. His presentation indicated that the freeway was a showplace for roadside development.

INTERRELATIONS OF VEGETATIVE MANAGEMENT AND EROSION CONTROL FOR A SOUND ROADWAY ENVIRONMENT
Sam Garrett

(Garrett's presentation was not available for publication.)

COMPARISONS OF AGRONOMIC AND ECOLOGICAL APPROACHES TO ROADSIDE MANAGEMENT
L.E. Foote

Roadside management came into existence gradually over time as a scientific and administrative approach to roadside maintenance. In the 18th and 19th centuries, roadside vegetation was generally cut by hand (and later by machine) for forage. Roadsides were pastured by staked or free-roaming animals, burned, farmed, or neglected. Often, the roadsides were cut to avoid fire hazard or to provide good visibility against lurking highwaymen, to clear brush, and to provide a neat appearance.

With the scientific agriculture movement of the

Table 1. Comparisons of the agronomic and ecological approaches to roadside management.

Factor	Agronomic Approach	Ecological Approach
Action	Direct	Indirect
Appearance	Neater, more formal, more cared for, more structured, man-formed	More natural, less cared for, less structured, nature formed
Vegetation	Monoculture, single best species	Heteroculture—broad group of species to fit a group of conditions
Inputs	Energy, labor, money, equipment, materials	Time, management, education, seed
Cost	Higher	Lower
Soil	Added inputs applied so it can be treated as a single-like item	Inputs applied to fit a range of edaphic conditions—treated as a mosaic
Fertilizer	Blanket applications, may have to repeat	More single element or unbalanced application to favor certain spaces at cost to others
Nitrogen	Applied, may have to frequently repeat	From legumes and/or soil as much as possible
Weeds	More of a problem	Less of a problem
Public perception of weed problem	Less of a problem	More of a problem
Herbicides	More use, broadcast, for group of plants—more done at one time	Less use spread throughout season, spot application, more for single species
Wildlife habitat	Low to moderate	High
Fire hazard	Low	High
Energy	High inputs	Low inputs
Mowing	More frequent, more area	Less frequent, less area, may not mow at all
Time response	More rapid	Slower, needs more time

late 1800s and early 20th century, agronomists advocated roadside mowing for weed control purposes. For almost the entire first 50 years of this century, mowing, tillage, and crop rotation were the main weapons available to fight weeds. The only one of these that could be readily used on roadsides was mowing, though some states also used fire on a regular basis. Considerable agronomic research efforts were directed at weed control through mowing during the first 30 years of this century.

Starting in the early 1930s, many states added roadside development units to their highway departments. These units often contained trained landscape designers, sometimes agronomists, and generally engineering personnel. The idea that the roadsides were the front yards of the nation and the concept of the complete highway (right-of-way fence to right-of-way fence) were stressed. Roadsides were more frequently mowed and treated in an agronomic manner like a well-cared-for lawn. This approach continued through into the 1960s and chemical weed control was added to the program. Through manuals and training, the approach became institutionalized into many highway department operations.

In the late 1960s, a different approach developed. This was generated by rising costs, increased roadside acreages, environmental and ecological concerns, and the wider knowledge of and appreciation for the ecological approach to vegetation management as put forth by the science of land management. The formal definition of rangelands included public rights-of-way. Table 1 compares the differences in the agronomic and ecological approaches to roadside management. From a review of this table, it will be readily apparent why, in today's era of shrinking funds for transportation agencies, the trend in roadside management has been toward the ecological approach--i.e., the applied science of range management.

MANAGEMENT OF ROADSIDE VEGETATION: SOME PRINCIPLES FROM RANGE SCIENCE

Roger Q. Landers, Jr.

Roadside vegetation is both virtuous and villainous. On the one hand, it may provide welcome shade at rest stops; on the other, an immovable object for an out-of-control vehicle, avenues of wildflower beauty or routes of weed infestations, restful scenery or depressive monotony, and erosion stabilization or pavement destruction. Management makes the difference. Because roadside vegetation is most often a mixture of plant species, its management is more often based on principles from range rather than agronomic sciences. In other words, roadsides are more like rangeland than farmland.

Plants growing in the right-of-way tend to be the same kind as those growing on adjacent land. There are some striking exceptions to this, but generally they are responding to a similar climate and soil. These broad vegetational types of naturally occurring communities of trees, shrubs, forbs, and grasses provide the basis for management. Types change with different rainfall amounts and patterns. The dry summers and mild moist winters of southern California produce chaparral communities; the moist summers and snowy winters of New England produce deciduous forest communities.

Disturbance of the natural vegetation along the roadside during the process of road construction, repair, or maintenance usually initiates a sequence of changes in vegetation during the recovery process. An area begins to revegetate, with a tendency over many years to become similar to the adjacent vegetation. Dandelion, quackgrass, Johnsongrass--the list of species that are capable of moving into relatively new sites and staying there is almost endless. Some of these become permanent members of the community along with the native plants from across the right-of-way line.

We might explore the possibilities of selecting the proper species and manipulating them in the proper way to establish a self-maintaining roadside vegetation. It sounds good, but there are problems. In the first place, it is difficult to find stable combinations of species acceptable for roadside needs. Where annual rainfall averages more than 15 in, the vegetation tends to grow too rank with woody plants and shrubs to be tolerated. In other words, the naturally occurring community is not acceptable as a roadside vegetation despite the low maintenance potential.

The Illinois model indicated that, when you plant lawn grasses in a climate that supports natural communities of tall grass, prairie, and oak forest, the vegetation is not self-maintaining. The Iowa model used taller grasses, primarily smooth bromegrass for an initial installation. After a period of vegetation, although the roadside is not self-maintaining, the Iowa condition is subsidized to a lesser extent than it would be if it were maintained as a lawn. It can be concluded that the more the roadside vegetation is like the natural vegetation of the region, the less energy is required to maintain it.

The main objective of roadside vegetation management should be to keep the highway a safe and pleasurable place to drive. What is growing along the roadside should not imperil nor distract the driver, yet it should provide a series of restful glances for the experienced driver and a certain flow of countryside scenes for the passengers. For ecological and economical reasons, the composition of roadside vegetation should depend on the locally adapted native species and a selected number of introduced species that are dependable. Due to the variability of most roadside conditions, a mixture of species has to be used since no single species has the adaptive scope to cover it all.

This program should promote beauty, prevent erosion, and reduce the spread of noxious plants. Mowing is an important maintenance procedure that has been designed for average vegetation of the region. Mowing height, interval, and placement, particularly on slopes, are very important to the roadside program, In the Iowa model, they found that by raising the mowing height 3 in, more vigorous birdsfoot treoil could be retained in the Interstate medians on a less frequent mowing schedule. In the same model, the backslopes were not mowed and a vigorous stand of smooth brome, switchgrass, and other taller species was developed. This had a desirable result and proved to be a good natural habitat for certain nesting birds.

The use of herbicides has traditionally been associated with the control of noxious species adjacent to crops and pastures into which they could readily spread. Often, it is the other way around. In Texas, glyphosate and velpar are currently approved for sterilization around signposts, guiderails, culverts, bridges, and warning posts to make the mowing effort less restrictive and more efficient. Sterilants should be applied no closer than three times the distance between the dripline of the tree and the trunk of the tree. Roadside vegetation management is too important to be left to the field operators. It must be closely supervised by ecologically trained personnel who recognize the limitations of mowing and spraying. The design of roadside facilities, placement of signs, construction of slopes, and other land-mowing operations should be done with maintenance in mind.

INFLUENCE OF RESEARCH AND DEVELOPMENT ON ROADSIDE MANAGEMENT

D. James Morre

Research is an important source of new developments in roadside management. However, for research to impact practice, it must be implemented. Sight distances must be maintained, signs not obscured, erosion prevented, and a healthy weed-free turf maintained. Research should include a planning phase that involves an analysis of the problem, outlines objectives and procedures, and assembles the required personnel and resources. This is followed by the actual conduct of the research, which may require several years.

Testing under field conditions is especially slow because weeds germinate and grass seedheads form only at a particular time each year. One must usually wait a year to repeat or confirm an observation although some additional information can come from the laboratory. After analysis, recommendations are formulated and, if appropriate, implementation is performed. Implementation is aided if the major findings are evaluated under actual-use conditions as part of the research project. All should be aware of advantages, benefits, and projected or actual cost savings as well as any disadvantages or undesirable features. An individual should be prepared to modify recommendations to accommodate local needs.

In Indiana, the present program of research was initiated in 1966. Between 1966 and 1970, surveys were made to determine weed and brush species and densities and to further identify the problem. Work also included the evaluation of various herbicides. In the first period, only environmentally safe amine forms of 2,4-D were used as a fall-spring rotation. In the fall, hard-to-kill perennial and biennial weeds, such as thistle, milkweed, wild carrot, and curled dock, are actively moving nutrients from the foilage to the underground roots in preparation for the winter. Herbicides likewise moved to the roots. In the spring, plants are at a most susceptible stage--either just at the beginning of growth or just on germination. Most annual and winter annual weeds have been eliminated from Indiana roadsides by this treatment. Annual grasses including crabgrasses and the foxtails were reduced by about 90 percent. At least 3 years are required for a sufficient weed population to become reestablished and to justify another spray application.

A major advantage of the fall-spring rotation is environmental safety due to the fact that the crops are dormant. Through improved weed control, we were able to reduce from five-cycle mowing to three-cycle mowing with a net cost saving of $300 000/year.

Banvel plus 2,4-D was used to reduce mowing or even eliminate mowing altogether. Two-cycle mowing was possible through careful timing where it was required for safety or appearance. Mowing was delayed until the grass reached a height of 18 in, when fescue was starting to form seedheads. The only problem encountered was encroachment of brush. Either spraying for brush control once every 3 years or late one-cycle mowing was recommended. This research resulted in a first year saving of nearly $1 000 000.

We are now in phase 4 of the program--chemical mowing. The objective is to develop and test materials or mixture materials that will eliminate the need for mechanical mowing.

Research has a continuing and important role in roadside vegetation management. A few examples from the Indiana program illustrate how research, once implemented, can lead to new maintenance practices with substantial cost savings. Many research and implementation activities would be facilitated by more information on what are the desirable or necessary ingredients of a well-maintained roadside and of special problems where solutions are currently unavailable. Research, and especially the implementation of research, ultimately involves not only the researcher but the user as well. An important ingredient of research implementation is good planning that begins even before the research is initiated.

APPLICATION OF WEED CONTROL MATERIALS WITH NEW SPRAYING SYSTEMS

Ray Dickens

(Dickens' presentation was not available for publication.)

GROWTH SUPPRESSION STUDIES ON ROUGH TURF

William E. Chappell

A renewed interest by the agricultural industry in the development of growth regulators has been partially attributed to the energy crisis. The use of these materials in an integrated management program would reduce the number of mowings and conserve fuel as well as labor and would provide needed savings while still maintaining an acceptable appearance.

Three studies were undertaken to establish the efficacy of specific plant regulators. Study 1 concerned a product known as EL-72500 for the suppression of cool season grasses on highway rights-of-way. A test section was established near Harrisonburg, Virginia. For comparison purposes, 180-ft^2 plots were used. The turf was a mixed stand of tall fescue and bluegrass as a predominant species. At the time of application, the turf was 2-4 in in height and had just broken dormancy. A second plot had creeping red fescue as the predominant turf species.

There appears to be an inconsistency in the results of this study in that the lower rates of application of the material appeared to be more efficient. This inconsistency may be explained by the composition of the turf species within these plots. Lower rates were applied to areas dominated by fescue, while the plots with the higher rates contained significant quantities of bluegrass. The bluegrass was more prolific with respect to seedhead production. The optimum rate in this situation appears to be 2-3 lb (ai)/A rate. No significant increased suppression is given by higher rates. It was observed that there was a nearly linear response between the rates of application and the blade length retardation.

Although the number of seedheads produced is considerably greater than the turf treated with a conventional growth regulator, the seedstalks were reduced in height. Previous work indicates that seedhead density may be reduced by 95 percent with application of maleic hydrazide or melfluidide. However, unaborted seedheads develop normally and attain nearly full height. This all-or-nothing response does not appear to be prevalent with applications of EL-72500.

There was some objectionable appearance in the treated areas, especially where the higher rates were applied. There was an apparent general discoloration and a reduction in stand density. Only minimal tipburn and general chlorosis were noted. If the applications are made at earlier stages of development, it may help to alleviate this problem.

Study 2 included a product known as PP-333. Again, this used both the wettable powders and liquid formulations. Tall fescue was the predominant species and ranged from 2 to 5 in in height at the time of treatment. Individual plots were 3000 ft^2 in area.

Very favorable results were given by both formulations of this material. The reduction in seedhead density was greater than expected and comparable to melfluidide standard. The dispersable powder formulation did result in tip burn, which was approaching an unacceptable level. This did not occur with the granulation formulas. There was some objectionable appearance as noted with study 1.

Study 3 compares the use of all of the above noted plant regulators for use on rough turf at a site near Shawsville, Virginia. Tall fescue was the predominant species with lesser amounts of creeping red fescue and bluegrass. The turf ranged from 7 to 9 in in height at the time of treatment. Granular formulations and water soluble formulations were used. The PP-333 did not give the levels of seedhead density reduction that were experienced in the previous study. Seedhead height was generally reduced by more than 50 percent with this compound. The wettable powder formulation of EL-72500 gave a reduction in seedhead density and blade length suppression comparable with those given by the PP-333 treatments. The reduction of seedhead height was somewhat less. Neither of the experimental compounds inhibited seedhead formations as well as the standards, although seedhead height and blade length were appreciably reduced with respect to the standards. The standards performed as expected with meleic hydrazide providing a 99 percent reduction in seedhead density.

Tip burn appeared to be erratic and rather inconsistent. The general thatchy appearance previously described occurred on plots treated with PP-333 and EL-72500. This condition did not appear to be objectionable as in prior applications. The thatchy appearance subsided over the growing season with eventual growth of the turf. There was a slight general chlorosis on turf treated with the standards. This was not considered objectionable. No objectionable appearance occurred on plots treated with melfloridide.

MULTIFLORA ROSE CONTROL STUDIES WITH SOIL APPLIED HERBICIDES

William E. Chappell

Efforts in Virginia are currently under way to arrest the spread of multiflora rose and to eradicate existing stands in an attempt to reclaim and maintain grazing land. This is due to the spread from highways where this material was planted for use as living fences, for headlight glare, and as crash barriers. These studies were conducted to determine the efficacy of several herbicides for the control of multiflora rose.

Two sites in southwestern Virginia were selected for testing. All of the herbicides were uniformly distributed by hand, with the exception of Spike, which was applied with a stainless steel backpack sprayer. The treatments were applied on March 28, 1979, at the initiation of bud break, and they were evaluated on October 11, 1979, at the first site. At the second site, the initial treatments were applied on April 12, 1979, and were evaluated on October 15, 1979. All of the treatments at this site were applied to the soil near the base of the stem.

Weather conditions were very favorable for evaluating soil-applied herbicides. In general, the results obtained at the first site were somewhat less than expected. Amdon 10-K was the only treatment that gave complete control. The treatments of DPX-3674 did give impressive levels of control; however, it is questionable whether the high rates used in this study would be acceptable on a commercial scale. These treatments also resulted in the eradication of forage grasses in the treated area. Spike 20 P applied at 3 and 6 lb/acre also gave ratings that were similar to those of Amdon 10-K. Although none of the treatments applied at the second site gave complete control, several resulted in impressive ratings. Amdon 10-K gave very high ratings. Spike 20 P also gave impressive control. Very high ratings were also recorded for the relatively high application rates of the dry formulations of other herbicides. The liquid formulations, Banvel and Tordon K, gave ratings higher than expected. Although the rates of the liquids were relatively high in comparison with the dry formulations, they were easily and effectively applied with the spot-gun applicator. The results for the first test are given below [the control rating is based on a subjective, visual estimate of crown injury (0 = no control, 10 = complete crown death); ratings with the same letter are not significantly different at the 5 percent level of the Duncan's multiple range test].

Treatment	Rate [lb(ai)/A]	Avg Control Rating
Amdon 10-K	4	10.0
Banvel 5G	8	5.3
Banvel 5G	10	6.3
Banvel 5G	15	6.0
Banvel XP	8	5.6
Banvel XP	10	5.6
DPX-3674-A	10	8.7
DPX-3674-A-1	10	8.7
DPX-3674-A-1	20	9.3
Spike 20 P	2	6.7
Spike 20 P	3	7.7
Spike 20 P	6	8.0
Spike 80W	3	7.0
Control	--	0.0

PERFORMANCE-BASED CONTRACT SPRAYING
Donald Dalton

Dalton's presentation indicated that a performance specification with a written guarantee for herbicide spraying could be a valuable tool for the maintenance engineer.

NEW DEVELOPMENTS FROM DUPONT
Turney Hernandez

Herbicides are maintenance tools and we must learn to use these tools to maximize return on our maintenance investment, keeping in mind the many factors that affect performance. The key to success in vegetation management is the proper use of these herbicides in programs designed and planned over the long term.

The E.I. DuPont Company has roadside and industrial weed control specialists in most states in the United States. They work as a team in the roadside market. The company's objective is to supplement the efforts of roadside vegetation management specialists in every state with plot work, equipment adaptation or modification, helping with surveys, and assisting in developing efficient and effective use programs. We want to help you, the roadside vegetation management supervisor, accomplish the best job at the lowest cost. To do this, we position DuPont products along with those of other manufacturers in programs to accomplish this objective. These programs must be safe and satisfy the needs of your state. Some new developments from DuPont are

1. The development of a new 2-lb/gal water soluble formulation of Velpar;
2. The introduction of a 10 percent pelleted formulation of Velpar called the Gridball, which contains 0.335 g active ingredient per pellet for brush control; and
3. The introduction of krenite S, a new formulation containing a suitable surfactant.

DuPont is also developing three promising new herbicides. A broadleaf weed killer that would control most of the problem annuals at rates of 0.25-1.25 oz/acre, a compound that is selective for control of Johnsongrass at rates between 0.25 and 1 lb/acre, and a foliage absorbed brush control that appears to be broad spectrum.

DOW HERBICIDES THAT WILL BE AVAILABLE IN THE FUTURE FOR ROADSIDE WEED CONTROL
Robert D. Fears

For many years, the Dow Chemical Company has sold herbicides for roadside weed control and will continue to develop herbicides for this use. These herbicides will have the ability to be used without adverse effects on applicators, wildlife, fish, or the environment. They will exhibit unique biological activity that will give advantages in weed control not offered by competitive products.

Due to continued cost escalation of raw materials, energy, and labor, new herbicides will sell at higher prices. As with present herbicides, the new products will also control a wider spectrum of woody plant species when mixed with other chemicals such as 2,4-D or Tordon.

One of the new products that Dow now has available for roadside weed control is Garlon. Garlon is the trade name for triclopyr or 3,5,6-trichloro-2-pyridnyl-oxyacetic acid. Through field tests and commercial applications, it has been demonstrated that Garlon herbicides are highly effective for the control of many woody plants and some broadleaf weeds. Herbicidal action of Garlon or triclopyr is through characteristic auxin-type response.

Formulations of triclopyr include Garlon 3A herbicide, which is a water-soluble triethylamine salt containing 3 lb of triclopyr/gal and Garlon 4 herbicide, which is an oil-soluble, water-emulsifiable butoxyethyl ester containing 4 lb of triclopyr acid equivalent/gal. Garlon herbicides are low in acute oral toxicity to mammals. Undiluted Garlon 3A is moderately to severely irritating and injurious to eyes and may cause slight to moderate skin irritation. However, when diluted with water for ground application, it becomes essentially nonirritating to the skin and may cause only slight discomfort and effects to the eyes. Undiluted Garlon 4 is essentially nonirritating to eyes and may be slightly irritating to the skin. Neither formulation is absorbed through the skin in acutely toxic amounts. Although Garlon 4 is toxic to fish, Garlon 3A is very low in toxicity to fish. Both formulations have very low toxicity to mallard duck and Japanese quail. Under temperature and moisture conditions favorable for microbial activity, triclopyr degrades quite rapidly in soil.

Lontrel, the trade name for DOWCO 290 or 3,6-dichloropicolinic acid, is the second new herbicide that Dow is developing. It has exhibited excellent herbicidal activity against members of the Polygonaceae, Compositae, and Leguminosae plant families. Like Garlon, DOWCO 290 induces characteristic auxin-type responses in growing plants. Lontrel 205, which contains 2 lb of 2,4-D acid equivalent and 0.5 lb of DOWCO 290 acid equivalent per gallon as the alkanolamine salts and M-3972, which contains 3 lb of DOWCO 290 acid equivalent per gallon as the monoethanolamine salt, are formulations being tested for weed control in turf and on roadsides.

DOWCO 290 and its formulations have low acute oral toxicity to mammals and are not absorbed through the skin in acutely toxic amounts. DOWCO

290 as the 3,6-dichloropicolinic acid is very slightly irritating to the skin on repeated or prolonged contact. It may be injurious to eyes, and some impairment of vision may occur if not flushed from the eyes promptly. These effects on skin and eyes are reduced by formulating DOWCO 290 into Lontrel 205 or M-3972. DOWCO has very low toxicity to fish, bobwhite quail, and mallard ducks. Garlon and DOWCO will effectively supplement the biological activity of Dow's existing herbicides such as 2,4-D and Tordon.

DEVELOPMENTS IN THE ELI-LILLY COMPANY
A.T. Perkins

Perkins presented the new developments that are occurring in the Eli-Lilly Company. However, he requested that no information be published at this time in accordance with company policy.

FUTURE IN CHEMICAL ROADSIDE VEGETATION MANAGEMENT
Roy R. Johnson

Union Carbide Agricultural Products Company has developed and is marketing many herbicides for the management of grasses, broadleaf weeds, and brush that grow on highway rights-of-way. Along with these herbicides and plant growth regulators, Union Carbide has developed application equipment to apply herbicides uniformly and with a minimum of drift. The Directa-Spra is widely used by municipal, county, and state highway departments. Where aerial application is feasible, the Microfoil boom provides accurate application with little drift potential. Two new devices, the Spirometer and the Mini-Wobbler, are currently being commercially developed. These devices can apply herbicides and plant growth regulators to highway vegetation in a swath of up to 50 ft from the spray vehicle without using a boom and at forward speeds of 10-15 mph. Typical spray volumes are 25-50 gal/acre. These application devices were used to treat several thousand acres in 1980. Use on typical highway sites will be investigated in 1981.

FLEXIBILITY IN ROADSIDE VEGETATION MANAGEMENT PROGRAM
C.W. Middleton

Major challenges concerning inflation and energy use that we all talk about are opening the door to a number of significant changes. Many of these challenges are related to the optimum use of a changing budget and are concerned with such areas as holding mowing cost down and vegetation problems that occur with reduced mowing.

Today's planning of highway chemical prescription programs has changed radically in just 2 years. The flexibility and ingenuity of tank mixes are also becoming more essential for a successful program.

Two years ago, the industry had three flexible materials that were either premixed or tank mixed and were used with other industrial products such as Hyvar, Spike, Krenite, Embark, and MSMA. These last three were used in every season of the year. Now 2,4,5-T is no longer available from Velsicol or other suppliers for right-of-way use. Two broad spectrum chemical tools are left for selective weed and brush control: 2,4-D and Banvel (Dicamba). These two materials are flexible in many common use situations: highway (including ditch bank labeling), utilities, home lawns, corn, pastures, rangeland, railroads, forestry, aquatic, watersheds, soil sterilant, and grass inhabitation areas.

Three new product lines are in various stages of development from Velsicol:

1. Vegatrol DPA (available as an ester or amine) was introduced this year; this product should complement our Vegatrol A4D and LV4D;
2. We will also introduce Banvel C.S.T. (cut-surface treatment) for selective brush control; this material is applied as a ready-to-use concentrate; it contains no 2,4-D and should be used on a freshly cut surface such as tree trunk frill or a freshly cut stump and should be ideal for brush cutting crews; this product will increase our present product line of Banvel XP pellets, 4WS, 720 and Banvel 520 (oil and low oil mixes); and
3. Ravage (Test Code VEL. 5026) is our new total vegetation control product, which has been submitted for approval by the Environmental Protection Agency.

FUTURE IN CHEMICAL ROADSIDE VEGETATION MANAGEMENT
Anthony Stacha

Ciba-Geigy markets a number of products that are used in roadside vegetation management programs in the United States. These product formulations are Pramitol 25E, Primitol 5PS, Atratol 80W, Atratol 8P, Aatrix 80W, Aatrix 4L, Aatrix Nine 0, Princep 4L, Princep 80W, and Princep Caliber 90. Due to the diversity of weed problems and rainfall in the United States, the uses of these products vary from complete bare ground control chemicals in some areas to selective control of undesirable species depending on rates used.

Princep has been used for a number of years in the western United States for selective control on highway rights-of-way. Recently, Aatrix has obtained a state label in Oklahoma for a different type of selective control, that is, broadleaf weed control in bermuda grass along the roadsides.

My experience in Texas has been centered around the application of Pramitol 25E under asphalt shoulders to prevent weed and grass encroachment. This use of Pramitol 25E considerably extends the life of these shoulders. Pramitol 25E (under shoulders) can be applied on the ground before laying asphalt by mixing 20-30 gal of Primitol in a minimum of 100 gal of water and uniformly spraying on a well-prepared surface. Pramitol 25E may also be applied at the same rate and may be mixed directly with the cutback asphalts such as RC, MC, and SC. This later program can be applied by the contractor and requires no special equipment and labor. The only additional cost is the cost of the chemical. Tests have shown that the long control of Pramitol 25E under highway shoulders to prevent weed encroachment, thus extending the life of the shoulder, is a very economical program and in some cases appears to double shoulder life.

Currently, registration is pending with the Environmental Protection Agency on Dual 8E alone and as a tank mix with Princep for weed control in field and liner grown woody ornamentals. The granting of this registration offers potential for Dual and

Dual/Princep where various ornamentals represent the roadside landscaping.

Also, Ciba-Geigy is testing a new compound identified as CGA-82725, which is a postemergence grass control herbicide. The complete activity of this compound has not been reported to date.

A registration for a Tandex/Princep mixture is currently being planned. This combination will offer a potential for either selective control of annual weeds, or complete vegetation control, depending on rates applied. Ciba-Geigy is striving to find new and better compounds for use as well as to determine new uses for old compounds to better service the roadside vegetation management programs in the United States.

FUTURE IN CHEMICAL ROADSIDE VEGETATION MANAGEMENT
Stephen R. Muench

(Muench's presentation was not available for publication.)

FUTURE IN CHEMICAL ROADSIDE VEGETATION MANAGEMENT
M.R. Jones

Chevron Chemical Company has two herbicides that can be used for right-of-way maintenance--Ortho Paraquat CL and Ortho Diquat 2 spray. Ortho Paraquat CL is a restricted herbicide; it can be applied only by licensed applicators. It is a contact herbicide with a quick burndown or disiccation on grasses and weeds. Sometime ago we made available a reference book on Paraquat Toxicology and Poisoning. This listed treatment procedures, methodology, and information on Paraquat.

Ortho Diquat 2 spray has been labeled for right-of-way, highway, and other areas that have unwanted weeds and grasses. It is also a contact herbicide and it is a nonrestricted product. It is compatible with many residual herbicides to help develop a complete maintenance program. Both terrestrial and aquatic species are listed on the label that makes the product a dual-purpose contact herbicide. Diquat 2 spray has an LD 50 of 440. It carries a warning statement on the label.

Ortho X-77 spreader is a non-Ionic surfactant that is recommended for use with both Ortho Paraquat CL and Ortho Diquat 2 spray. It is necessary to add a non-Ionic surfactant to obtain the best results with either of these products. This aids in wetting both weed and grass species and helps inhibit foaming.

FUTURE IN CHEMICAL ROADSIDE VEGETATION MANAGEMENT
John W. Matteson

Embark[R] 2-S Plant Growth Regulator (PGR) is a versatile, newly developed product from 3M designed to reduce the cost of grass maintenance in locations such as highway rights-of-way, airports, golf courses, and cemeteries. Embark 2-S PGR is formulated as a diethanolamine salt solution containing the equivalent of 2 lb active ingredient/gal. Toxicological studies show that, when used according to label recommendations, Embark PGR presents no hazard to the user or the environment.

Embark PGR may be tank mixed with 2,4-D for total vegetation management. Research has shown that no incompatibility exists when Embark PGR is tank mixed with Dicamba, MCPP, and other broadleaf weed control herbicides. Embark PGR will reduce or eliminate mowing requirements for a minimum of 5 weeks on Bermuda grass and a minimum of 8 weeks on cool-season grasses such as Kentucky bluegrass, tall fescue, chewings fescue, red fescue, and several other species. Year-long seedhead suppression can be attained on cool-season species by making spring applications before the seedhead develops. Fall applications give spring vegetative growth suppression and seedhead control on many cool-season species. Mowing may be made before or after application or not at all. The important thing to remember is that the grass must be actively growing and healthy and not cut too short to get sufficient absorption of the chemical.

Any spray equipment that will apply 15-150 gal/acre of spray solution and give uniform coverage can be used for Embark PGR application. The quality of application is more dependent of the equipment operators than of the equipment itself. During its 2 years on the market, Embark has shown many states and municipalities that its use will reduce the labor assigned to mowing, thus allowing more flexible use of manpower and equipment, will reduce mowing risks, and fits in well with total vegetation management.

3M is continuing its research with Embark PGR to increase its utility in vegetation management. Other chemicals from the 3M research laboratories, such as MBR 18337, are showing promise as turf management tools of the future.

HERBICIDE SPRAY EQUIPMENT
J.M. Custer

(Custer's presentation was not available for publication.)

HYDRO-SEEDING AND MULCHING MACHINERY
Bob Jones

Establishment of vegetation of roadsides falls into two basic categories: the planting of living plants and the planting of seeds. One of the critical factors of successful planting is that of providing adequate moisture. The cost of irrigation made it necessary to seek ways to take better advantage of rainfall. Man learned centuries ago that a covering, such as rocks, leaves, or twigs, would help protect the new vegetation. Moisture was better retained in the soil, soil temperatures were moderated, and the plants were protected from erosion. In some cases a planting has been successful when under normal conditions it might not have been. In some cases, the reverse is true. The agricultural community has dealt with this less than 100 percent probability of success from the beginning of time.

Straw or hay mulching (high-profile mulch) has proved to be the most successful technique in the arid climates of the West. The process involves the planting of seed and fertilizer in the soil with one piece of machinery, then mulching with a layer of hay or straw with another piece of machinery, and then tacking the mulch to the ground with sometimes a third piece of machinery.

Hydro-mulching, sometimes referred to as low-profile mulch, is a recent technological development in which the seed, fertilizer, and mulch are applied in a one-step process. Hydro-mulching has experienced significant success in the more humid eastern United States. The differences in the effects of the two mulches are simply that the higher-profile straw mulch is a more effective insulator and it helps retain moisture better. R.E. Blaser found that straw mulch tacked with wood fiber could possibly be the best treatment for a late fall planting, thus expecting the emergence of seedlings the following spring. If this procedure is adopted, it may well be that a new piece of equipment will evolve that combines the use of straw-mulching with hydro-mulching.

Other research has been done on the use of poly foams to simulate the high-profile effect of straw with possible use of the hydro-mulch machine. A significant advance is predicted in the near future to develop a machine that will pump a thicker slurry of wood fiber in the conventional hydro-mulching process. If the ratio of water to wood fiber can be reduced in the process, then the economics of hydro-mulching will be improved for a significant labor savings.

One piece of machinery likely to develop in the future is a machine combining high-profile and low-profile mulch. A second piece of machinery possible in the future will be some type of foam mulch dispenser. The futuristic machine we will all see in the next few years is a hydro-mulch capable of pumping more fiber per gallon of water.

WICK APPLICATORS
Wayne W. Huffine

Several wick applicators are commercially available; however, Oklahoma uses BoBar rope applicator for roadside weed control investigations. It is designed for use on rights-of-way, including irregular terrains. We have worked with two BoBar wick applicators--one, an experimental unit about 6.5 ft wide mounted on the front of a pick-up truck, and the other, a three-unit BoBar Compensating Feed Rope Applicator that uses the tractor's existing hydraulic system and control valve. With both wings fully extended, it will effectively treat an area 14 ft wide.

One of the unique features of this kind of applicator is the ability to control high-growing weed species, such as Johnsongrass, while permitting low-growing erosion-resistant vegetation, such as Bermuda grass, to remain. Johnsongrass can effectively be controlled by using an appropriate herbicide with this machinery. For best results, the herbicide should be applied to actively growing plants when most have reached the boot to head stage of growth. The wick applicators are designed to apply herbicide to the stem and underside of leaves and undesirable plants. The advantages of the applicator are (a) it can be used in wind, (b) it can be used adjacent to water and desired plant life, and (c) it is generally considered efficient and economical. Some of the disadvantages are (a) the transport vehicle is limited to rather smooth surfaces, (b) the ropes must be kept clean, and (c) when stored for considerable time, the ropes must be kept out of bright light.

The front-mounted unit, weighing about 800 lb, tends to make the tractor front heavy with a loss of traction in some situations, such as when the front-mounted unit is operated straight down from the face of a rather steep slope, and it becomes necessary to back up to turn around. The addition of weights to the rear wheels can generally remedy this situation.

The following table and other data represent a sample of the program evaluation of herbicides and speeds of application for the control of alfalfa on roadsides with a compensating feed rope applicator: date treated--July 2, 1980; date scored--July 15, 1980; plot size, 32 ft x 100 ft; replications, 3; herbicide dilution, 2 parts water to 1 part herbicide; method of scoring, 10 = complete control and 1 = no effect.

Expt. 4-H-7-80
Treatments

Herbicide	Speed of Application (mph)	Alfalfa Control Score
1. Roundup (3 lb ae/gal)	3	2.0
2. Roundup (3 lb ae/gal)	4	2.3
3. Roundup (3 lb ae/gal)	5	2.0
4. Weedmaster (1 lb ai dicamba plus 3 lb 2,4-D/gal)	3	6.0
5. Weedmaster (4 lb ai/gal)	4	5.7
6. Weedmaster (4 lb ai/gal)	5	5.3
7. 2,4-D (4 lb ai/gal)	3	1.7
8. 2,4-D (4 lb ai/gal)	4	2.0
9. 2,4-D (4 lb ai/gal)	5	1.7
10. Banvel (4 lb ai/gal)	3	5.0
11. Banvel (4 lb ai/gal)	4	5.0
12. Banvel (4 lb ai/gal)	5	4.3
13. Check	-	1.0
Significant differences		**
CV		13%
LSD.01		1.11

MOVING TREES MECHANICALLY
George Wassenaar

(Wassenaar's presentation was not available for publication.)

EQUIPMENT TO IMPROVE HERBICIDE APPLICATION EFFICIENCY
John Kubacak

Cibolo Manufacturing has developed a one-man operated herbicide sprayer called the Swinglok^{tm}. It is ideal for use by state highway departments, cities, and counties. It is capable of such diverse spraying operations as applying bareground herbicides under guardrails, signs on shoulders, selective treatments in the right-of-way, and foliage. The system attaches to the front bumper of the vehicle and incorporates special design booms for versatility and flexibility. This system allows for selective spraying up to 36 ft in the right-of-way. The spray swath consists of four 9-ft sections, each of which can be operated independently or in any combination by the flip of a switch on the dashmounted control panel. The Swinglok system eliminates the age-old problem of bending or breaking of long booms resulting from accidental contact with mailboxes, signs, and trees in the right-of-way. This system was designed to keep the spray truck traveling on the highway shoulder at a constant rate of speed to allow for precision application of herbicides. This system will allow maintenance departments to standardize spray equipment assuring maintenance engineers their herbicide program is the same with all spray truck operators. The Swinglok system is available in different models: (a) Model A--This system will spray one herbicide solution in a single pass down the roadside; (b) Model BS--This system allows the operator to spray two different herbicide solutions in separate operations either independently or simultaneously (e.g., spraying guardrails with bareground herbicides while applying selective herbicides across the right-of-way); and (c) Model S36--This system is used primarily for selective or brush applications.

EQUIPMENT AND THE MANAGEMENT OF ROADSIDES
Bill G. Morris

A major objective of the Florida Department of Transportation is the development and administration of a routine and preventive roadside maintenance program. To achieve this objective, it is essential that equipment capable of accomplishing the desired work in an effective and efficient manner be selected and used. We provide for continuous review of new equipment and, on occasion, provide for improved maintenance techniques. With the availability of funds diminishing, it becomes increasingly important that a fleet of cost-effective equipment be available to achieve the various tasks of roadside maintenance. Proper specifications and purchasing practices favor a fleet of performance equipment capable of meeting these needs.

A variety of specialized equipment is necessary to perform roadside maintenance functions. The selection of equipment is influenced by the type of terrain, climate, and soils that exist at a particular locality. Roadsides are predominantly turf and require varied techniques to perform routine and periodic work. Good turf is essential. Mowing represents a significant portion of the roadside maintenance activity, and it is accomplished generally with equipment in combinations of varying size.

In addition to mechanical mowing, we are now reviewing the potentiality of the rope-wick concept where herbicides are used to chemically mow. This system allows for the removal of the tall, unsightly competitive grasses and has potential for reducing mechanical mowing requirements. The herbicide program equipment consists of a 2-ton truck with an aluminum bed and front-mounted spray platform for workmen, which allows visual communication between the applicator and the driver. A sprayer is constructed on the truck and uses a variety of application systems to achieve the desired work. Periodic major turf renovations are performed on roadside shoulders and slopes to maintain proper grade and allow for proper road surface drainage. Tractor-mounted rotovators are used to till the soil, and grading is achieved by using motor graders. Spot shoulder repairs are performed by using a tractor equipped with a front-end loader and back blade. One piece of equipment performs the required grading and loads the excess materials. The majority of shoulder reworking sites receives an application of hay mulch distributed by a truck or trailer-mounted power mulch blower. Tractor-mounted broadcast spinner-type distributors spread fertilizer over the site followed by the incorporation of seed and mulch into the soil. A tractor-drawn hydraulic controlled seeder-mulcher-roller with coulter blades and rubber tires is used to place seed in soil, cut in the previously distributed mulch, and provide needed compaction to the roadside area. Bituminous materials are placed on the mulch to control erosion. Routine fertilization work is accomplished by using bulk fertilizer distributors. These units are a minimum of five times more productive than alternate means of distribution. Proper drainage is essential to Florida's roads. Roadside ditches are maintained with hydroscopic excavators, mobile draglines, and herbicide units. Outfalls are maintained with track draglines and herbicide units having four-wheel drive when appropriate. Specialized equipment, such as tree spades, cranes, and well-point systems, may be leased or rented when these are determined to be more feasible.

Proper support equipment makes each roadside maintenance activity more productive. A fleet of diesel tractors with tandem trailers is maintained for the purpose of transporting equipment to varied work sites. Forklifts and yard loaders provide field activities with necessary materials in a timely manner.

Various manuals and employee training courses have been developed and are administered in an effort to improve the operating efficiency and effectiveness of employees and ascertain safe and proper equipment usage.

IMPACT OF "KEEP AMERICA BEAUTIFUL" ON ROADSIDE MANAGEMENT
William R. Nash

Nash explained the circumstances under which Keep America Beautiful, Inc., would work with the governing body to establish a program whereby the public would be made aware of the cost of litter and the associated problems. A plan was outlined whereby a town could decrease its litter problem considerably through a planned program of education and involvement. Successful programs have been carried out in 192 cities and counties across the nation. The Keep America Beautiful organization has a program development department, which along with field personnel stands ready to work with departments and agencies in designing efforts based on the "Clean-Community System" to identify the various factors that impact on the cleanliness of the roadside and how these factors might best be addressed.

LEAD COMPOUNDS IN MULE DEER AND VEGETATION
Larry T. Irwin

Studies of lead compounds from motor vehicle exhaust along with major highways have shown significant levels in vegetation up to 91 m away in small animals and in domestic livestock. However, little is known about the levels in wild ungulates, such as pronghorn antelopes or mule deer, which may use foraging and resting areas adjacent to highways.

Researchers found mule deer in certain areas to spend two-thirds of their time annually within 300 m of an Interstate highway. Since lead is cumulative poison and the highway has been in its present location more than 50 years, there was concern for the welfare of the deer which may inhale motor vehicle exhaust and ingest vegetation that may contain lead. In addition, those deer are subject to human consumption; hence, a concern for human health. An appropriate research site was selected, and a collection permit was obtained to collect five mule deer. The first specimen was collected within an hour after it was killed by a vehicle, and the remaining four were shot with a high-powered rifle. In addition, portions of two adult males were collected at some distance from major roads.

Whole deer organs and fetuses were dried and samples of plant and animal tissue were ashed. Lead content of plant and animal tissue was determined by using atomic absorption spectrophotometry. Concentrations of lead compounds in randomly selected samples were also verified by the Wyoming State Chemistry Laboratory. A paired difference test and paired test were used to statistically compare lead in deer and plant tissues, respectively.

Levels of lead in sagebrush up to 90 m from the Interstate were significantly higher than in plants growing in the area 6.5 km north of the highway. Values ranged from a high of 20 µg/g dry weight 15 m from the Interstate and decreased to control values at 90 m from the highway. Baseline levels were established to be 1-4 µg/g. Levels of lead in true mountain mahogany near the Interstate were not significantly different from those found in plants from the control area, but they were much lower than those found in big sagebrush growing in similar sites. It was found that deer from the Interstate area contained significantly more lead than deer from the control area. Levels of lead in deer from the Interstate area ranged from trace amounts in the hip muscle to 10.8 µg/g dry weight in the antlers of the young male. Bones, kidneys, and livers contained more lead than other organs. Composite samples of the near-term fetuses contained amounts equivalent to those found in the livers of the adult deer.

Lead is a cumulative poison, building up in bones and taking the place of calcium. Thus, the relatively higher levels found in the antlers of one of the deer in this study was not unexpected. Antler-shedding could be a pathway to rid the body of some of the lead burden. In bone salt form it is not toxic, but during high calcium metabolism, as probably occurs in the growth of mule deer fawns, skeletal lead may be modelized and acute lead toxicity may result.

The data for fetuses suggest an even stronger possibility for toxicity to mule deer fawns, which apparently absorb lead across the placenta during fetal development. In addition, a considerable part of the maternal dose can be transmitted via milk to suckling rats and mice, in which case subclinically dosed mothers may give birth to chronically poisoned offspring. The manifestations of such a problem for a wild ungulate population would likely go unnoticed because of the confounding effects of mortality due to other causes. The levels in deer tissue are not considered a threat for human consumption. However, the possibility may exist for lead poisoning of other wild ungulates in areas with higher levels of traffic.

ACCOMMODATING BILLBOARDS ALONG ROADSIDES

George McInturff

A problem of serious proportions in a number of states involves the uncontrolled growth of trees and underbrush on the rights-of-way, which eventually obscure legally maintained commercial advertising signs. In some areas, this uncontrolled growth of volunteer vegetation can render an otherwise valuable advertising sign useless in a matter of several years, thereby depriving the owner of the sign and the owners of the land on which the sign is placed rental income that would otherwise accrue to them. If the sign produces income of several hundred dollars a month, which many do, the loss of a number of such signs through undergrowth blockage can be severe. The problem is relatively new. With the advent of the Interstate program in 1956, its wide rights-of-way, and the ever-increasing costs of maintenance, many highway departments discontinued fence-to-fence mowing. Scrub pine and other volunteers grew and the problem became severe. One solution is for the highway department to permit trimming and cutting on the right-of-way under carefully controlled conditions. Six states now have procedures to accomplish this and others have them under consideration. The work of clearing and thinning should be done under carefully controlled conditions. These must provide for the safety of the traveling public and the restoration of the area to a condition environmentally equal to or superior to that which existed prior to the work.

In South Carolina the outdoor advertising company must furnish a scale drawing of the site and a list of vegetation to be trimmed or removed. All work is under the direct supervision of the highway department and is accomplished from the sign side of the right-of-way. At the company's expense, a reputable landscaping firm must prepare the list of vegetation to be trimmed or removed and a sketch of replacement plantings. The company must produce a performance bond and agree to reimburse the highway department for the costs of supervision and inspection. Replacement plantings must be nursery-grown stock and the company must agree to replace any plant that dies within 1 year. In one project, the vegetation removed consisted of about 200 scrub pine, and the replacement plantings consisted of 100 creep myrtle and 100 oleander.

A benefit of vegetation control is highway safety. According to the National Highway Traffic Safety Administration, 27 percent of the national fatality toll in 1978 was caused by collisions with roadside hazards. Trees and shrubbery presented the greatest overall hazard. Fatal collisions with trees claimed 3260 lives in 1978. In 1979, it increased to 3299. The Federal Highway Administration's Handbook of Highway Safety Design and Operating Practices notes, "The clear roadside concept has gained wide acceptance and many research studies have confirmed the effectiveness of removing trees and utility poles, and making shoulders and slopes traversable." Vegetation control, including tree removal, is not contrary to good highway landscaping practices. The Guide for Highway Landscape and Environmental Design, prepared by the Operating Committee on Roadside Development of the American Association of State Highway and Transportation Officials, contains guidelines for the selective thinning of trees "to create a natural transition between the open clearing of the site and the undisturbed woods, to form bays and open areas in woods, to thin heavy stands, to remove undesirable species, and to open views to vistas." We believe that vegetation control to provide visibility to legal outdoor advertising displays can be done in a safe and effective manner and will benefit the motorist, the highway department, and the outdoor advertising company.

COMPOSITION AND INCIDENT OF ROADSIDE LITTER IN THE MEDICINE BOW MOUNTAINS, WYOMING

Mark L. Mason

Prior to the establishment of a litter survey or control program, it is useful to estimate the density and composition of existing litter and the rate at which it accumulates. Litter composition and accumulation rates were established on both roadside plots and truck turnouts in the Medicine Bow Mountains of Wyoming. The study revealed that the litter composition at truck turnouts was different from that along the roadside; litter density decreased linearly with distance from a human settlement; highest litter accumulations occurred during the highest traffic volumes; and maintained areas had significantly lower litter accumulation rates; there were approximately three times more pop-top tabs than aluminum containers. Variables affecting study plot location were (a) locations vulnerable to wind, (b) higher elevations with early and late season snow cover, (c) distance from a human settlement, and (d) high-use recreation areas.

Preliminary studies also provide time-travel factors that allow management to design litter survey or control programs. Some of the factors that were found to affect plots/day/team were (a) quantity of litter on plot; (b) plot size; (c) counting versus counting and collecting litter; (d) distance between plots; (e) vegetation density, height, and type; (f) road width; (g) slope of roadside; and (h) available vehicle and manpower. Management considerations for litter studies should focus on a flexible statistical design to contend with missing data and adjusted sampling dates.

Since litter control programs are subject to budget limitations, litter collection crews may be best used after peak litter accumulation periods. If most managed areas do in fact receive substantially lower litter accumulation rates, then it may be to the taxpayers' advantage to have roadside vegetation managed to conceal litter.

INTEGRATED VEGETATION MANAGEMENT ON LOS ANGELES COUNTY ROADS

Martin Pruett

Since the advent in the late 1940s of modern hormone-type herbicides, we have seen highway mileage increase to nearly 4 million miles. A major part of this growth has been in the form of high-speed turnpikes, the Interstate system, as well as extensive improvements and upgrading of state and county highways. This tremendous mileage growth along with increasing travel speeds and a more sensitive public eye have placed great demands on the shoulders of the landscape architect and the highway maintenance engineer.

The County of Los Angeles is one of extremes, and there is a variety of climatic and geographical conditions. On the coastal plain near the ocean, the vegetation grows year-round. In the nearby mountains, the weeds grow very fast in the late winter and spring due to the heavy rains and warm weather. In the desert area, the rainfall is relatively light and the growth of weeds is not as great as in the coastal areas.

The County is divided into road divisions, and we have 28 crews that use five 100-gal and ten 500-gal spray rigs. For special problems like tumble weed, we have three grinders that reduce the tumble weed hauling to 1/10 of what it used to be.

We continue to use nearly every implement that has ever been developed to control vegetation and are experimenting through the Agricultural Commission with several types of biological control. Our Agricultural Commission provides a training officer for our spray crews each year to fulfill legal requirements.

On some stands of Russian thistle, we have released a moth that tunnels in the stem of the plant. The impact of this insect is not yet clear. We have noticed a build-up of larva and heavy tunneling and what we thought were dead and dying plants, but we are having trouble relating the amount of insect damage to the actual harm to the plant. We should know in a few years just what value it might have. We have also been experimenting with a weevil for the control of puncture vine. In years of good rainfall and good plant growth conditions, weevils sometimes cannot suppress plants and then outbreaks of puncture vine occur. However, the weevils catch up later and suppress the plant growth. The objectives of the roadside maintenance program are to control unwanted growth along the roadsides, to reduce roadside fires, to eliminate the unsightly appearance of unwanted growth, to prevent pavement breakage from plant roots, and to improve visibility for greater driver safety and to improve drainage.

Areas to be kept free of vegetation range from 18 in to 14 ft wide along the road shoulders. Clear visibility is important for vehicle safety and vegetation control and is an important fire protection measure.

In prior years, the County either denuded the system through mechanical means or a surface application of oil; however, increasing costs have led to the adoption of longer-lasting chemical treatments. The use of the highly efficient herbicides in roadside vegetation control has greatly reduced our time commitment to this discipline. The chemicals used in the past season include Hyvar X and Korvar I in the coastal plains. Lorox was used in areas requiring short-term control, Fenamine used for Russian thistle control, Princep 80 used in the mountain areas near pine trees, and Phytar 560 used for spot treatment in the spring. Economics is a key reason for the use of chemicals in a vegetation control program. The development of herbicides has made it possible for many maintenance units to virtually eliminate hand cutting of brush and weeds. Weed-free highway rights-of-way can be an important part of any district's good neighbor policy.

PENNSYLVANIA'S ROADSIDE MANAGEMENT PROGRAM

Robert Ross

In Pennsylvania, we think of the state's 90 000 miles of roadside as the front yard for its 12 000 000 residents and the untold millions who travel through the Keystone state to other points in the Northeast. However, there is no attempt to maintain these yards in the manner normally attributed to yard or lawn type maintenance as highways are commercial arteries and the roadside treatment must be attuned to this priority with roadside amenities managed as a secondary consideration.

The Pennsylvania roadside management program is fundamentally based on the two ingredients common to most highway problems, i.e., need and resources. An individual, educated in the biological sciences, is employed in each of the 11 engineering districts.

The state roadside programs are formulated in Harrisburg's central office and implemented at the district levels with modification to suit local needs as dictated by population, traffic, terrain, and other environmental factors. The district roadside unit is involved in all facets of design, construction, and maintenance that relate to the roadside and its environment. In this capacity, roadside slopes and soil areas can be designed, graded, rounded, finished, and vegetatively treated to yield the best finished product with maintenance in mind. In many cases, the pre-design public hearings commit the department to specific practices that, if not performed in concert with the project construction, would possibly be delayed indefinitely due to subsequent lack of funds, traffic congestion, political changes, and many other factors. Through this complete-project concept, all construction projects throughout the state, regardless of location, financing, or systems classification are given comprehensive consideration and treatment.

The 14 specific herbicide materials purchased on an annual basis have played a major role since the early 1950s. Roadside vegetation management along the 1200-mile Interstate Highway System and limited access highways has been centered around the culture of the legume-Crownvetch. These plantings have been virtually maintenance free for 20 years as the legume is self-feeding; controls erosion; smothers most weeds, litter, and volunteer trees; and provides both attractive bloom and foliage. Along older sections of these two classes of highway, vegetation succession is taking place to a climax forest ecology. In the lower-class roads, which constitute the larger percentage of the state's highway system, the climax vegetation is established and management of its encroachment through trimming, removal, and the use of herbicides continues.

Currently, we expend more than $4 million annually on brushing, trimming, and tree removal in an effort to keep highways open for vehicular traffic, and these costs keep increasing as the emphasis on natural regeneration, reduced mowing, reduced herbicide use, and inflation continues. In order to combat increasing costs, we evaluated the technique of helicopter herbicide application for Canadian thistle control along several sections of Interstate and limited access highway in May and June 1979. We will be evaluating this technique of application for tree and brush control by using Krenite in late August. To date, this technique is very efficient and appears to offer a new dimension in the management of roadside vegetation.

CHEMICAL ROADSIDE VEGETATION MANAGEMENT PROGRAM IN NORTH CAROLINA

W.D. Johnson

The North Carolina Department of Transportation's Landscape Unit has developed a very progressive herbicide and growth regulator program in an effort to facilitate the control of vegetation along our roadsides and reduce the hand labor and machine operations that would otherwise be necessary to properly control the vegetation. The main operations that are parts of this herbicide growth regular program are briefly described here.

There is a great savings potential in the cost of routine mowing through the use of growth regulators. The control of broadleaf weeds must also be included when attempting to control the rate of growth of grasses. Savings from this program range from approximately $25 to $40/acre/growing season. In 1980, approximately 14 000 acres were treated and we estimated potential savings of $560 000 by the reduction in the number of routine mowings. Generally, we hope that more than 50 percent of the area only will be mowed one time with the remaining parts possibly requiring two mowings. The normal number of mowings without treatment is 5-6 per season. We have used MH-30 and Embark as the two growth control agents with spring application and some limited fall application. The MH treatment is the only one that we have used that will allow for season-long control with just the fall cleanup mowing. Embark has shown excellent results when combined with a spring mowing after application and then, of course, the fall cleanup mowing. Also, 2,4-D is applied with either MH or Embark in a spring application for broadleaf weed control. In some instances, it is necessary to follow up in early June with another weed control spraying; however, we are attempting to go through the season with only the fall cleanup mowing. We have gotten excellent results from a 2,4-D-MCPP-Dicamba mixture for this follow-up spraying.

Over the years, we have used a large number of products in an attempt to control the vegetation under guardrails, as the specialized mowing and maintenance of vegetation would otherwise be very expensive. We have now begun to shy away from some of the long-term residual herbicides. Our current program involves a Roundup-Surflan or Roundup-Simazine treatment or a combination of these two preemergence herbicides with Roundup.

It seems obvious that various herbicides would provide significant savings over hand labor to remove vegetation that has grown into the joints of concrete-capped islands or through asphalt islands. We use residual type herbicides such as Spike or Pramitol under many of the asphalt islands and use a Roundup-Spike treatment normally for vegetation that has broken through if runoff is not a problem. One of the most effective treatments that we have used on concrete islands is to clean out the existing vegetation and blow out the joints with air pressure and then repour the joints with liquid asphalt containing Primitol 25E. At this point in time, we do not know how long this protection will last.

Brush control is important adjacent to bridges so that larger trees do not grow and affect the structure itself. The main brush control agent now being used is Krenite and we have found that the no-brownout characteristic is very beneficial. We also chemically prune limbs with this product. We are now beginning to use Garlon and a mixture of 2,4-D-MCPP-Dicamba on brush.

Vines and brush are the main problems along right-of-way fence lines that are visible to the highway. Krenite has worked well in controlling trumpet creeper and other vines and brush in this area. We are now experimenting with some Banvel pellets in areas not adjacent to wood lines.

As a clean out for existing vegetation, we have found no equal to Roundup. We are using Treflan 5G, Caseron 4G, and, in some cases, Surflan as preemergence treatments.

In portions of North Carolina, the Bermuda grass grows well, and we use Roundup to control this aggressive grass to prevent the failure of asphalt pavements. We have also used some Spike treatments placed immediately before the paving operation.

To control the vegetative growth around signs, delineators, and other stationary objects, we have used Pramitol 5PS and Spike 5G pellets. Runoff can cause serious problems when an excessive amount of pellets is placed on areas with any kind of slope.

Roundup is our main product for control of Johnsongrass. Asulox appears to have some potential for the control of Johnsongrass, particularly where fescue grasses are growing. Asulox will not normally hurt fescue.

We attempt to control Kudzu along our roadsides and will enter into agreements with private property owners to treat roadsides adjacent to their property if they will agree to treat their own. We have used Krenite with good success as an early fall treatment along with Roundup or the 2,4-D-MCPP-Dicamba mixture as a spring-summer treatment.

Multiflora rose has been designated as a pest in North Carolina. We have used either Roundup, Banvel, or Krenite in an effort to control this pest. All three appear to be effective.

The use of herbicides and growth regulators, as listed here, seems absolutely necessary to provide the North Carolina Department of Transportation with the tools to control vegetation along our roadsides and maintain the aesthetics of our highway system. We are very proud of our strides in recent years in the use of chemical products to control roadside vegetation, and we are proud that some parties have indicated that our program is as progressive as any that can be found in the United States.

FLORIDA'S ROADSIDE VEGETATION MANAGEMENT PROGRAM

Bill G. Morris and J.A. Lewis

Florida's Department of Transportation has long recognized the benefits to be derived from a sound vegetation management program. Florida has a combination of rural and urban conditions with nearly 12 000 miles of state-maintained roadway spread over an area of 60 000 miles². The state is irregular in shape and is fronted by the Atlantic Ocean and the Gulf of Mexico. This geographic area, coupled with varied terrain, rainfall, temperature, and growing seasons, results in a variety of vegetation management programs.

Management of our roadsides begins at the desgin phase. We maintain a close working relationship with the department's design staff and support ongoing vegetation research that is performed in-house and with the university system where repetitious vegetation problems are best solved.

Generally roadside maintenance is categorized as either maintained or nonmaintained. Maintained areas receive routine and as-needed applications of fertilizer, mowing, and herbicides. Nonmaintained limits are allowed to regenerate and/or are supplemented with native tree species. Period fertility is accomplished by using a high-analysis (24-6-8) 50 percent water insoluble nitrogen source. Although this program contributes to a more dense, stable turf, it does not contribute to additional mowing requirements. Various size mowers are used on roadside applications. Frequencies vary depending on location and attending land use.

The department has developed a comprehensive manual on chemical weed and grass control that includes details of herbicide materials, plant identification, calibration programs, special considerations, equipment, and so forth. It provides detail and specifies desired treatment limits, nozzle configurations, and related application pressures and speeds.

A five-day classroom and field training program is held for applicators, and they must exhibit technical competency for certification. We have attempted to minimize the number of materials used in the program and evaluate them on a cost-effective basis. 2,4-D, 2,4-D-Dicamba, Banvel 720, Dalapon, Hexazionone (Velpar), Glyphosate (Roundup), Diquat (Ortho), and Oryzalin (Surflan) are the mainstays of our current programs. These programs consist of selective weeding, brush and grass control, abatement, aquatic, drainage ditch, and ornamental work. A daily herbicide spray report is maintained by crews. The report provides for the recording of essential information and allows for program performance evaluation.

From an economic standpoint, Florida is seriously questioning mowing needs. A no-mow test area was established in 1977. This resulted in the recognition that a dense and uniform established weed-free bahia or Bermuda turf is acceptable in appearance, therefore, making it possible to virtually stop mowing in certain areas without serious consequence.

It was recognized at the beginning that for the projects to be successful, a well-established turf condition relatively free of competitive tall grasses and broadleaf weeds would be required. This was verified with the discontinuance of mowing. Control of broadleaf weeds has been successful with the use of 2,4-D and 2,4-D-Dicamba; however, control of the tall competitive grasses such as Johnson, vasey, quinea, smut, para, and napier is requiring an alternate program.

At the beginning of this program, no acceptable product or application techniques were available to selectively remove the competitive grasses from the desired bahias and/or Bermudas. We have since experimented with low-rate overspray programs by using Hexazinone (Velpar) and Asulam (Asulox or Johnix). Each of these provided favorable results for particular plant control but neither material has effectively removed all of the undesired grasses.

Our latest approach to the control of these grasses has been the Rope-Wick concept and using the herbicide Glyphosate. The unique factor in this procedure is that the material is applied only to the taller, undesired grasses by using the rope-wicks resulting in essentially no material waste. Control of the undesired grasses coming in contact with the wick is satisfactory.

With the information gathered to date, certain modifications to our management practices are being considered. These include the expansion of the rope-wick concept coupled with a reduction in mowing and expanded selective broadcast programs.

USE OF CHEMICAL TOOLS IN MANAGING VEGETATION ALONG TEXAS ROADSIDES

Tom Allen

The vegetation management program of Texas has been designed to maintain the integrity of the asphalt surface, prevent or reduce soil erosion, provide safety for the traveling public, achieve maintenance efficiency, and provide beauty. The use of chemicals was demonstrated as the most efficient and economical method of controlling undesirable vegetation. Herbicides are the major chemical tool used along roadways; however, insecticides and plant growth regulators may become important as our knowledge increases.

The chemical vegetation management program was divided as follows.

1. Complete vegetation control (bare ground). The use of a residual herbicide at the proper rate will provide complete vegetation control unless resistant species are present. The number of these species must be considered. This type of vegetation management may be desirable in areas where it can be

economically maintained or where plant growth decreases maintenance efficiency or creates a fire hazard. Water soluble Hexazinone will control most of the forbs and grasses along Texas roadsides and is noncaustic and low in mammallian toxicity. For best results, this material should be applied early in the spring, and no application should be made near desirable vegetation.

2. Selective plant removal or weeding can be accomplished by using a chemical applied either as a pre- or post-emergent application. Glyphosate is used for Johnsongrass control and it is miscible with water, noncaustic, and low in mammallian toxicity. However, it is highly corrosive to galvanized containers. A Hexazinone treatment in late summer or fall at a low application rate will effectively control field bindweeds; however, it is not recommended because of the chemical's ability to maintain a bare ground for a period of 8-12 months. In general, field bindweed is controlled in the same manner as Johnsongrass.

3. Woody plant control or brush control. A number of woody plant species are serious problems as they produce stipular spines that can cause flat tires or injury to individuals. These species include mesquite, huisache, blackbrush, twisted acacia, guajuillo, and cat claw acacia. At present, there are a number of experiments in progress at various locations, and the most promising herbicides appear to be Hexazinone and tebuthiuron. No foliar-applied herbicides have produced acceptable results on these species.

4. Bermuda grass release is a term for the chemical treatment of an area to damage or kill all of the vegetation with the exception of Bermuda grass. There are two methods of applications recommended. First, an overspray of glyphosate is used that would kill the taller growing species and possibly up to 20 percent of the Bermuda grass. This treatment is recommended in areas where driving a tractor may be hazardous. The second method is to use a tractor-drawn rope-wick applicator with glyphosate that treats the higher growing vegetation only with a contact material.

5. Chemical mowing by using the rope-wick applicator over areas where Bermuda grass is absent is effective when the height of the rope-wick is above the desirable vegetation.

6. Treatments around ornamental planting are accomplished by using glyphosate plus Oryzalin. As a treatment around the base of the planting, care must be taken not to apply the chemical to the green portion of the ornamental planting.

7. Prepavement treatment with pramitol under the asphaltic surface has successfully controlled vegetation growth for a period of up to 4 years.

8. Plant growth regulators or retardants are used to slow down the growth of plants to reduce the frequency of mowing. This program is still in the research stage.

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