A RESEARCH REPORT ON

Roadside Vegetation Management

PREPARED BY

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RESEARCH SUPPORTED BY
Iowa Department of Transportation
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DECEMBER 1975

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INTRODUCTION[1]

According to prevailing ecological theory one would expect the most stable vegetation on sites which are least disturbed (Odum 1971). According to theory one would also expect the most diversity of species on undisturbed sites (Odum 1971). This stable and diverse community would be produced over a period of many years through a process of plant succession where annual herbs are replaced by perennial herbs and finally woody plants would come to dominate and perpetuate the community.

Another ecological theory holds that the complexity (structure and species diversity) of a plant community is dependent upon the amount of disturbance to which it is subjected (Woodwell, 1970). According to this theory the normal succession of a plant community through its various stages may be arrested at some point depending upon the nature and severity of the disturbance.

In applying these theories to roadside vegetation it becomes apparent that mass herbicide spraying and extensive mowing of roadsides has produced a relatively simple and unstable vegetation. It follows that if disturbances were reduced not only would the roadside plant community increase in stability but maintenance costs and energy usage would be reduced.

In this study we have investigated several aspects of reduced disturbances on roadside vegetation. Research has centered on the effectiveness

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[1]The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of Linn County nor the Iowa Department of Transportation, Highway Division.

of spot spraying techniques on noxious weed control, establishment of native grass cover where ditch cleaning and other disturbance has left the bare soil exposed and the response of roadside vegetation when released from annual mass spraying.

STUDY AREA

This study was carried out in Franklin Township, Linn County, Iowa. Linn County is located in east-central Iowa and has a climate classified as a humid microthermal (Daf) according to Trewartha (1943). Linn County has a mean yearly precipitation of about 84 cm (33 inches), with approximately 70% falling from April through September.

During the period of the study precipitation was above normal all three years. At the Cedar Rapids number 1 station, located approximately 24.1 km (15 miles) WNW of the center of Franklin Township, precipitation was 17.88 cm (7.04 inches) above normal in 1971, 20.52 cm (8.08 inches) above normal in 1972 and 18.67 cm (7.35 inches) above normal in 1973. Temperatures during the same period varied from above to below normal. During 1971 the average temperature was 0.06 C (0.1°F) above normal, 1.17 C (2.1°F) below normal during 1972 and 0.89 C (1.6°F) above normal during 1973 (Climatological Data 1971,1972,1973).

The study was began in 1971 and continued through 1972 and 1973. During these years Franklin Township was exempted from the usual mass-spray weed control program in Linn County. Spot spraying of sour dock and Canada thistle, hand cutting of wild parsnip and biennial thistle, and mowing of

shoulders of the roadway were the only vegetation management techniques used.

Mass spray treatment provided outside Franklin Township during the period of the study was as follows:

1971 -- 453.6 g (1 lb.) 2,4-D and 453.6 g (1 lb.) 2,4,5-T invert emulsion at the rate of not less than 7.57 liters (2 gal) per 1.61 km (1 mile).

1972 -- same mixture without use of invert emulsion.

1973 -- same mixture with addition of FOMEX.[1]

DOCK

Methods

Study plots to determine effects of spot spraying on dock density were set out in 1971 (figure 1). Dock plots were on upland sites; two treatment plots in Franklin township and two control plots in Linn township, adjacent to the north of Franklin township. Plots were approximately 75.5 m (15 rods) long and included the entire width of the ditch. Treated plots were sprayed with hand sprayers using a 2% solution of a low-volatile ester form of 2,4-D in water (figure 2). Treatment was done between 15 and 25 May for three years. Control plots received the usual county-wide mass spraying in June of each year. Evaluation of mortality was made 7 to 14 days following treatment.

In 1972 and 1973 two plots, each 150.9 m (30 rods) long and including the entire ditch, were used to determine the efficiency of locating and

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[1]Colloidal Products Corp., P.O. Box 621, Petaluma, California 94952

Figure 1. Smooth dock.

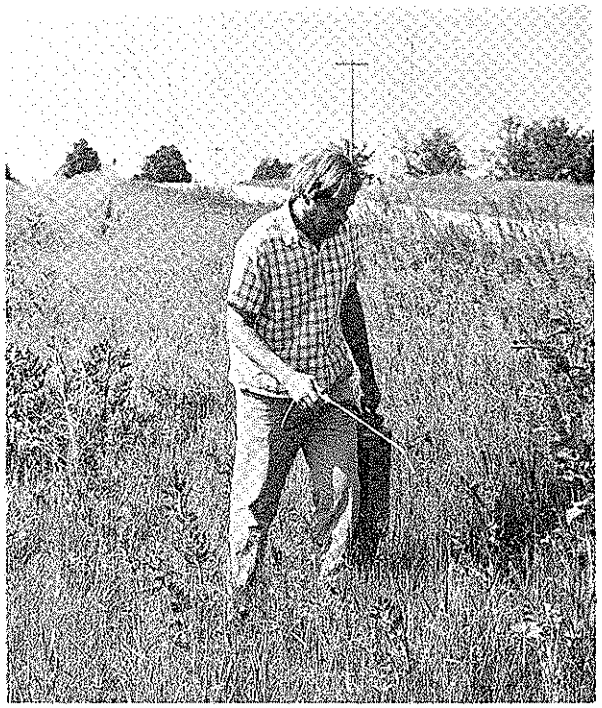

Figure 2. Hand spraying dock.

treating dock, and the effect of follow-up spraying to eliminate the species. Seven to ten days after the first spraying a second treatment was made, noting the number of plants killed and the number missed by the first spray.

Results

Density of dock plants in study plots decreased 49.3% while density increased 5.7% in control plots from 1971 to 1973 (figure 3). Density decreased in both treated and control plots from 1971 to 1972 but significant differences were evident in 1973.

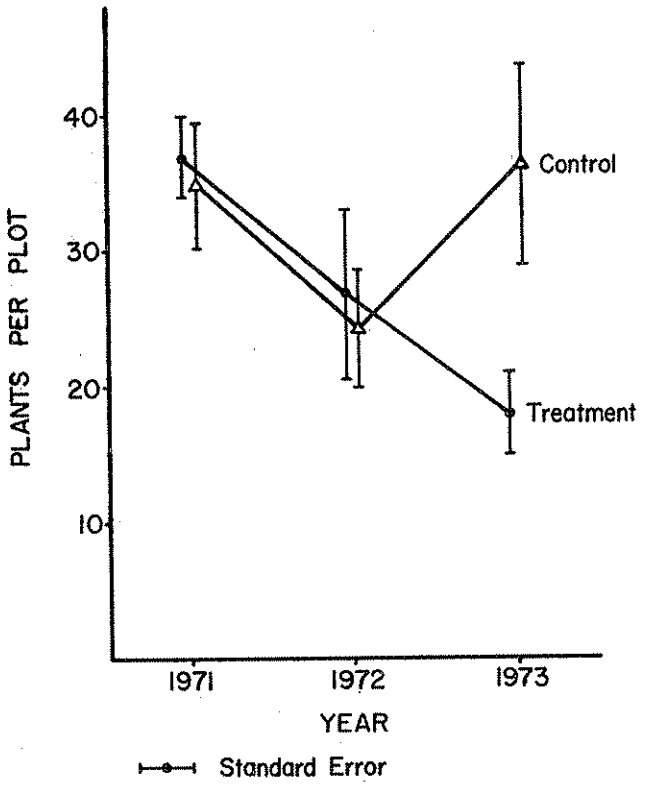

Figure 3. Number of Dock plants per plot.

Follow-up spraying for dock increased percent kill. In plots given a single treatment in 1972 and 1973 density decreased 29.4 ± 0.85% while in plots given two treatments density decreased 58.9 ± 12.5% (Table 1).

TABLE 1.--Number of Dock Plants per plot using single and follow up treatments

	Single Treatment			Follow-up Treatment		
Plot	1972	1973	Change	1972	1973	Change
A	22	15		35	10	
B	33	23		28	15	
MEAN	27.5	19	-8.5	31.5	12.5	-19.0
MEAN % CHANGE		-29.4 ± 0.85%[a]			-58.9 ± 12.5%[a]	

[a]Standard error of the mean

Under the conditions and techniques used in this study efficiency of treatment declined as density declined. During the first year 70% of the plants were killed, about 60% were killed the second year and 52% the third year.

Discussion

Sour dock and smooth dock appear to be quite easy to control with spot spraying techniques. Density of dock was significantly reduced during the three year study. Eradication of dock may be more difficult due to the inability to locate all plants in a single operation. Percent kill decreased each year of the study indicating that young plants, too small to be spotted in May, were furnishing most of the plants for the next year. Only when the residuum of seeds in the soil was reduced would elimination of the weed be possible.

A follow-up spray does increase kill percentage considerably and if

it could be coupled with another operation might be feasible.

Establishment of new plants is most evident in areas where the vegetation has been disturbed such as where ditches have been cleaned, fill dirt removed, etc. Elimination of these sites or control by rapid revegetation would greatly reduce dock populations.

WILD PARSNIP

Methods

Effectiveness of 2,4-D spray and hand cutting of wild parsnip (figure 4) was evaluated at two sites. Plots 5.03 m (one rod) long and the

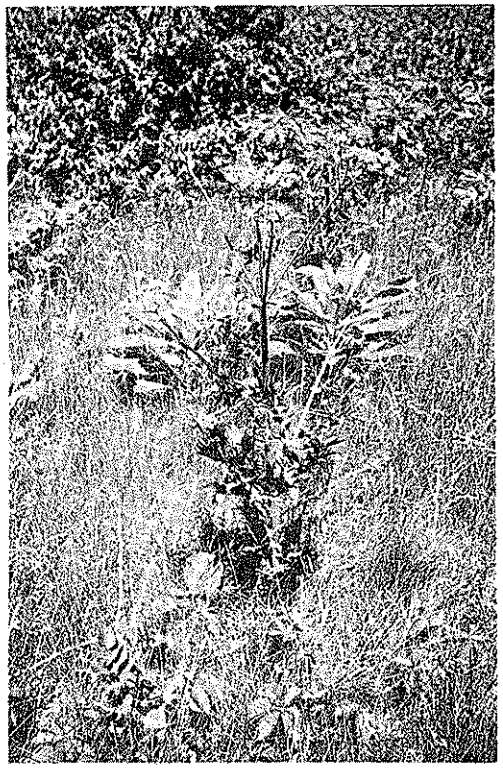

Figure 4. Wild parsnip.

entire width of the ditch were laid out and counts of plants made. Buffer zones were located between spray and no spray treatments. At site 1 pre-treatment counts and spray treatments were made on 26 May 1971. Herbicide concentration and application were the same as for dock. Post-treatment counts of plants were made on 30 May, 1972 and on one half of the plots on 6 June 1973. The remainder of the plots had been disturbed by mowing.

On 30 May, 1972 another site (site 2) was set out in a similar manner with the addition of 5 plots which were hand cut. Spraying was done on 30 May, 1972 and cutting was done about 15 days later. Counts of plants were made on 6 June, 1973.

Results

Wild parsnip was quite susceptible to 2,4-D applied in late May or early June. At site 1 in the spray plots the number of plants per plot was reduced 66.1% while density in the control plot decreased 11.8% (see Table 2). In the spray plots the second year after spraying (1973) the count increased 293% or 33% above the original count. In the control plot the increase from 1972 to 1973 was 107%, 82.7% above the original count.

At site 2, one year after spraying or cutting treatments, the number of plants in control plots had decreased by 10.1%, decreased by 20.4% in cutting treatments and decreased by 93.8% in spray treatments (see Table 3).

TABLE 2.--Number of wild parsnip plants per plot at site 1

Subplot	1971	1972	Change	1973	Change
Sprayed					
A	51	20	-31	67	+ 47
C	91	10	-81	114	+104
E	100	4	-96		
G	30	58	+28		
Mean	68	23	-45*		
Plots A and C only			-56*	90.5	+ 75.5*
Control					
B	69	28	-41	150	+122
D	265	287	+22	252	- 35
F	56	18	-38		
H	50	58	+ 8		
Mean	110	97.75	-12.25ns[a]		
Plots B and D only			- 9.5ns	201	+ 43.5ns

* Significant change at P = 0.05

[a]ns = No significant change

TABLE 3.--Number of wild parsnip plants per plot at site 2

	Control		Cut		Spray	
	1972	1973	1972	1973	1972	1973
	72	94	13	24	111	10
	33	35	17	32	149	25
	201	182	143	82	108	5
	278	214	179	122	300	1
			231	204		
Mean	146	131.2	116.6	92.8	167	10.25
CHANGE	-14.8ns[a]		-23.8ns		-156.75**	
% CHANGE	-10.1%		-20.4%		- 93.9%	

[a]ns = No significant change

** Significant change at P = 0.01

Discussion

Population densities of wild parsnip may fluctuate greatly from year to year. However, results show that spraying with 2,4-D in late May or early June before plants had begun flowering was very effective, and since the species is a biennial, control extended through the next growing season. Because of a large residuum of seeds in the soil, control was only temporary and the second year following treatment populations were as dense as before treatment. Cutting the plants prior to seed maturity had no significant change upon density the next year. Also, plants cut off above even the lowest node (leaf) usually produced secondary inflorescences from the axils of the remaining leaves so that seed production could not be prevented except by persistent and careful cutting.

Control of seed production should be possible by spraying every other year rather than annually. Under ideal storage conditions Barton (1961) found wild parsnip seeds remained viable for a maximum of six years. After a few years of control the seed reserves in the soil would be considerably diminished and if off-road seed sources were not available the plant could be eventually eliminated.

In addition to its competitive ability wild parsnip is objectionable because of its ability to produce skin rashes when leaves or plant sap comes in contact with the skin.

CANADA THISTLE

Methods

Canada thistle (figure 5) patches were located while treating dock plants in mid- to late May in 1971. Additional patches were discovered and marked during the remainder of the research project. Patches were marked by tying plastic tape on fence posts or utility poles adjacent to the roadside ditch. Each patch located was marked on a master map and assigned a number. Area of each patch was determined in late July of each year of the project by determining the length of the patch and multiplying by the width of the roadside ditch.

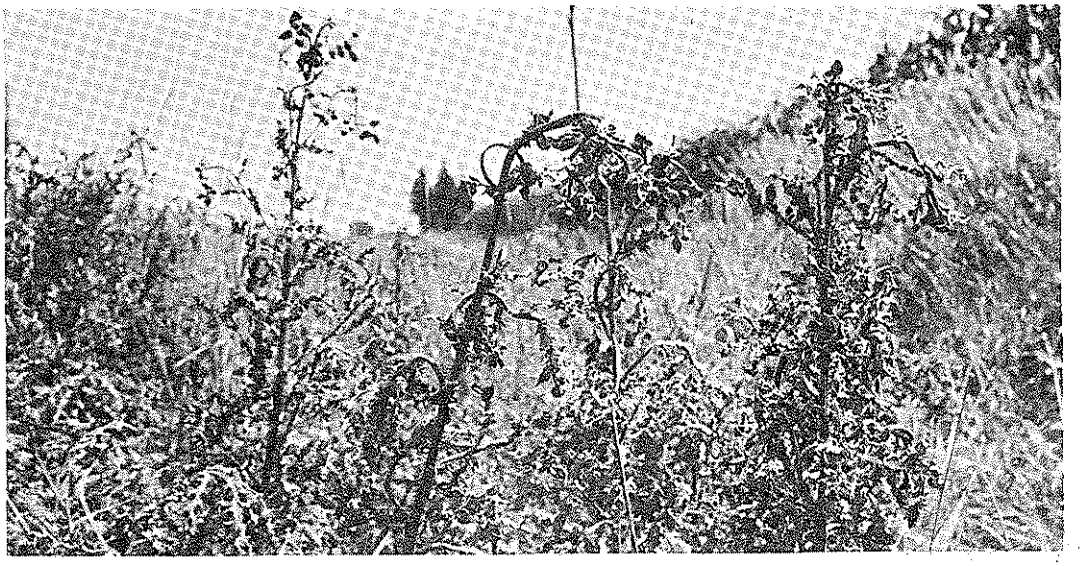

Figure 5. Canada thistle after herbicide treatment.

All Canada thistle patches were treated with a low-volatile ester form of 2,4-D or Banvel.[1] During the first year treatment was with 2% solution of 2,4-D in water between 22 and 29 June 1971. In 1972 0.0625% solution of Banvel in water was used on 6 and 7 June. In 1973 a 0.125% solution of Banvel was sprayed on 29,30 and 31 May. A 200 gallon sprayer equipped with a hand boom and developing 1.36 atmospheres of pressure (20 PSI) was used.

Seven treatment plots and one control plot (in adjacent Linn township) were laid out in Canada thistle patches to determine changes in plant density. Each plot consisted of 20 subplots, each 20x50 cm (7.9 x 19.7 inches) and located 1 m (39.37 inches) apart on a transect laid parallel with the roadway at or near the lowest part of the ditch. Treatment plots were located in all parts of the township. The number of Canada thistle plants was recorded for each plot during July of each year of the study.

A number of patches were treated with Pramitol[2] or Tordon Beads[3] on June 5 and 6, 1973. Treatment rates were according to label directions. Nine plots which had been previously treated with Banvel were treated with Pramitol, 9 plots not treated with Banvel were treated with Tordon Beads and 8 plots previously treated with Banvel were treated with Tordon Beads. Examination of the plots for regrowth was made on July 24 and 25, 1973 and casual observations were made in May, 1974.

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[1]Manufactured by Velsicol Chemical Corp., 341 E. Ohio St., Chicago, Ill. 60611

[2]Manufactured by CIBA-Geigy Corp., Ardsley, N.Y. 10502

[3]Manufactured by Dow Chemical Company, 6000 W. Touhy Ave., Chicago, Ill. 60648

Results

Total area of Canada thistle patches located in the township roadsides was 2.41 ha (5.95 acres) in 1971, 3.27 ha (8.08 acres) in 1972 and 2.73 ha (6.74 acres) in 1973. During the summer of 1971, 74 patches were located. In 1972, 66 additional patches were located and 34 more were located in 1973. It is difficult to estimate the number of patches which became established after 1971. Many were missed during the first year because they did not bloom or were not observed for other reasons. The mean patch size was 325.4 m^2 (3,503 ft^2) in 1971. Mean areas of new patches located in 1972 was 135.2 m^2 (1,455 ft^2) and 113.6 m^2 (1222.4 ft^2) for new patches located in 1973. This trend toward smaller size indicates that some new establishment was probably taking place although smaller patches would also be more likely to be overlooked.

A study of trends in patch size of 70 patches located in 1971 was made. Of large patches, those larger than the mean, 18 decreased in size while 3 increased. For patches less than the mean, 22 decreased in size and 27 increased. Of the latter patches increasing in size, 17 of 27 were below 92.9 m^2 (1000 ft^2).

Density of Canada thistle decreased by 45.0% after spray treatment in 1971 and 30.9% after treatment in 1972 (see Table 4). Density of thistle in a control plot treated by the mass spray method increased 3.8% from 1971 to 1972 and 36.4% from 1972 to 1973. From 1971 to 1973 there was an overall decrease in density of 62.0% in treated plots and an increase of 55.0% in the control plot.

TABLE 4.--Number of Canada thistle plants in 20 20x50 cm (7.9 x 19.7 inches) subplots

Species Plot Number	1971	1972	Difference 1971 to 1972	1973	Difference 1972 to 1973
			Treated Plots		
9	77	26	-51	22	- 4
18	45	14	-31	15	+ 1
19	2	3	+ 1	3	0
51	36	14	-22	26	+12
57	20	13	- 7	6	- 7
63	46	39	- 7	11	-28
67	21	27	+ 6	11	-16
Mean	35.3	19.4	15.9	13.4	- 6.0
% Change			-45.0%		-30.9
Overall % Change (1971 to 1973)					-62.0*
			Control Plot		
27	29	33	+ 4	45	+12
% Change			+13.8		+36.4
Overall % Change (1971 to 1973)					+55.0%

* Significant change at p = 0.1

In patches treated with Banvel and then Pramitol, regrowth occurred in 1 of 9 patches in July, 1973. In May of 1974 occasional plants were evident in all 9 patches and considerable damage had been done to existing grass cover.

In patches treated only with Tordon Beads, regrowth had occurred in 8 patches and 1 had no evidence of regrowth in July, 1973. In May of 1974 all patches had Canada thistle present.

In patches treated with Banvel and then Tordon Beads, 4 of 8 patches had regrowth in July 1973. By May, 1974 regrowth was evident in all 8 patches.

Density and vigor of Canada thistle in patches receiving Pramitol or

Tordon Bead treatment appeared to be considerably diminished but density plots were not set out in these sites to measure precise changes.

Discussion

In Franklin township Canada thistle patches infested less than 5% of the roadside ditches. This estimate might be 100% too high or even more as patches were estimated as if they occupied the complete ditch when in many instances only the foreslope or backslope was occupied. In the study area this averaged a maximum of 40.2 m (8 rods) of Canada thistle per 1.6 km (1 mile) of ditch.

The problem of establishment of new patches is difficult to evaluate. Intensive searches of ditches would be necessary to assure the absence of Canada thistle. Because of the observed decrease in size of newly discovered patches it is likely that some establishment took place during the study period. At present there is no information available on what this establishment rate might be. It is clear from the data that the density of Canada thistle plants can be reduced considerably using methods of spot spraying early in the growing season. Vigor was not measured (plant weight, height, etc.) but appeared to decrease considerably during the period of the study (see photos) on most patches.

Several herbicides were used during the course of the study and each offered certain advantages and had certain drawbacks.

Banvel is most effective when plants are small, 5 to 10 cm (2 to 4 inches) tall. Therefore Canada thistle must be sprayed from mid to late May

in Linn County. This herbicide gives fair top kill when used at the rate of 236 ml (1 cup)/ 3784 l (100 gallons) of water, and at 473 ml (1 pint)/ 3784 l (100 gallons) of water gives good top kill without impairing grass cover except for reducing seed production. Agricultural crops susceptible to Banvel, such as soybeans, are usually not affected by accidental spray drift from applications made in May or early June.

The low-volatile ester form of 2,4-D is most effective on Canada thistle if applied up until flower buds are developing. Various patches show considerable variation in flowering time, from early to late June. Therefore, it is difficult to spray all patches at the optimum time. Also the hazards of drift, both when applying the herbicide and later when the herbicide volatilizes into the air present problems when using 2,4-D.

Tordon Beads were most effective on small plants and also as a follow-up treatment after an initial spraying with Banvel or 2,4-D. In 1973 plants in most patches were treated with Tordon Beads at the end of June and near the end of July. Regrowth in the spring of 1974 appeared to be greatly reduced. Repeated applications of Tordon Beads on individual plants several times per season over two or more years shows promise of an effective eradication measure.

Pramitol is a soil sterilent which destroys all vegetation when it is applied at sufficient application rates. In Canada thistle patches where the Pramitol spray was applied to individual plants almost complete kill was made. Regrowth the following spring apparently came from plants missed by the treatment. The most serious drawback to this type of treatment is the complete

loss of cover in the treatment area. As grass roots and tops decay, erosion becomes a threat and regrowth of any significant amount of vegetation is prevented for more than one year. Also, reduced competition can lead to increased thistle vigor.

Based upon results of this study, minimum control of Canada thistle, i.e., prevention of flowering and control of vigor and spread, was achieved with mid- to late May treatment with Banvel. More intensive treatment, using Tordon Beads (on individual plants) several times during the growing season appeared to reduce population densities considerably.

NATIVE-GRASS SEEDING

Methods

Several types of areas were seeded to evaluate the feasibility of establishing native grasses on roadside rights-of-way. The major area seeded was 6.9 ha (17 acres) of newly graded roadway just north of Lisbon, Iowa. The seedbed was prepared with a spring-tooth harrow and drag and seeding was done with a hydromulcher (figure 6). A mulch of wood fibers (Conwed Hydromulch[1]) was also used. Seeding was done during the first week in June, 1971. The seed mixture consisted of five grass species (see Table 5). Management consisted of mowing the shoulder of the roadway and spraying noxious weeds during the three years of the study.

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[1]Manufactured by Conwed Corporation, 332 Minneapolis St., St. Paul, Minnesota.

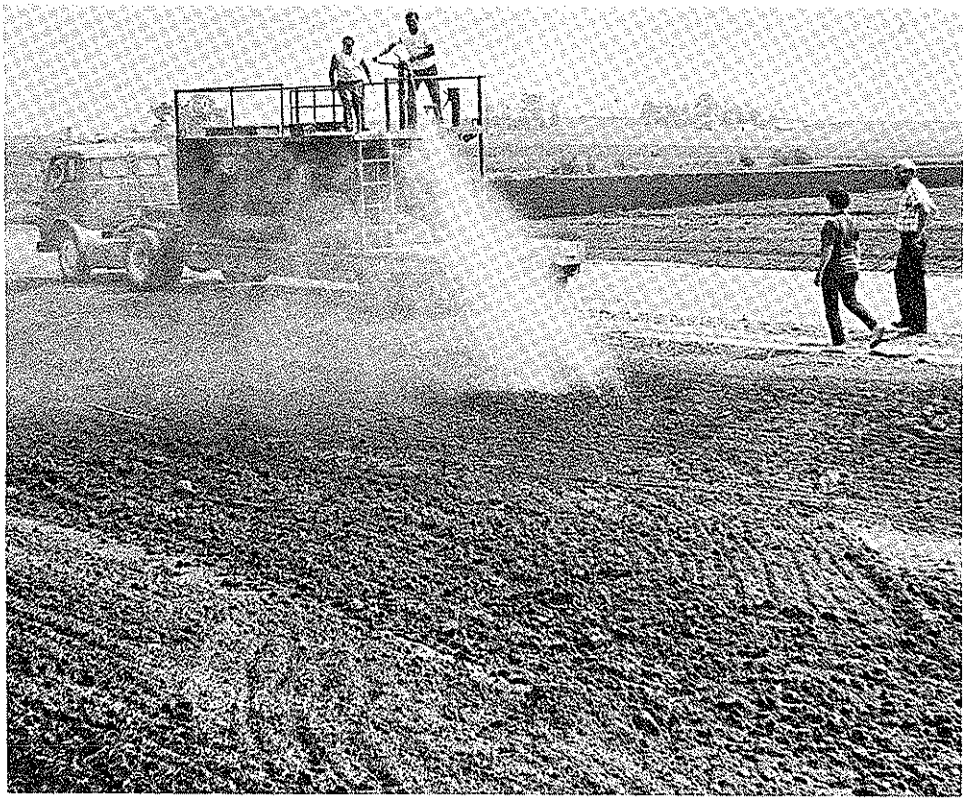

Figure 6. Roadside being seeded with hydromulcher.

TABLE 5.--Prairie grass seed mixture

Species	kg PLS[1]/ha	Pounds PLS /A	PLS/m^2	PLS/ft^2
Big bluestem *Andropogon gerardi* var. pawnee	2.24	2.0	81.81	7.6
Little bluestem *Andropogon scoparius* var. blaze	1.34	1.2	77.50	7.2
Side-oats grama *Bouteloua curtipendula* var. trailway	0.89	0.8	37.67	3.5
Indian grass *Sorghastrum nutans* var. holt	1.12	1.0	43.06	4.0
Switch grass *Panicum virgatum* var. pathfinder	0.89	0.8	76.42	7.1
Total	6.50	5.8	316.46	29.4
Perennial ryegrass *Lolium perenne*	1.22 kg/ha (1 pound/A)			

[1]PLS -- Pure live seed

Sample plots were evaluated for presence of all species during October of 1971, 1972 and 1973. Ten subplots, each 20x50 cm (7.9 x 19.7 inches) were taken at 10 meters (32.8 feet) intervals within each of three plots. Plot A received no grass seed except perennial ryegrass. Plots B and C received the prairie mixture and ryegrass. Plot C also was seeded with a mixture of 50 other prairie species in addition to the prairie grass mixture and ryegrass.

In addition to new grades, eleven small areas where ditches had been deepened to improve drainage were seeded. The mixture and rate described in Table 5 was used. All areas had been cleaned the fall prior to seeding. No cultivation was done prior to seeding. Seeding was done during the first week of June 1971 and 1972. Evaluation consisted of casual searches for seedlings during 1972 and 1973.

Introduction of prairie grasses by seeding was also attempted into existing vegetation. The mixture described in Table 5 was used at 1/2 the given rate. Six areas with either loamy or sandy soil were seeded in early June, 1971. Casual search for seedlings were made in 1972 and 1973.

Results

Results on the newly graded roadway showed that satisfactory stands of native grasses were obtained using a hydroseeder-mulcher. During the third growing season native grasses dominated the seeded plots of right of way at 80% frequency (see Table 6 and figure 7). That is, 80% of the 20x50 cm. (7.9 x 19.7 inch) quadrats contained a native grass plant. Percent frequency

TABLE 6.--Percent frequency on newly graded roadway

	Plot A			Plot B			Plot C		
	1971	1972	1973	1971	1972	1973	1971	1972	1973
Prairie grasses									
big bluestem*		20	20	40	20	20	40	20	20
little bluestem*				40	20	20	20	10	40
indian grass*		10		30	10	40	10	0	10
switchgrass*		20	10		40	60	10	30	50
side-oats grama*		10		40	30	10	50	30	50
tall dropseed					10				
Canada wildrye*									10
ALL prairie grasses		20	30	90	70	80	70	60	80
Other prairie species									
purple prairie clover*								10	
tick trefoil*					10				
yellow coneflower*									10
white heath aster			30		10				
Canada goldenrod			10						
horsetail								10	10
scouring rush							10		
groundcherry				10					
Non-prairie grasses									
yellow foxtail	90	100	80	80	90	70	80	90	70
green foxtail	10	100	60		50	30		40	10
witchgrass		90	30	80	80	10	40	30	
ryegrass*	70	20	40	60			90	20	10
Muhley grass				10					
crabgrass							10		
stinkgrass	10								
fall panicum		10		40	30	10		20	
barnyard grass			10		30		10		10
bluegrass		10	60		10	10	10	40	40
smooth bromegrass			10						
timothy									10
Weedy forbs (non-grasses)									
smartweed	40	80		10	40	20	10		
kochia	10			10			10		
lamb's quarters							20		
dandelion				10					
field thistle			10						
clover species	10		20	10		30		40	40
little ragweed		10	30						
Canada thistle		10						10	
horseweed		20	40			20		10	30
woodsorrel								20	10
plantain								10	
sweet clover			30						
cinquefoil								10	

*Seeded species

Figure 7. Backslope in third growing season after being seeded with native grasses.

of native grasses ranged from 70% to 90% during the three years of the study. Of the five species seeded in the mixture (Table 5) all became established with switchgrass and side-oats grama highest at 40% to 60% frequency. Big and little bluestem ranged from 20 to 40% while indian grass ranged more widely, from 10% to 40%. Canada wildrye established to a lesser extent from a few grams of seed used in plot C and tall dropseed was a volunteer in one plot.

A few other prairie species became established as a result of seeding or volunteer plantings. Sampling was not sufficiently intensive to adequately represent the establishment but several species were encountered

(see Table 6). Purple prairie clover, tick trefoil and yellow coneflower were encountered in sampling and white prairie clover, black-eyed Susan and thimble weed were present in plot C. White heath aster and Canada goldenrod volunteered in plots A and B.

During the first two years after seeding, the weedy annual grasses, especially the foxtails dominated the plots (see Table 6). Although percent frequency remained high, weedy grasses were dominant only in plot A during the third year (1973). All weedy grasses showed a decrease in percent frequency. An example is witchgrass in plot B which was at 80% in 1971 and 1972 but decreased to 10% in 1973. Several perennial grasses began to appear in 1972 and 1973. Bluegrass was most common but smooth bromegrass and timothy were also present.

A limited number of weedy forbs (non-grasses) were present, in most cases during the first two growing seasons (see Table 6). Smartweed and kochia were in this group which was being replaced by several clover species and horseweed (Conyza canadensis) in the third year.

Of eleven excavated ditches receiving no seedbed preparation prior to seeding, native grasses became established in only one site. This establishment was very limited but evaluation was difficult because the adjacent property owner mowed the ditch periodically which discouraged the native grasses preferentially over ryegrass and bluegrass.

Overseeding of native grasses into existing vegetation produced no establishment in any of the six areas seeded.

Discussion

Native prairie grass species seeded into a prepared seedbed in roadsides appeared to produce adequate cover after a period of about three years. A seeding rate of about 325 pure liveseeds/per square meter (30 PLS/Ft^2) produced an adequate stand but doubling that rate would give more assurance of a sufficient stand. Considerable washing of seeds, mulch and soil just after seeding due to heavy rains also affected the stand, especially on fore- and backslopes. The use of straw mulch on areas susceptible to erosion would also help insure a stand.

Native prairie forbs became established to a very limited extent but several species were quite successful. Three legumes, purple prairie clover, white prairie clover and tick trefoil increased in prominence during the three years even though limited sampling failed to show this. Also yellow coneflower and black-eyed Susan competed favorably with the grasses and were blooming prominently during 1973.

The ryegrass cover crop was inadequate to suppress weeds and provide cover for erosion control during the first growing season. The use of a different grass species, additional species such as alfalfa or the use of a pre-emergent herbicide such as Atrazine or Bladex are alternatives which should be investigated.

Comparisons of areas having seedbed preparation with those without preparation dramatically show the need for seed bed preparation. It is probable that more "safe sites" for seed germination would be available immediately after ditch cleaning operations than after a delay through the

winter months. However, weather conditions would not be suitable for establishment of seedlings during much of the summer when ditch cleaning operations might be done.

While carrying out dock spraying operations it became obvious that cleaned areas in ditches represented major areas for colonization of weedy species. The period of time these pioneer species would dominate could be greatly reduced if a vigorous perennial vegetation were introduced under suitable conditions as in the prepared seedbed study area. To minimize weedy growth in roadside ditch newly denuded areas, such as cleaned ditches, should be seeded with perennial grasses, such as native prairie species, at the earliest suitable time.

The introduction of native prairie species into existing vegetation by seeding does not appear to be successful. It may be however, that sufficient time has not yet elapsed to definitely rule out establishment. One author (PAC) scattered seeds of native grasses and forbs on a roadside in northern Iowa and 7 years elapsed before any native grasses became evident (unpublished data).

ROADSIDE VEGETATION DYNAMICS

Methods

Roadside vegetation dynamics were evaluated by measuring the cover of each species present during July of each year of the study. Seventy plots were laid out throughout the township to sample all vegetation types present. Each plot consisted of 20 subplots, 20 x 50 cm (7.9 x 19.7 inches) placed

1 m (39.37 inches) apart on a transect in the bottom of the ditch parallel with the road (figure 8). Evaluation of the plots consisted of estimating coverage of each species present in the plot after a method developed by Daubenmire (1959). Nine plots were treated with herbicide for control of Canada thistle and served as controls. Fifty-one plots were untreated and served as experimental plots. Ten plots were lost or disturbed during the study. Certain plots were placed arbitrarily and therefore results do not represent an unbiased estimate of Franklin Township roadside vegetation.

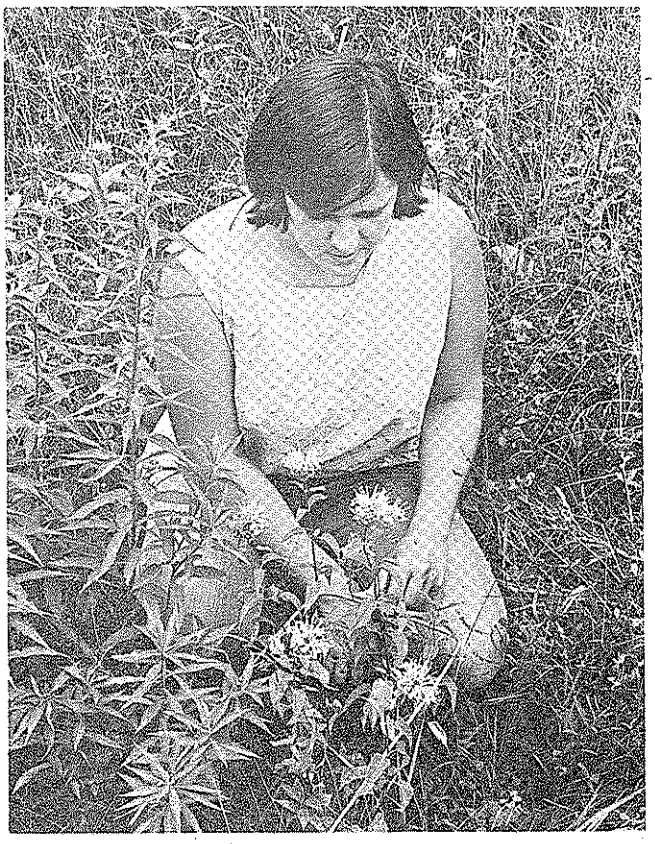

Figure 8. Technician prepares to sample vegetation with metal frame quadrat.

Results

During the three-year study of roadside vegetation 122 species of plants were observed in plots. Thirty-four species (27.9%) were native prairie species; 12 (9.8%) were introduced species common on roadsides; 43 (35.2%) were weedy introduced species; 20 (16.4%) were woody species (trees or shrubs) and 13 (10.7%) were classified as miscellaneous being mostly woodland edge species (see Appendix 1).

During the course of the study the number of species per plot increased in both control and experimental plots. Controls increased slightly from 9.6 to 10.2 species per plot, an insignificant amount. In experimental plots the increase was from 14.4 to 16.1 species per plot, a highly significant increase.

Total coverage increased in both control and experimental plots between 1971 and 1973. In experimental plots total coverage increased from 133.5% to 212.8% while control plots increased from 122.1% to 168.4%.

Grasses dominated both control and experimental plots. In 1971 grasses accounted for 69.8% of the relative cover in experimental plots and 87.3% in control plots. By 1973 grass domination had decreased in experimental plots to 62.8% while domination in control plots had increased slightly to 87.5% (see Table 7).

TABLE 7.--Percent relative cover of grasses and non-grasses.

	Control		Experimental	
	1971	1973	1971	1973
all grasses	87.3	87.5	69.8	62.8
non-grasses	12.7	12.5	30.2	37.2
	100.0	100.0	100.0	100.0

Further breakdown of cover data indicates that considerable change was occurring in experimental plots while only slight change took place in control plots (see Table 8 and figures 9, 10, 11 and 12). The relative cover of native prairie species increased in experimental plots from 17.5% to 22.1% while relative cover of weedy species increased from 10.8% to 14.8%. Relative coverage of common roadside species decreased from 66.0% to 60.1% and relative cover of woody species decreased from 2.8% to 1.9%. Relative cover of miscellaneous species also declined, from 2.0% to 1.1%.

TABLE 8.--Percent relative cover of several vegetation types

	Control		Experimental	
	1971	1973	1971	1973
prairie	8.9	8.9	17.5	22.1
common	82.3	81.1	66.9	60.1
woody	0.1	0.0	2.8	1.9
weedy	8.8	10.0	10.8	14.8
miscellaneous	0.0	0.0	2.0	1.1
	100.1	100.0	100.0	100.0

In control plots native prairie relative coverage remained constant at 8.9%, cover of weedy species increased from 8.8% to 10.0% and cover of common roadside species decreased from 82.3% to 81.1%. Woody species accounted for less than 0.1% of the cover in 1971 and none were encountered in plots in 1973. No species in the miscellaneous category were present in control plots.

Changes in relative cover between annual[1] and perennial species was minimal in control plots. Relative cover of perennials decreased from 91.0%

[1]In this report "annual" refers to both annual and biennial species.

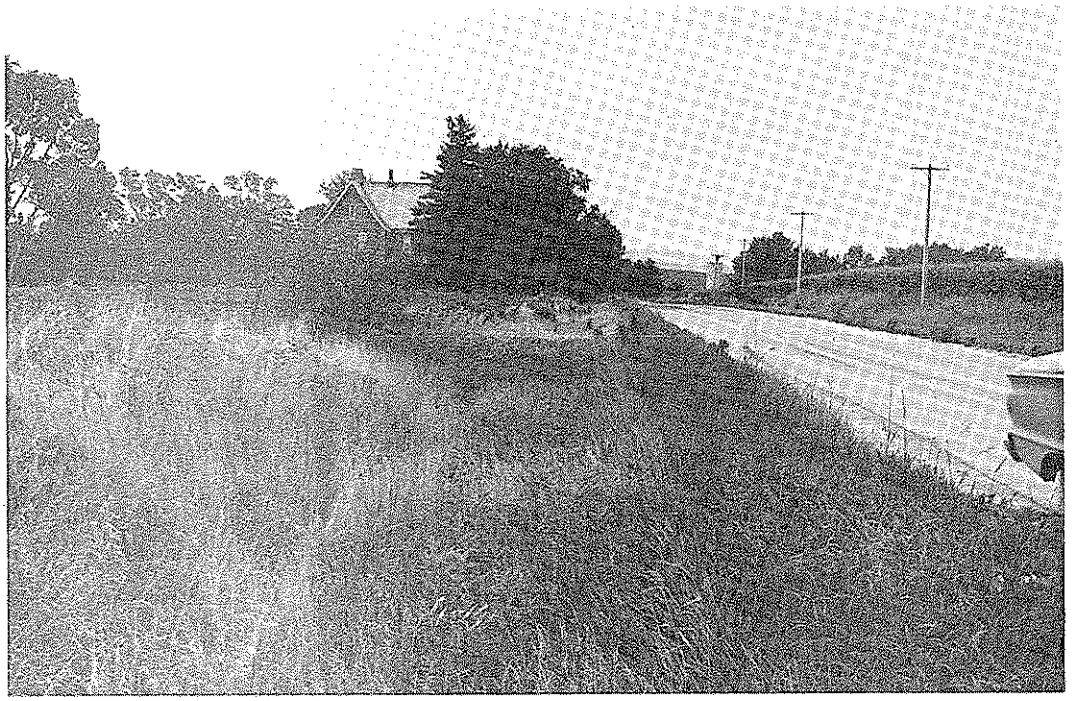

Figure 9. Experimental (non-sprayed) sampling plot, July, 1971.

Figure 10. Experimental (non-sprayed) sampling plot, July, 1973.

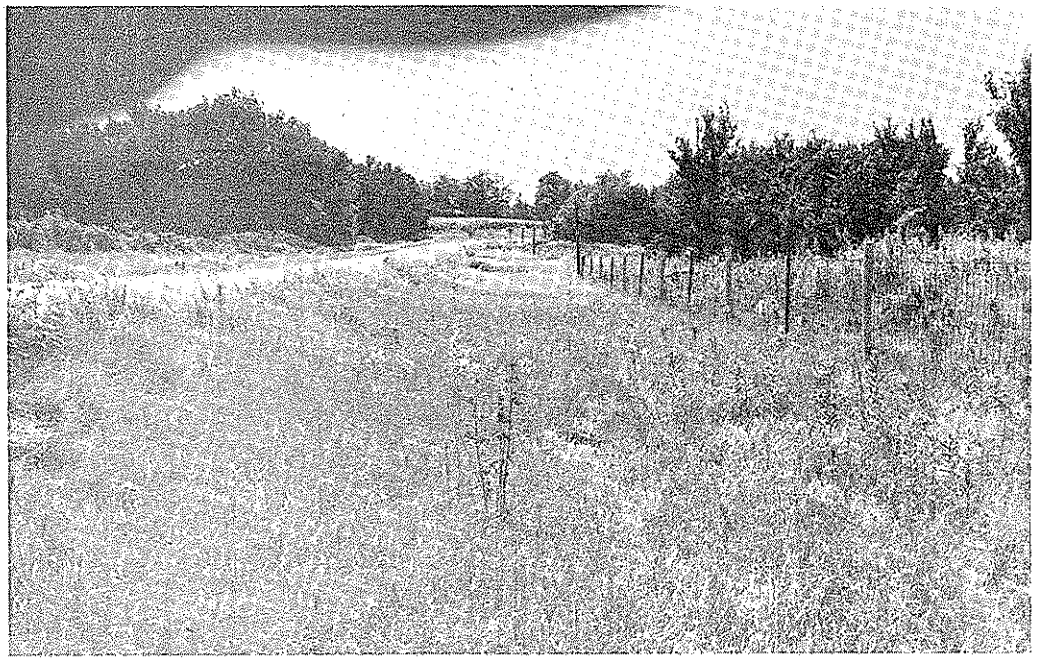

Figure 11. Control (mass sprayed) sampling plot, July, 1971.

Figure 12. Control (mass sprayed) sampling plot, July, 1973.

to 88.9% while relative cover of annuals increased from 9.0% to 11.1% (see Table 9).

TABLE 9.--Percent relative cover of perennial and annual vegetation

	Control		Experimental	
	1971	1973	1971	1973
perennial	91.0	88.9	87.7	82.5
annual	9.0	11.1	12.3	17.5
	100.0	100.0	100.0	100.0

Somewhat more change occurred in experimental plots. Relative cover of perennials decreased from 87.7% in 1971 to 82.5% in 1973. Annuals increased from 12.3% to 17.5%.

Very little change occurred in relative coverage of woody plants between 1971 and 1973. In control plots relative cover of woody plants decreased 0.01% to 0.0% (see Table 10). In experimental plots the initial relative coverage was somewhat higher than in control plots at 2.7%. By 1973 the relative coverage had decreased to 1.9%.

TABLE 10.--Percent relative cover of herbaceous and woody vegetation

	Control		Experimental	
	1971	1973	1971	1973
herbaceous	99.99	100.0	97.3	98.1
woody	0.01	0.0	2.7	1.9
	100.00	100.0	100.0	100.0

A study of species increasing or decreasing more than 1% in absolute cover between 1971 and 1973 revealed that relatively few species accounted

for most of the shifts in cover.

Among the perennials showing increase or decrease of 1% absolute cover in control plots redtop, timothy, ryegrass, little bluestem, white heath aster, wood sorrel, Canada goldenrod and violet increased in relative cover while smooth bromegrass, bluegrass, Muhley grass and dandelion decreased. Horsetail, ragwort and alfalfa remained about the same in relative cover (see Table 11). Those species increasing comprised 6.5% of the absolute perennial cover in control plots in 1971 and 14.0% in 1973.

In experimental plots redtop, smooth bromegrass, reed canarygrass, tall dropseed, white heath aster, horsetail, wood sorrel, ragwort, Canada goldenrod and rigid goldenrod increased in relative cover (see Table 11). Muhley grass, timothy, bluegrass and alfalfa decreased while ryegrass, little bluestem, dandelion and violet remained about the same in relative cover. Those species increasing comprised 28.1% of the absolute perennial cover in experimental plots in 1971 and 38.8% in 1973.

Of annual species in control plots fluctuating more than 1% in absolute cover between 1971 and 1973 three species including little ragweed, foxtail and black medick increased in relative cover (see Table 12) and two species declined; giant ragweed and wild lettuce. Those species increasing comprised 47.7% of the absolute annual cover in control plots in 1971 and 69.5% in 1973. In experimental plots giant ragweed, partridge pea, white sweet clover, yellow sweet clover, red clover and white clover increased in relative cover while wild lettuce decreased (see Table 12). Those species increasing comprised 30.3% of the absolute annual cover in experimental plots in 1971 and 64.1%

TABLE 11.--Percent relative cover of perennial species fluctuating more than 1% in absolute cover between 1971 and 1973

Species	treatment	1971	1973	change
red top	C[1]	0.08	0.98	+0.90
	E[2]	1.51	1.80	+0.29
smooth bromegrass	C	15.16	12.35	-2.81
	E	15.59	16.59	+1.00
muhley grass	C	2.53	0.0	-2.53
	E	1.73	0.53	-1.20
timothy	C	1.99	2.79	+0.80
	E	1.42	0.94	-0.48
reed canary grass	C	0.0	0.0	0.0
	E	0.11	0.95	+0.84
bluegrass	C	62.03	49.25	-12.18
	E	42.86	36.13	-6.73
ryegrass	C	0.08	1.37	+1.29
	E	0.13	0.25	+0.12
tall dropseed	C	0.0	0.0	0.0
	E	3.39	4.95	+1.56
little bluestem	C	2.24	2.49	+0.25
	E	0.19	0.38	+0.19
white heath aster	C	0.09	0.36	+0.27
	E	0.91	1.29	+0.38
horsetail species	C	0.35	0.30	-0.05
	E	0.97	1.20	+0.23
wood sorrel	C	0.07	0.21	+0.14
	E	0.40	0.94	+0.54
ragwort	C	0.0	0.01	+0.01
	E	0.40	1.33	+0.93
alfalfa	C	0.03	0.0	-0.03
	E	1.30	0.17	-1.13
Canada goldenrod	C	0.61	0.88	+0.27
	E	1.31	1.65	+0.34
rigid goldenrod	C	0.0	0.0	0.0
	E	0.10	0.75	+0.65
dandelion	C	0.66	0.53	-0.13
	E	0.67	0.72	+0.05
violet species	C	0.75	1.13	+0.38
	E	1.06	1.10	+0.04

[1]C = Control (mass sprayed)

[2]E = Experimental (not sprayed)

TABLE 12.--Percent relative cover of annual species fluctuating more than 1% in absolute cover between 1971 and 1973

Species	treatment	1971	1973	change
common ragweed	C[1]	0.61	1.73	+1.12
	E[2]	1.27	1.33	+0.06
giant ragweed	C	1.03	0.38	-0.65
	E	0.67	3.16	+2.49
partridge pea	C	0.0	0.0	0.0
	E	0.87	1.32	+0.45
white sweet clover	C	0.0	0.02	+0.02
	E	1.03	2.64	+1.61
yellow sweet clover	C	0.0	0.0	0.0
	E	0.35	1.33	+0.98
red clover	C	0.0	0.0	0.0
	E	0.64	1.41	+0.77
white clover	C	0.39	0.33	-0.06
	E	0.37	1.24	+0.87
foxtail species	C	3.16	3.86	+0.70
	E	0.11	0.03	-0.08
wild lettuce	C	0.88	0.10	-0.78
	E	1.08	0.72	-0.36
black medick	C	0.53	2.16	+1.63
	E	0.61	0.59	-0.02

[1]C = Control (mass sprayed)

[2]E = Experimental (not sprayed)

in 1973.

Noxious weeds (other than Canada thistle, previously discussed) contributed very little to roadside cover. Total relative cover for noxious weeds in control plots increased from 0.0% to 0.25% between 1971 and 1973 while in experimental plots relative cover of noxious weeds decreased from 0.69% to 0.65% (see Table 13). Only field thistle exceeded 0.5% absolute cover (see Appendix 1). Changes in relative cover of six species of noxious weeds encountered (excluding Canada thistle) during the study are given in Table 13. Of the three species which were targets of mechanical control in experimental plots field thistle and dock decreased in relative cover while bull thistle remained virtually the same. Queen Anne's lace and horse nettle showed increases of about 0.1% in relative cover in experimental plots.

TABLE 13.--Percent relative cover of noxious weed species

Species	treatment	1971	1973	change
field thistle	C[1]	0.0	0.10	+0.10
	E[2]	0.50	0.24	-0.26
bullthistle	C	0.0	0.15	+0.15
	E	0.01	0.04	+0.03
Queen Anne's lace	C	0.0	0.0	0.0
	E	0.08	0.17	+0.09
dock species	C	0.0	0.0	0.0
	E	0.07	0.01	-0.06
red sorrel	C	0.0	0.0	0.0
	E	0.01	0.07	+0.06
horse nettle	C	0.0	0.0	0.0
	E	0.02	0.12	+0.10

[1]C = Control (mass sprayed)

[2]E = Experimental (not sprayed)

Two weedy species of some interest are hemp and wild parsnip. Hemp decreased in relative cover from 0.33% to 0.05% in control plots and 0.14% to 0.04% in experimental plots. Wild parsnip was encountered only in experimental plots and increased from 0.56% to 0.70% relative cover from 1971 to 1973.

Discussion

Several important trends are evident in roadside vegetation where no spray was applied while relatively little change occurred in spray plots.

Total cover increased in both control (sprayed) and experimental (non-sprayed) plots but significant increase occurred only in experimental plots. Control plot cover increased 38% from 1971 to 1973 while experimental plot cover increased 59%. Total cover is an indicator of productivity and structure of the vegetation. By 1973 absolute cover in experimental plots was 212.77 (Appendix 1). This indicates that the average plot had more than two layers of vegetation over the entire plot. Usually this is caused by taller plants which spread leaves above the grasses thus creating a multi-layered structure.

Complexity was also increased as indicated by the increase in the number of species per plot. A highly significant increase of 11.8% occurred in experimental plots between 1971 and 1973 while in control plots a non-significant increase of 8.3% occurred.

Using other vegetation measures control plots changed very little. Virtually no change occurred in relative cover of grasses and non-grasses,

perennials and annuals, herbaceous and woody plants and in further breakdown into prairie, common roadside, woody, weedy and miscellaneous categories (see Tables 7, 8, 9 and 10). Some changes were occurring within categories, however. Most notable was the increase of little ragweed and black medick (Table 12) and decrease of bluegrass and smooth bromegrass (Table 11).

Several trends were observed in relative cover distribution in experimental plots. There was a decrease in the importance of grasses with relative cover going from 69.8% to 62.8% between 1971 and 1973. The largest decrease was suffered by bluegrass. A number of groups of plants increased in relative cover with common roadside and weedy annuals increasing most. Four cultivated legumes; yellow and white sweet clover, and red and white clover provided most of the increase, while the contribution of giant ragweed was also considerable (see Table 12).

Several perennial prairie plants increased in relative cover also. These included tall dropseed, white heath aster, ragwort, and Canada and rigid goldenrod. Alfalfa, a cultivated legume, decreased considerably (Table 11).

Very little change occurred in the relative cover of woody plants. In experimental plots there was a slight decrease from 2.8% to 1.9% relative cover. Only a few woody plants were encountered in control plots in 1971 and none were present in 1973 (see Table 8). Over a longer time period no doubt woody plants would begin to make significant increases in cover if not controlled.

Noxious weeds, other than Canada thistle, do not appear to present a great problem. All are annual (or biennial) except for horse nettle, and

control is possible either by cutting or spot spraying.

Hand cutting of biennial thistles apparently had some effect on cover, especially field thistle, which decreased from 0.50% to 0.24% relative cover in experimental plots. Bull thistle increased very slightly; 0.03% in experimental plots and 0.15% in control plots (see Table 13).

From the results of this study it appears evident that the roadside vegetation under a mass spraying program had reached a state of equilibrium. When the stress of mass spraying was removed the vegetation reacted by shifting toward species which were formerly inhibited by spray but were competitive and aggressive when released from herbicide treatment. The changes in species composition produced a vegetation where taller species such as goldenrod, asters, sweet clover and giant ragweed are more important (figures 13 and 14). The uniformity of a pure grass cover was broken up into a more varied cover. Patchiness produced by perennial forbs (non-grasses), variation in height between grasses and certain taller annuals and perennials, and other visual changes including color were evident in roadside vegetation released from annual spraying (figure 15). After a number of years woody vegetation would also begin to make even more radical changes.

Responsible roadside vegetation management is a compromise between lowest possible costs, and safety and convenience for roadway users. If vegetation is allowed to go its course, forests will develop on the roadsides (in east-central Iowa) and poor drainage, inadequate sight distance, snow drifts and other consequences will impair the usefulness of the roadway. On the other hand, repeated mowing and/or spraying of roadsides can reduce

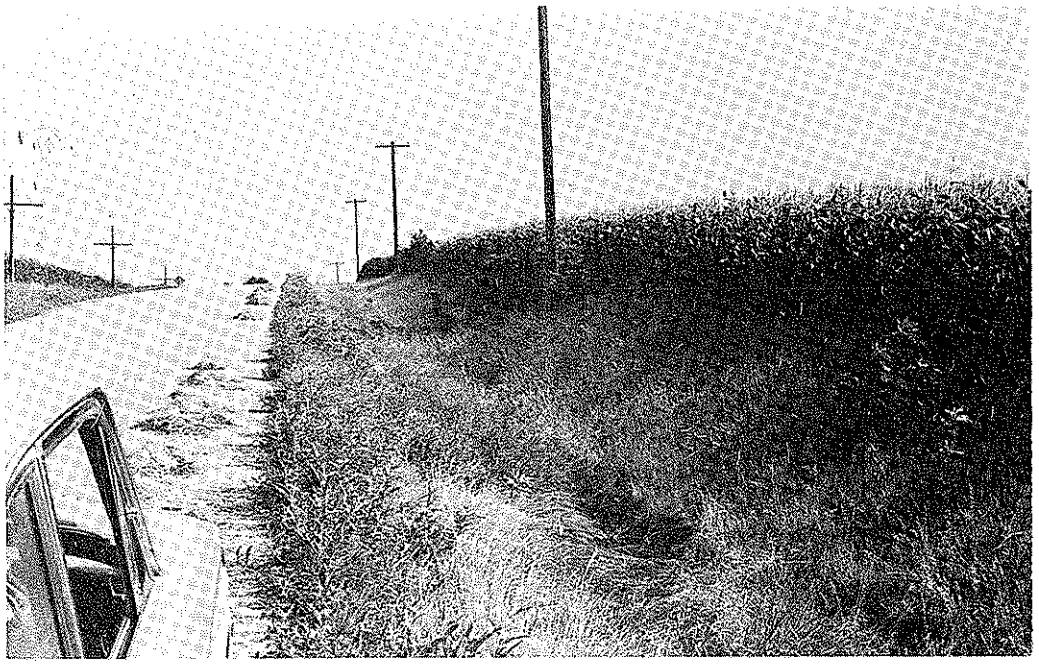

Figure 13. Experimental (non-sprayed) sampling plot, July, 1971.

Figure 14. Experimental (non-sprayed) sampling plot, July, 1973. Note invasion by giant ragweed.

roadside vegetation to a manicured lawn with its attendant high-maintenance costs. The key to good management of roadsides is to strike a balance between these two extremes.

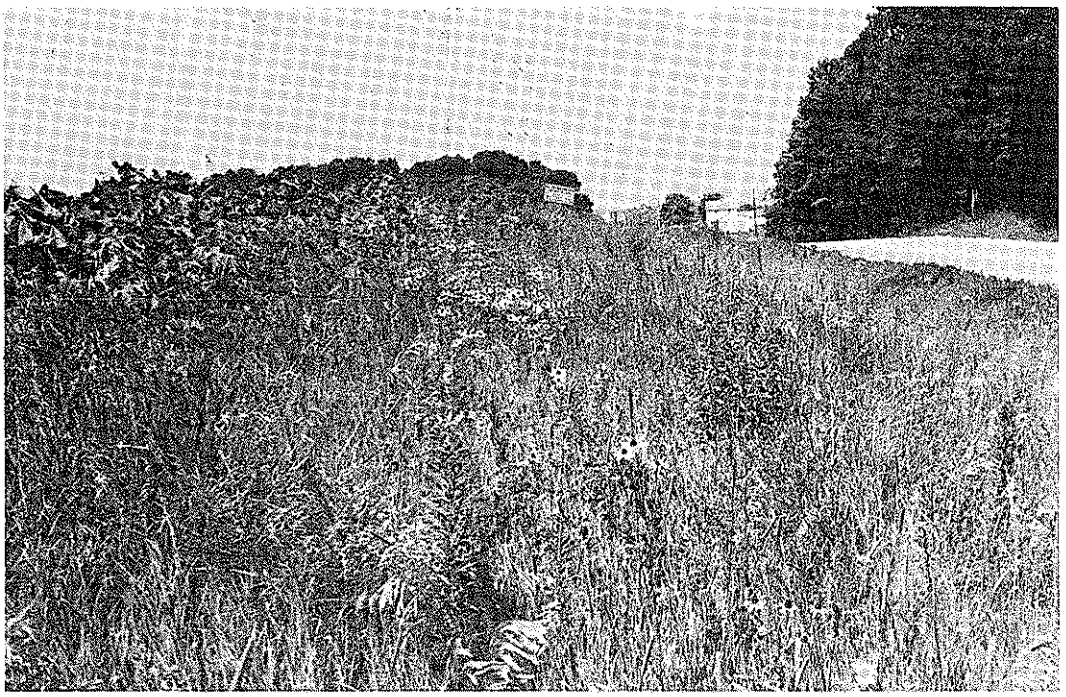

Figure 15. Roadside not sprayed for 3 years. Note flowering of black-eyed Susan and presence of other forbs (non-grasses).

Any form of disturbance such as grazing, cutting, spraying, etc. tends to prevent a plant community from reaching its potential development (Woodwell 1970). Also, disturbance generally prevents optimum height development. Thus, with greater disturbances a simpler, shorter plant community

will develop. Roadside vegetation managers thus can select the community they desire by the amount of disturbance they inflict on the vegetation.

If a mass-sprayed roadside were treated with only spot spraying the vegetation very likely would develop into a forest (in east-central Iowa). Therefore woody plant control would have to be introduced. However, with such a limited vegetation management program the end result would be a considerably more diverse vegetation than that produced using mass-spraying techniques.

ROADSIDE SPOT SPRAYING TECHNIQUES

During the course of this study techniques evolved which may be useful in instituting a spot-spraying program. The following is a scenario of events through the season. Keep in mind that this work was done in east-central Iowa and would have to be modified for other geographic locations.

May 15-30. Spot spray dock and biennial thistle. Two hand-sprayer operators ride in a pick-up box while the vehicle is slowly driven down the right side of the road. On most secondary roads, dock and biennial thistle can be sprayed without leaving the vehicle. For dense stands of weeds or those out of range the vehicle is stopped and the operators walk to the weeds. In Franklin and adjacent townships in Linn County each crew averaged about 10-12 miles of roadway per day.

This crew also marks Canada thistle patches with flagging tape or more permanent markers and notes their location on a map.

May 20-30. Spray Canada thistle patches. A two man crew operates a pick-up mounted sprayer equipped with a hand boom and 50 feet of hose. The sprayer is operated at a low pressure of approximately 1.35 atmospheres (20 PSI). Using maps locating all thistle patches and with patches marked at the site we were able to spray all Canada thistle patches on 100 miles of roadway in 3½ to 4 days.

June. Follow-up operations of undetermined length to threat noxious weed targets missed on the first treatment, especially Canada thistle patches, dock and biennial thistles. Some biennial thistles are easily overlooked on the first treatment and may be treated into July. Manpower needs are much reduced but variable depending upon thoroughness of the initial treatments.

Marking and mapping Canada thistle patches at this time speeds up spraying operations the following year.

INTEGRATED ROADSIDE VEGETATION MANAGEMENT

Our observations on this research project indicate that several aspects of roadside vegetation management must be integrated to produce optimum results. The principle operations are noxious weed control, brush control and ditch cleaning.

In spot spray programs brush must be treated separately. Much of the time brush is simply cut but not killed. The use of a stump application of a brush killer would greatly increase the effectiveness of this procedure.

A most vulnerable site for weed establishment on roadsides is the bare soil left in ditch cleaning operations (figure 16). Most weeds are adapted to these conditions and many years pass before most desirable vegetation is in control (figure 17). Seeding of these sites should follow the cleaning as soon as possible. Seedbed preparation is necessary and favorable weather conditions must prevail if seeding is to be successful.

With this integrated program of roadside vegetation management, noxious weeds and woody vegetation are controlled without resorting to mass-spraying and sites where weeds could colonize are soon under the domination of desirable, perennial species.

Figure 16. Ditch cleaning operations leave bare soil exposed for invasion by weeds.

Figure 17. Weedy roadside resulting from ditch cleaning spoils being piled on the backslope.

CONCLUSIONS

Dock

Density of dock decreased more than 50% in three years when spot sprayed in May with 2,4-D. Control plots remained at original densities.

Wild parsnip

Spot spraying with 2,4-D gave nearly complete control for a two year period following spraying but populations returned to pretreatment levels the third year. Hand cutting of flowering plants had no significant effect upon density the succeeding year.

Canada thistle

Results indicate less than 5% of the roadside area in Franklin Township was infested with Canada thistle. Total area of infestation fluctuated during the study, while patches located increased. Results were inconclusive on incidence of new patch establishment. Density within patches was reduced 62% over three years when treated with Banvel or 2,4-D, while a control treated with the usual mass-spray increased 55%.

Native grass establishment

Satisfactory stands of native prairie grasses were established using a hydroseeder. Seedbed preparation appears to be necessary for establishment. No establishment was observed in overseeding into existing roadside vegetation.

Vegetation dynamics

Very little change was observed in vegetation subjected to mass-spraying procedures in three years of study. In non-sprayed plots there was significant increase in total cover and number of species per plot. Relative grass cover decreased while relative cover of annuals and perennial herbs increased. No significant change was observed in cover of woody vegetation. Clover, sweet clover and giant ragweed were identified as annuals increasing most in cover.

ACKNOWLEDGEMENTS

The authors wish to thank Miss Gayle Wallace for her fine work in the technical phases of this research project. We also wish to thank Mr. Steven Roberts and Mr. Harold Dolling of the Division of Highways, DOT; Mr. Bill Harrington, Linn County Engineer and members of his department as well as the Linn County Board of Supervisors for the many ways they have aided in this project.

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APPENDIX 1--Species encountered in vegetation dynamics sample plots.

Common Name	Scientific Name	Perennial (P) Annual (A)	Herbaceous (H) Woody (T)	Plant Community Type[1]	Control/Experimental	Number of Plots	% Absolute Cover 1971	% Absolute Cover 1973	Change in % Absolute Cover
Grasses									
squirrel-tail barley	Hordeum jubatum	A	H	W	E	1	0.06	0.05	-0.01
bluegrass	Poa spp.	P	H	R	C	8	75.73	83.94	+8.21
					E	50	57.20	76.89	+19.69
little bluestem	Andropogon scoparius	P	H	P	C	1	2.74	4.19	+1.46
					E	2	0.25	0.80	+0.55
bottle brush grass	Hystrix patula	P	H	M	E	1	0.0	0.08	+0.08
Japanese brome	Bromus japonicus	A	H	W	E	1	0.01	0.01	0.0
smooth brome	Bromus inermis	P	H	R	C	8	18.51	44.68	+26.17
					E	44	20.80	35.30	+14.50
crabgrass	Digitaria spp.	A	H	W	C	3	0.0	0.38	+0.38
					E	13	0.26	0.61	+0.35
tall dropseed	Sporobolus asper	P	H	P	E	16	4.52	10.53	+6.01
foxtail	Setaria spp.	A	H	W	C	2	3.86	6.50	+2.64
					E	6	0.15	0.07	-0.08
Muhley grass	Muhlenbergia racemosa	P	H	R	C	4	3.09	0.0	-3.09
					E	32	2.31	1.13	-1.18
oats	Avena sativa	A	H	W	C	1	0.0	0.01	+0.01
redtop	Agrostis alba	P	H	R	C	2	0.10	1.66	+1.56
					E	14	2.01	3.82	+1.81
reed canary grass	Phalaris arundinacea	P	H	R	E	3	0.15	2.02	+1.87
ryegrass	Lolium spp.	A	H	R	C	2	0.10	2.30	+2.20
					E	8	0.17	0.54	+0.37

[1]P = Prairie; R = Common roadside; W = Weedy; T = Woody; M = Miscellaneous

Common Name	Scientific Name	Perennial (P) Annual (A)	Herbaceous (H) Woody (T)	Plant Community Type[1]	Control/Experimental	Number of Plots	% Absolute Cover 1971	% Absolute Cover 1973	Change in % Absolute Cover
Virginia wild rye	Elymus virginicus	P	H	M	E	1	1.41	0.92	-0.49
wild rye	Elymus villosus	P	H	M	E	1	0.25	0.0	-0.25
timothy	Phleum pratense	P	H	R	C	5	2.43	4.71	+2.28
					E	25	1.90	2.00	+0.10
witch grass	Panicum capillare	A	H	W	C	5	0.03	0.18	+0.15
					E	27	1.82	0.95	-0.87
Non-grasses									
alfalfa	Medicago sativa	P	H	R	C	1	0.04	0.0	-0.04
					E	6	1.73	0.36	-1.37
Canada anemone	Anemone canadensis	P	H	P	E	2	1.04	1.16	+0.12
long head anemone	Anemone cylindrica	P	H	P	E	1	0.0	0.08	+0.08
white ash	Fraxinus americana	P	T	T	E	1	0.25	0.0	-0.25
asparagus	Asparagus officinalis	P	H	W	E	6	0.39	1.27	+0.88
arrow leaved aster	Aster sagittifolius	P	H	P	E		0.10	0.0	-0.10
white heath aster	Aster pilosus	P	H	P	C	3	0.11	0.60	+0.49
					E	22	1.21	2.74	+1.52
wild bean	Strophostyles helvola	P	H	M	E	1	0.04	0.16	+0.12
bedstraw	Galium spp.	P	H	P	E	3	0.49	1.23	+0.74
tall bellflower	Campanula americana	P	H	M	E	1	0.0	0.02	+0.02
bindweed	Convolvulus sepium	P	H	W	E	9	0.80	0.89	+0.09
black bindweed	Polygonum convolvulus	A	H	W	C	1	0.87	0.21	-0.66
					E	6	0.18	0.03	-0.15

Common Name	Scientific Name	Perennial (P) Annual (A)	Herbaceous (H) Woody (T)	Plant Community Type[1]	Control/Experimental	Number of Plots	% Absolute Cover 1971	% Absolute Cover 1973	Change in % Absolute Cover
black-eyed Susan	Rudbeckia hirta	A	H	P	E	4	0.46	0.84	+0.38
black medick	Medicago lupulina	A	H	W	C	1	0.65	3.64	+2.99
					E	8	0.81	1.26	+0.45
bloodroot	Sanguinaria canadensis	P	H	M	E	1	0.01	0.02	+0.01
blue-eyed grass	Sisyrinchium campestre	P	H	P	E	1	0.01	0.0	-0.01
bouncing bet	Saponaria officinalis	P	H	W	E	1	0.0	0.16	+0.16
box elder	Acer negundo	P	T	T	E	1	0.0	0.01	+0.01
campion	Lychnis alba	A	H	W	E	1	0.08	0.13	+0.05
carrion flower	Smilax herbacea	P	H	M	E	1	0.0	0.06	+0.06
eastern red cedar	Juniperus virginiana	P	T	T	E	1	0.01	0.01	0.0
black cherry	Prunus serotina	P	T	T	E	2	0.18	0.46	+0.28
cinquefoil	Potentilla spp.	P	H	W	C	1	0.0	0.08	-0.08
clematis	Clematis virginiana	P	H	M	E	1	0.0	0.03	+0.03
red clover	Trifolium pratense	A	H	R	E	22	0.86	3.00	+2.14
white clover	Trifolium repens	A	H	R	C	3	0.47	0.55	+0.08
					E	19	0.49	2.66	+2.17
white sweet clover	Melilotus alba	A	H	W	C	1	0.0	0.03	+0.03
					E	22	1.38	5.62	+4.24
yellow sweet clover	Melilotus officinalis	A	H	W	E	15	0.18	3.02	+2.84
yellow coneflower	Ratibida pinnata	P	H	P	E	1	0.01	0.48	+0.47
eastern cottonwood	Populus deltoides	P	T	T	C	1	0.01	0.0	-0.01
					E	1	0.23	0.0	-0.23

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Culver's root	Veronicastrum virginicum	P	H	P	E	1	0.01	0.11	+0.10
dandelion	Taraxacum officinale	P	H	W	C	5	0.81	0.33	-0.47
					E	37	0.89	1.53	+0.64
dock (smooth, sour)	Rumex spp.	P	H	W	E	4	0.10	0.02	-0.08
dogwood	Cornus spp.	P	T	T	E	1	0.01	0.0	-0.01
elderberry	Sambucus canadensis	P	T	T	E	2	0.02	0.19	+0.17
American elm	Ulmus americana	P	T	T	E	4	0.01	0.0	-0.01
daisy fleabane	Erigeron annuus	A	H	W	E	1	0.22	0.16	-0.06
daisy fleabane	Erigeron spp.	A	H	W	C	2	0.04	0.04	0.0
					E	11	0.40	0.25	-0.15
flower of an hour	Hibiscus trionum	A	H	H	E	1	0.01	0.0	-0.01
wild garlic	Allium canadense	P	H	P	E	1	0.16	0.10	-0.06
germander	Teucrium Canadense	P	H	P	E	1	0.08	0.84	+0.76
goat's beard	Tragopogon dubius	A	H	W	E	8	0.15	0.10	-0.05
Canada goldenrod	Solidago canadensis	P	H	P	C	1	0.75	1.49	+0.74
					E	25	1.75	3.52	+1.77
rigid goldenrod	Solidago rigida	P	H	P	E	6	0.13	1.60	+1.47
gooseberry	Ribes Missouriense	P	T	T	E	1	0.0	0.01	+0.01
wild grape	Vitis riparia	P	T	T	E	1	0.0	0.01	+0.01
ground cherry	Physalis spp.	P	H	P	E	18	0.12	0.98	+0.86
hemp	Cannabis sativa	A	H	W	C	1	0.40	0.08	-0.32
					E	4	0.19	0.09	-0.10

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mullein	Verbascum thapsus	A	H	W	E	4	0.04	0.13	+0.09
hedge mustard	Sisymbrium officinale	A	H	W	E	1	0.0	0.02	+0.02
black nightshade	Solanum nigrum	A	H	W	C	2	0.0	0.01	+0.01
					E	8	0.23	0.38	+0.15
white oak	Quercus alba	P	T	T	E	4	0.05	0.26	+0.21
wild parsnip	Pastinaca sativa	A	H	W	E	11	0.75	1.50	+0.75
partridge pea	Cassia fasciculata	A	H	P	E	5	1.16	2.81	+1.65
pellitory	Parietaria pensylvanica	A	H	W	C	3	0.19	0.05	-0.14
					E	24	0.63	0.05	-0.57
pepper grass	Lepidium virginicum	A	H	M	E	2	0.01	0.01	0.0
sand phlox	Phlox bifida	P	H	M	E	1	0.25	0.29	+0.04
Austrian pine	Pinus nigra	P	T	T	E	1	0.01	0.0	-0.01
plantain	Plantago Rugelii	P	H	W	C	3	0.0	0.30	+0.30
					E	9	0.05	0.09	+0.04
evening primrose	Oenothera biennis	A	H	P	E	2	0.02	0.12	+0.10
Queen Anne's lace	Daucus carota	A	H	W	E	1	0.11	0.36	+0.25
common ragweed	Ambrosia artemisiifolia	A	H	W	C	4	0.75	2.92	+2.17
					E	28	1.70	2.86	+1.16
giant ragweed	Ambrosia trifida	A	H	W	C	3	1.26	0.64	-0.63
					E	32	0.89	6.75	+5.86
ragwort	Senecio plattensis	P	H	P	C	1	0.0	0.01	+0.01
					E	11	0.53	2.82	+2.29

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honeysuckle	Lonicera spp.	P	T	T	E	1	0.01	0.0	-0.01
horse nettle	Solanum carolinense	P	H	W	E	4	0.03	0.26	+0.23
horsetail	Equisetum spp.	P	H	P	C	2	0.43	0.51	+0.08
					E	12	1.29	2.55	+1.27
horseweed	Conyza canadensis	A	H	W	C	1	0.57	0.21	-0.36
					E	7	0.30	0.13	-0.17
knotweed	Polygonum erectum	A	H	W	E	2	0.0	0.03	+0.03
lamb's quarters	Chenopodium album	A	H	W	C	1	0.76	0.0	-0.76
					E	5	0.01	0.0	-0.01
wild lettuce	Lactuca canadensis	A	H	P	C	6	1.07	0.17	-0.90
					E	39	1.44	1.54	+0.10
Turk's cap lily	Lilium michiganense	P	H	P	E	1	0.11	0.13	+0.02
honey locust	Gleditsia tricanthos	P	T	T	E	1	0.01	0.02	+0.01
wing angled loosestrife	Lythrum alatum	P	H	P	C	1	0.0	0.21	+0.21
					E	4	0.50	0.61	+0.11
sugar maple	Acer saccharum	P	T	T	E	3	1.92	1.97	+0.05
common milkweed	Asclepias syriaca	P	H	P	C	7	0.76	1.00	+0.24
					E	39	1.27	1.46	+0.19
swamp milkweed	Asclepias incarnata	P	H	P	E	1	0.0	0.05	+0.05
whorled milkweed	Asclepias verticillata	P	H	P	C	5	4.09	4.78	+0.69
					E	37	2.40	2.87	+0.47
motherwort	Leonurus cardiaca	P	H	W	E	1	0.04	0.01	-0.03
mulberry	Morus alba	P	T	T	E	5	0.49	0.44	-0.05

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black raspberry	Rubus spp.	P	T	T	E	1	0.0	0.08	+0.08
wild rose	Rosa spp.	P	T	T	E	5	0.36	0.55	+0.19
rush	Juncus spp.	P	H	R	E	1	0.0	0.01	+0.01
sedge	Carex spp.	P	H	R	C	2	0.47	0.43	-0.04
					E	23	1.75	2.25	+0.50
self-heal	Prunella vulgaris	P	H	M	E	4	0.12	0.21	+0.09
smartweed	Polygonum hydropiper	A	H	W	C	1	0.0	0.25	+0.25
					E	5	0.24	0.30	+0.06
Soloman's seal	Polygonatum Biflorum	P	H	M	E	5	0.44	0.68	+0.24
red sorrel	Rumex acetosella	A	H	W	E	2	0.02	0.15	+0.13
spiderwort	Tradescantia ohiensis	P	H	P	E	5	0.25	0.57	+0.32
wild strawberry	Fragaria virginiana	P	H	P	E	2	0.83	1.30	+0.47
sunflower	Helianthus grosseserratus	P	H	P	E	2	0.0	0.01	+0.01
biennial thistles									
field thistle	Cirsium discolor	A	H	W	C	3	0.0	0.17	+0.17
					E	23	0.67	0.51	-0.16
bull thistle	Cirsium vulgare	A	H	W	C	1	0.0	0.25	+0.25
					E	3	0.01	0.08	+0.07
sow thistle	Sonchus spp.	A	H	W	E	1	0.0	0.22	+0.22
velvet leaf	Abutilon theophrasti	A	H	W	E	5	0.09	0.0	-0.09
Venus' looking glass	Triodanis perfoliata	A	H	M	E	4	0.08	0.01	-0.07
blue vervain	Verbena hastata	P	H	P	E	8	0.82	0.38	-0.44

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milk vetch	Astragalus canadensis	P	H	P	E	1	0.34	0.38	+0.04
violet	Viola spp.	P	H	P	C	6	0.91	1.91	+1.00
					E	35	1.41	2.34	+0.93
Virginia creeper	Parthenocissus quinquefolia	P	W	T	E	2	0.04	0.01	-0.03
black walnut	Juglans nigra	P	T	T	E	1	0.02	0.01	-0.01
wood-sorrel	Oxalis stricta	P	H	W	C	3	0.08	0.36	+0.28
					E	32	0.54	1.99	+1.45
woundwort	Stachys palustris	P	H	P	E	2	0.61	0.99	+0.38
yarrow	Achillea millefolium	P	H	P	E	6	0.10	0.29	+0.19
Totals					C	9	122.1	168.4	+46.3
					E	50	133.5	212.8	+79.3

APPENDIX 2--Additional species mentioned in the report text.

Common Name	Scientific Name
Grasses	
big bluestem	Andropogon gerardi
little bluestem	Andropogon scoparius
green foxtail	Setaria viridis
yellow foxtail	Setaria leutescens
side-oats grama	Bouteloua curtipendula
barnyard grass	Echinacloa muricata
indian grass	Sorghastrum nutans
stinkgrass	Eragrostis cilianensis
switch grass	Panicum virgatum
Canada wildrye	Elymus canadensis
Non-grasses	
purple prairie clover	Petalostemon purpureum
white prairie clover	Petalostemon candinum
horsetail	Equisetum arvense
kochia	Kochia scoparia
scouring rush	Equisetum laevigatum
thimbleweed	Ratibida columnifera
Canada thistle	Cirsium arvense