Report Number 94-32

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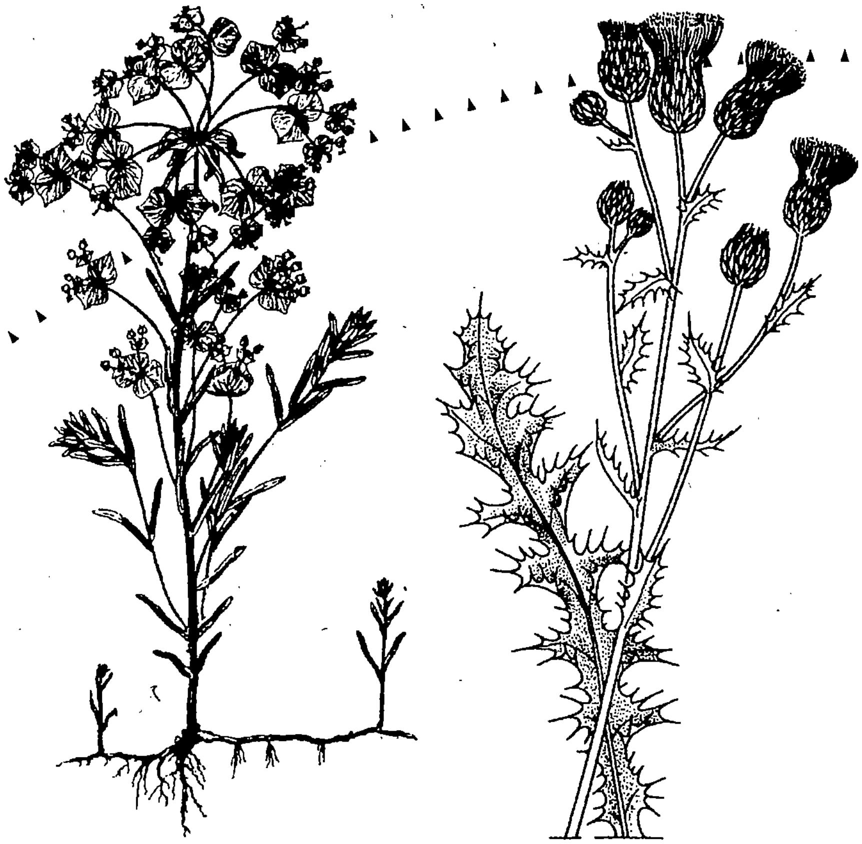

Controlling Leafy Spurge and Canada Thistle by Competitive Species

MINNESOTA DEPARTMENT OF TRANSPORTATION

ACKNOWLEDGEMENT

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32650620 c.1

Technical Report Documentation Page

1. Report No. MN/RC-94/32	2.	3. Recipient's Accession No.
4. Title and Subtitle Controlling Leafy Spurge and Canada Thistle by Competitive Species		5. Report Date June, 1994
		6.
7. Author(s) David D. Biesboer, Bettina Darveaux, and Willard L. Koukkari		8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Plant Biology, University of Minnesota, 220 Biological Sciences Center, 1445 Gortner Avenue, St. Paul, Minnesota 55108		10. Project/Task/Work Unit No.
		11. Contract(C) or Grant(G) No. (C) Mn/DOT 67375 TOC #56 (G)
12. Sponsoring Organization Name and Address Minnesota Department of Transportation, Office of Research Administration, 117 University Avenue, M.S. 330, St.Paul Minnesota, 55155		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract (Limit: 200 words)

A study was performed to assess the use of perennial native grasses in the control of leafy spurge and Canada thistle and also to evaluate the effects of herbicides applied during the fall to leafy spurge crown buds. As part of an integrated vegetation management program, grass treatments containing the native prairie grass little bluestem established well and were effective at reducing the cover of leafy spurge. Paramount to the success of using native grass species is getting adequate grass establishment which necessitates the careful selection of grass species adapted to the specific site conditions. A fall application of the herbicide picloram at 0.5 and 1.0 lb ai/acre was very effective at controlling leafy spurge and may be mediated via the direct absorption of picloram by the elongated crown buds at this time. The report contains an extensive literature review of the biology and weed control efforts of both leafy spurge and Canada thistle.

17. Document Analysis a. Descriptors: Leafy Spurge, Euphorbia Esula, Canada Thistle, Cirsium Arvense, Weed Control, Picloram, Glyphosate, Crown Buds, Prairie Grasses, Integrated Vegetation Management		18. Availability Statement No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161.	
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 90	22. Price

CONTROLLING LEAFY SPURGE AND CANADA THISTLE BY COMPETITIVE SPECIES

Final Report

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Acknowledgments

We are indebted to the following people for all of their help and support in our research project. We wish to thank Paul Ramquist for his field and laboratory assistance in several of the leafy spurge bud experiments as well as for his sense of humor which helped make the menial tasks more bearable. We are grateful to Jennifer Nelson, Julie Thompson, Michele Irwin, and Alyson Loos for their assistance in the crown bud elongation of herbicide treated crown buds experiment, and to Kevin Betts for his help in the combustion of the ^{14}C labelled buds. We would like to thank Carrol Evans, Mr. Hitchcock, and the Mn/DOT maintenance crews located at Owatonna and Forest Lake for all their help and cooperation in disking the field sites, mowing, and burning the field plots. We also would like to thank Mary Mitchell at the Minnesota Valley National Wildlife Refuge for permission to conduct experiments on the refuge property, for coordinating the disking and mowing, and for conducting the burning of our plots. We are grateful to Leo Holm for all of his helpful suggestions and ideas in the designing of the field experiments as well as in the reviewing of the final report. Finally, we would like to thank Roger Gast from DowElanco for supplying us with the ^{14}C labelled picloram and the Local Road Research Board for financial support of the project.

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Executive Summary

One purpose of the study was to evaluate the interfering ability of several perennial grasses with leafy spurge (*Euphorbia esula* L.) and Canada thistle (*Cirsium arvense* (L.) Scop.) using an integrated vegetation management approach. Grass interference was evaluated in the laboratory and in the field in southeastern Minnesota. Laboratory experiments consisted of grass and leafy spurge or Canada thistle seedlings grown together in pots. The effects of the grasses on root and shoot biomass of both leafy spurge and Canada thistle were determined. Of the five grass species tested, only the two cool-season grasses, Canada wildrye (*Elymus canadensis* L.) and smooth brome (*Bromus inermis* Leyss.), established well under the greenhouse growing conditions and significantly reduced the root biomass of both Canada thistle and leafy spurge. Field experiments were located in either leafy spurge or Canada thistle infested areas and consisted of plots seeded with various perennial grasses as monocultures and in combinations. Several management techniques, such as burning, mowing, fertilizing, and herbicide spraying, were used to promote grass establishment and reduce leafy spurge and Canada thistle. The effects of both the grass and herbicide treatments on the above-ground percent cover of leafy spurge or Canada thistle were evaluated. Results from the field experiments indicate a negative correlation between degree of grass establishment and leafy spurge cover. Three grass treatments, little bluestem (*Schizachyrium scoparium* (Michx.) Nash), little bluestem + side-oats grama (*Bouteloua curtipendula* (Michx.) Torr.), and little bluestem + side-oats grama + buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.) established well and significantly reduced the cover of leafy spurge. The effects of the grasses could not be evaluated for Canada thistle in the field experiments due to poor grass establishment. The herbicide treatments picloram at 1.0 lb/acre and imazethapyr at 0.25 lb/acre both were very effective in controlling leafy spurge but only for about one year. For preparation of the site prior to seeding the grasses, glyphosate at 1.4 lbs ai/acre followed by disking was very effective at reducing leafy spurge cover prior to grass establishment.

A second purpose of the present study was to investigate the effects of a late season application of the herbicides picloram and glyphosate on the vegetative crown buds of leafy spurge. The phenology of leafy spurge crown buds was also studied to determine when the crown buds would potentially be most vulnerable to a herbicide application. Crown bud growth was found to be a gradual process beginning shortly after flowering in mid-June and obtaining maximum size during senescence in October. Both picloram (1.0 lb ai/acre) and glyphosate (1.0 lb ai/acre) applied to senescing leafy spurge in the field in October significantly inhibited shoot expansion when grown under favorable conditions in the laboratory. Picloram applied directly to crown buds of fall collected leafy spurge crowns significantly inhibited bud growth. An

experiment using ^{14}C-picloram applied directly to crown buds at a rate approximating a field application of 0.5 lb ai/acre, indicated that picloram could be directly absorbed by the buds and inhibit bud elongation. Although glyphosate applied directly to crown buds did not significantly reduce bud elongation, the data does suggest that some glyphosate absorption had occurred. The long term effects of a fall application of picloram at 0.5 and 1.0 lb ai/acre resulted in significant reductions in leafy spurge above-ground cover in the two years following treatment. Glyphosate applied in the fall at 1.0 lb ai/acre resulted in a significant increase in leafy spurge above-ground cover by the following summer. Burning in the spring subsequent to the fall herbicide applications did not increase leafy spurge control. A late season application of picloram is thus more effective than glyphosate at controlling leafy spurge due to its ability to persist in soil and directly target the crown buds.

Based on the findings of the present study, the use of native prairie grasses as part of an integrated vegetation management program is a feasible approach to the control of leafy spurge and Canada thistle along Minnesota roadside right-of-ways. The use of native prairie grasses would also provide many other benefits in addition to weed control. The choice of native grass species to use would depend on the specific conditions present at each site. Herbicides would still be needed but at reduced rates. The herbicide picloram applied in the fall at 0.5 and 1.0 lb ai/acre was very effective at targeting leafy spurge crown buds and providing long-term control.

Introduction

Leafy spurge and Canada thistle are noxious deep-rooted perennial weeds that require control along highway right-of-ways. Traditional management of these weeds has relied heavily upon the usage of high rates of herbicides which are costly, environmentally unfriendly, and represent only a short term solution to the problem. A new long term approach to weed control is that of integrated vegetation management which uses combinations of weed control methods applied at the most appropriate times and in the most appropriate ways to maximize injury to the weeds and encourage the growth of the desireable species. An integrated vegetation management approach thus requires a thorough understanding of the biology and ecology of the weed so that weed control practices can be applied most efficiently.

The Minnesota Department of Transportation (Mn/DOT) has recently begun seeding natives species in the roadside rights-of-way because introduced species, such as brome and Kentucky bluegrass which had been planted extensively along the roadsides, deteriorate over time and allow the establishment of weeds. The use of native vegetation along roadsides has many advantages, one of which is the potential to better compete with the invading weeds. One of the main purposes of the present study was to evaluate the ability of several native prairie grasses to compete with leafy spurge and Canada thistle (Chapter 2). A second purpose was to determine how to best target the vegetative buds of leafy spurge in our control practices (Chapter 3). Lastly, the third purpose of the study was to make recommendations to Mn/DOT in their management of leafy spurge and Canada thistle infestations along roadside rights-of-way. (Chapter 4).

Chapter 1. Introduction

Leafy Spurge

Leafy spurge (*Euphorbia esula* L.) is a deep-rooted perennial weed which has become a serious problem in the Great Plains region of the United States and Canada (Pemberton 1985). In North America, leafy spurge is actually a complex of forms, species, and hybrids (Pemberton 1985, Dunn and Radcliffe-Smith 1980), the taxonomy of which is still unresolved. Leafy spurge has likely been introduced many times into North America from different regions of its native range in Eurasia (Best *et al.* 1980, Dunn and Radcliffe-Smith 1980). As early as 1827, leafy spurge was present in Massachusetts (Britton 1921). Most likely leafy spurge was introduced to North America as contaminants in ship ballast brought from Eurasia (Galitz 1980). It is thought that leafy spurge was introduced into southwestern Minnesota as a contaminant in oats brought from southern Russia in 1890 (Batho 1932 as cited in Bakke 1936). Although leafy spurge is adapted to a wide range of conditions, it is most commonly found and more vigorous in soils of coarse texture (Selleck *et al.* 1962). It occurs most often in grasslands and waste areas at sites which are not subject to frequent cultivation (Morrow 1979).

Leafy spurge reproduces both by seed and vegetatively. Like other members of Euphorbiaceae, the unisexual flowers are born in a cup-like structure called a cyathium (Raju 1985). The cyathia are arranged in terminal umbellate inflorescences on the shoot (Raju 1985). Insects are the principal pollinating agents (Bakke 1936, Selleck *et al.* 1962). The mature capsules, each containing three seeds, dehisces explosively disseminating the seeds as much as 15 feet away from the plant (Bakke 1936). Average seed yield has been found to be as high as 252 seeds per shoot (Selleck *et al.* 1962). The seeds can float on water and germinate readily (Bakke 1936). Leafy spurge reproduces vegetatively by buds located on the vertical underground portion of the shoot (the crown) and on the roots. Leafy spurge thus occurs in patches which can coalesce to form large stands (Pemberton 1985). The expansion of a patch is mostly the result of lateral long roots spreading out from the parent plant (Best *et al.* 1980). The perimeter of a patch usually extends from 2 to 3 ft in all directions in one season, although extensions greater than this have been documented (Selleck *et al.* 1962). The root system is very deep and extensive (Bakke 1936, Coupland and Alex 1954). Roots containing vegetative buds are predominantly present near the soil surface but can be found at much greater depths (Coupland and Alex 1955). Upon disturbance, root fragments from considerable depths have the capacity to initiate new buds and subseqently produce shoots (Raju *et al.* 1964).

The persistance of leafy spurge can be attributed to its deep and extensive root system which has an unlimited ability for regeneration; the presence of cork on the roots which forms a protective covering that resists drying (Bakashi and Coupland 1959); an efficient starch storage system in the roots (Bakke 1936, Bakshi and Coupland 1959, Dunn 1979); few natural enemies (Dunn 1979); and, a large long-lived soil seed bank present for reestablishment (Bowes and Thomas 1978).

Canada Thistle

Canada thistle (*Cirsium arvense* (L.) Scop.) is a naturalized perennial weed found throughout the northern half of the United States (Hodgson 1968), most commonly in agricultural areas (Moore 1975). Canada thistle probably was originally native to southeastern Europe and the eastern Mediterranean area but now occurs throughout Europe, North Africa, Asia Minor, across central Asia to Japan, South Africa, New Zealand, southeastern Australia, Canada, and the United States (Moore 1975). It most likely was introduced into North America as an impurity in crop seeds from Europe during the 17th century (Hodgson 1968, Moore 1975).

Canada thistle is found in open mesophytic areas in a wide variety of soils (Moore 1975). It can survive in dry habitats but does not do well in very wet soils (Moore 1975). The roots grow down to penetrate saturated soil so that the ultimate root length attained is determined by the depth of the water table (Hayden 1934). Seedlings require high levels of light for establishment thereby being successful only in disturbed soils where competition is limited (Hodgson 1968). Good light intensity is also required for flower production (Moore 1975).

Canada thistle reproduces vegetatively by an extensive underground root system and also sexually from seed. Canada thistle typically occurs in patches of genetically identical plants (Hodgson 1968). The radial growth of a patch can be rapid if competition is at a minimum (Hoefer 1981). Although the florets are perfect, Canada thistle is functionally dioecious (Hayden 1934). Staminate and pistillate patches must be within close proximity of each other for large quantities of seed to be produced (Hayden 1934, Hodgson 1968). Insects are the primary means of pollination (Derscheid and Schultz 1960). The plumose achene is dispersed by wind (Hayden 1934).

The persistance of Canada thistle despite great control efforts is largely due to its vigorous, horizontally spreading root system which can readily regenerate new shoots from adventitious buds located at any position along the roots (McAllister and Haderlie 1981). Adventitious root buds have the potential to produce new shoots at any time of the year after removal of the existing above-ground shoots (McAllister and Haderlie 1981). Fragments of Canada thistle roots only 10 mm long, even without the presence of visible buds, were able to produce shoots (Hamdoun 1972). Also, aerial and subterranean stem fragments left by tillage could form roots and produce new thistle infestations (Magnusson *et al.* 1987).

Long-term control of both leafy spurge and Canada thistle has been extremely difficult to achieve. In a limited number of situations, herbicides have been effective, but only for short durations. Herbicides are expensive and their use has become more restrictive, especially since they may contaminate ground water, persist in the soil, and must be applied continually to achieve even moderate control. A new approach to weed control practices, that of integrated vegetation management, shows great promise in managing populations of leafy spurge and Canada thistle.

Integrated Vegetation Management

Integrated vegetion management involves the use of combinations of weed control methods applied at the most appropriate times and in the most appropriate ways to maximize injury to the weed and promote the growth of the desireable species. Weed control methods presently available today include cultural (interfering plant species), physical (tilling, mowing, and burning), chemical (herbicides and fertilizing), and biological control (insects, pathogens, and grazing). The use of more than one method in the control of leafy spurge or Canada thistle at a particular site is not a new practice (e.g., see Derscheid *et al.* 1961, Derscheid *et al.* 1963, Hodgson 1958, and 1968, Selleck *et al.* 1962, and Thrasher *et al.* 1963). New management tools, such as biocontrol with insects and pathogens, are being developed and some are presently available for incorporation into an integrated weed control programs (Lym 1992). It is most important to apply the control method(s) such that the target plant is stressed but the desirable plant species are not injured and thus allowed to interfere with the weed (Beck 1992). As pointed out by Beck (1992) in the case of herbicide use, no single herbicide is ideally suited to use in every habitat for weed control. Herbicide use should be integrated into a management system where herbicide choice, rate, application timing, and frequency of application are tailored to the environmental situation (Beck 1992). This point should be extended to include any combination of weed control methods. In order to fine tune weed control practices to specific sites, basic information about the biology and ecology of the weeds as well as the desireable species are needed. This basic research could lead to the development of new weed control practices and to the improvement of already existing practices (Wyse 1991).

Objectives

The purposes of the present study were to: (1) evaluate the interfering ability of several perennial grasses established within leafy spurge and Canada thistle infestations along with an integration of additional vegetation management tools; (2) to investigate the effects of fall applied herbicides to the below-ground portions of leafy spurge; and (3) to make recommendations to the Minnesota Department of Transportation in their management of leafy spurge and Canada thistle infestations along roadside right-of-ways. This study included the following objectives:

(1) To determine which management practices are beneficial to the establishment of desirable perennial grasses within leafy spurge and Canada thistle infestations in Minnesota;
(2) To determine which combinations of perennial grass specie(s) will reduce cover of leafy spurge in Minnesota;
(3) To determine which combinations of perennial grass specie(s) will reduce cover of Canada thistle in Minnesota;
(4) To determine which herbicide(s) can effectively reduce leafy spurge and Canada thistle cover without being detrimental to the desirable perennial grasses;
(5) To determine when leafy spurge crown buds are most actively elongating so that weed control practices can be applied at the time when injury to these perennating organs is maximized;
(6) To evaluate the effects of a late season herbicide application of picloram and glyphosate on the elongation of leafy spurge crown buds;
(7) To determine if the herbicides picloram and glyphosate can be directly absorbed by leafy spurge crown buds and subsequently affect their elongation; and,
(8) To evaluate the long-term effects of a late season herbicide application of picloram and glyphosate followed by a spring burn on leafy spurge above-ground cover.

Literature Cited

Bakke, A.L. 1936. Leafy spurge, *Euphorbia Esula* L. Iowa Agric. Exp. Sta. Res. Bull. **198**:208-246.

Bakshi, T.S. and R.T. Coupland. 1959. An anatomical study of the subterranean organs of Euphorbia esula in relation to its control. Can. J. Bot. **37**:613-619.

Beck, K.G. 1992. Chemical control of leafy spurge - A summary. *In* Great Plains Agricultural Council Publication No. 144. Proceedings of the 1992 Leafy Spurge Symposium, Lincoln, Nebraska. pp 4-15 - 4-21.

Best, K.F., G.G. Bowes, A.G. Thomas, and M.G. Maw. 1980. The biology of Canadian weeds. 39 *Euphorbia esula* L. Can. J. Plant Sci. **60**:651-663.

Bowes, G.G. and A.G. Thomas. 1978. Longevity of leafy spurge seeds in the soil following various control programs. J. Range Manag. **31(2)**:137-140.

Britton, N.L. 1921. The leafy spurge becoming a pest. J. NY Botanical Garden **22**:73-75.

Coupland, R.T. and J.F. Alex. 1954. Distribution of the underground parts of leafy spurge (*Euphorbia esula* L.). Can. J. of Agric. Sci. **34**:161-176.

Derscheid, L.A. and R.E. Schultz. 1960. Achene development of Canada thistle and perennial sowthistle. Weeds **8**:55-62.

Derscheid, L.A., R.L. Nash, and G.A. Wicks. 1961. Thistle control with cultivation, cropping and chemicals. Weeds **9**:90-102.

Derscheid, L.A., G.A. Wicks, W.H. Wallace. 1963. Cropping, cultivation, and herbicides to eliminate leafy spurge and prevent reinfestation. Weeds **11**:105-111.

Dunn, P.H. 1979. The distribution of leafy spurge (*Euphorbia esula*) and other weedy *Euphorbia* spp. in the United States. Weed Sci. **27(5)**:509-516.

Dunn, P.H. and A. Radcliffe-Smith. 1980. The variability of leafy spurge (*Euphorbia* spp.) in the United States. North Central Weed Conference Research Reports **37**:48-53.

Galitz, D.S. 1980. A summary of the synonomy of leafy spurge. *In* North Dakota Research Report No. 77. Agric. Exp. Sta., ND State Univ., Fargo, ND. pp 1-6.

Hamdoun, A.M. 1972. Regenerative capacity of root fragments of *Cirsium arvense* (L.) Scop. Weed Res. **12**:128-136.

Hayden, A. 1934. Distribution and reproduction of Canada thistle in Iowa. Amer. J. Bot. **21**:355-373.

Hodgson, J.M. 1958. Canada thistle (*Cirsium arvense* Scop.) control with cultivation, cropping, and chemical sprays. Weeds **6(1)**:1-11.

Hodgson, J.M. 1968. The nature, ecology, and control of Canada thistle. USDA Tech. Bull. No. 1386.

Hoefer, R.H. 1981. Growth and Development of Canada thistle. North Central Weed Control Conference Proceedings **36**:153-157.

Lym, R.G. 1992. An integrated approach to leafy spurge control: Magic, myth, or mess? *In* Great Plains Agricultural Council Publication No. 144. Proceedings of the 1992 Leafy Spurge Symposium, Lincoln, Nebraska. pp 4-35 - 4-36.

Magnusson, M.U., D.L. Wyse, and J.M. Spitzmueller. 1987. Canada thistle (*Cirsium arvense*) propagation from stem sections. Weed Sci. **35**:637-639.

McAllister, R.S. and L.C. Haderlie. 1981. Canada thistle root antomy and root bud dormancy. North Central Weed Control Conference Proceedings **36**:157-160.

Moore, R.J. 1975. The biology of Canadian weeds. 13. *Cirsium arvense* (L.) Scop. Can. J. Plant Sci. **55**:1033-1048.

Morrow, L.A. 1979. Studies on the reproductive biology of leafy spurge (*Euphorbia esula*). Weed Sci. **27(1)**:106-109.

Pemberton, R.W. 1985. Native plant considerations in the biological control of leafy spurge. *In* Proc. VI Int. Symp. Biol. Contr. Weeds, August 19-25, 1984, Vancouver, Canada. E.S. Delfosse (ed.). Agric. Can. pp. 365-390.

Raju, M.V.S. 1985. Morphology and anatomy of leafy spurge. *In* A.K. Watson (ed.), Leafy spurge monograph series No. 3. Weed Sci. Soc. Am., Champaign, Il. pp. 26-41.

Raju, M.V.S., T.A. Steeves, and R.T. Coupland. 1964. On the regeneration of root fragments of leafy spurge (*Euphorbia esula* L.). Weed Res. **4**:2-11.

Selleck, G.W., R.T. Coupland, and C. Frankton. 1962. Leafy spurge in Saskatchewan. Ecol. Monogr. **32**:1-29.

Thrasher, F.P., C.S. Cooper, and J.M. Hodgson. 1963. Competition of forage species with Canada thistle as effected by irrigation and nitrogen levels. Weeds **11(2)**:136-138.

Wyse, D.L. 1991. The future of perennial weed control. *In* Great Plains Agricultural Council Publication No. 136 Proceedings of the 1991 Leafy Spurge Symposium, Minneapolis. p. 9.

Chapter 2. Controlling Leafy Spurge and Canada Thistle with Competitive Species and Combined Management Practices.

Abstract

The interfering ability of several perennial grasses were evaluated in the laboratory and in the field as part of an integrated vegetation management program designed to control infestations of leafy spurge (*Euphorbia esula* L.) and Canada thistle (*Cirsium arvense* (L.) Scop.). Laboratory experiments consisted of grass and leafy spurge or Canada thistle seedlings grown together in pots. The effects of the grasses on the root and shoot dry weights of both leafy spurge and Canada thistle were determined. Of the five grass species tested, only the two cool-season grasses, Canada wildrye (*Elymus canadensis* L.) and smooth brome (*Bromus inermis* Leyss.), established well under the greenhouse growing conditions and significantly reduced the root dry weights of both Canada thistle and leafy spurge. Field experiments were located in either leafy spurge or Canada thistle infested areas and consisted of plots seeded with various perennial grasses as monocultures and in combinations. Several management techniques, such as burning, mowing, fertilizing, and herbicide spraying, were used to promote grass establishment and reduce leafy spurge and Canada thistle. The effects of both the grass and herbicide treatments on the above-ground percent cover of leafy spurge or Canada thistle were evaluated. Results from the field experiments indicate a negative correlation between degree of grass establishment and leafy spurge cover. Three grass treatments, little bluestem [*Schizachyrium scoparium* (Michx.) Nash], little bluestem + side-oats grama [*Bouteloua curtipendula* (Michx.) Torr.], and little bluestem + side-oats grama + buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.] established well and significantly reduced the cover of leafy spurge. The effects of the grasses could not be evaluated for Canada thistle in the field experiments due to poor grass establishment. The herbicide treatments picloram at 1.0 lb ai/acre and imazethapyr at 0.25 lb/acre were very effective in controlling leafy spurge but only for about one year. For preparation of the site prior to seeding the grasses, glyphosate at 1.4 lbs ai/acre followed by disking was very effective at reducing leafy spurge cover during grass establishment.

Introduction

Plant interference can be broadly defined as the total influence of one plant upon another. This interference can be mediated via the removal of one or more limiting resources such as