



A weed education program, and the biology and control of spotted knapweed (*Centaurea maculosa* Lam.) in Montana
by Celestine Ann Lacey

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Agronomy
Montana State University
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Abstract:

Leafy Spurge (*Euphorbia esula* L.) and spotted knapweed (*Centaurea maculosa* Lam.) are introduced perennial weeds infesting over 1.1 million hectares of range and pastureland in Montana. In an effort to stop the spread of these weeds, a statewide weed education program was expanded in 1983; and research was initiated on the biology and control of spotted knapweed in Montana.

The educational program utilized newsletters, demonstration plots, field tours, and a ransom program to increase awareness and disseminate information on leafy spurge and spotted knapweed. Herbicide demonstration plots and field tours provided information on weed identification, control, and sprayer calibration. A ransom program was initiated in Sweetgrass County, Montana in 1984. The program led to increased public awareness and control of existing spotted knapweed infestations. The effectiveness of the weed education program was evaluated by surveying landowners in four counties. Results of the survey indicated that landowners attending tours were more aware of the weed problem than those that did not attend tours. The number of landowners utilizing weed control practices was also greater among tour participants.

The effect of low rates of picloram (4-amino-3,5,6-tri-chloropicolinic acid) and picloram in combination with 2,4-D ((2,4-dichlorophenoxy)acetic acid) on controlling spotted knapweed was evaluated at two locations in Montana. All rates of picloram significantly reduced spotted knapweed density compared to the control. The persistence of picloram in the soil determines the length of control of spotted knapweed. The reduction of spotted knapweed density resulted in forage increases of 200 to 770 percent.

Differential tolerance to 2,4-D was observed in spotted knapweed in field experiments conducted at two locations in Montana. When plants from both locations were grown under identical conditions in the field, there was no difference in response to 2,4-D. Laboratory studies indicate that uptake and translocation of ¹⁴C 2,4-D was the same in both strains of spotted knapweed. The observed tolerance to 2,4-D in the initial field studies appears to be the result of differences in plant vigor.

The longevity of viability of spotted knapweed seed in the soil was studied from 1982 through 1984. Results of the seed burial study showed that less than 50 percent of the seed had germinated two years after burial. In field studies, about 65 seed per 0.5 m² remained viable in soil 26 months after seed production was stopped.

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IN MONTANA

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Celestine Ann Lacey

A thesis submitted in partial fulfillment
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APPROVAL

of a thesis submitted by

Celestine Ann Lacey

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Leafy Spurge (Euphorbia esula L.) and spotted knapweed (Centaurea maculosa Lam.) are introduced perennial weeds infesting over 1.1 million hectares of range and pastureland in Montana. In an effort to stop the spread of these weeds, a statewide weed education program was expanded in 1983; and research was initiated on the biology and control of spotted knapweed in Montana.

The educational program utilized newsletters, demonstration plots, field tours, and a ransom program to increase awareness and disseminate information on leafy spurge and spotted knapweed. Herbicide demonstration plots and field tours provided information on weed identification, control, and sprayer calibration. A ransom program was initiated in Sweetgrass County, Montana in 1984. The program led to increased public awareness and control of existing spotted knapweed infestations. The effectiveness of the weed education program was evaluated by surveying landowners in four counties. Results of the survey indicated that landowners attending tours were more aware of the weed problem than those that did not attend tours. The number of landowners utilizing weed control practices was also greater among tour participants.

The effect of low rates of picloram (4-amino-3,5,6-trichloropicolinic acid) and picloram in combination with 2,4-D ((2,4-dichlorophenoxy)acetic acid) on controlling spotted knapweed was evaluated at two locations in Montana. All rates of picloram significantly reduced spotted knapweed density compared to the control. The persistence of picloram in the soil determines the length of control of spotted knapweed. The reduction of spotted knapweed density resulted in forage increases of 200 to 770 percent.

Differential tolerance to 2,4-D was observed in spotted knapweed in field experiments conducted at two locations in Montana. When plants from both locations were grown under identical conditions in the field, there was no difference in response to 2,4-D. Laboratory studies indicate that uptake and translocation of ^{14}C 2,4-D was the same in both strains of spotted knapweed. The observed tolerance to 2,4-D in the initial field studies appears to be the result of differences in plant vigor.

The longevity of viability of spotted knapweed seed in the soil was studied from 1982 through 1984. Results of the seed burial study showed that less than 50 percent of the seed had germinated two years after burial. In field studies, about 65 seed per 0.5 m² remained viable in soil 26 months after seed production was stopped.

PREFACE

Weeds are becoming a major threat to the productivity of rangeland in Montana. The two most troublesome weeds include leafy spurge (Euphorbia esula L.) and spotted knapweed (Centaurea maculosa Lam.).

Both weeds have a major impact on cattle carrying capacity of rangeland. Leafy spurge and spotted knapweed reduce the carrying capacity by up to 75 and 90 percent respectively (Alley et al., 1984; Chicoine, 1984). The cost to the cattle industry in Montana is approximately \$5.9 million in lost forage production (French and Lacey, 1983; Reilly and Kaufman, 1979).

The following thesis examines the use of an educational and research program on leafy spurge and spotted knapweed. The major emphasis of the thesis work included:

(1) A public education program was expanded in 1983 in an effort to increase awareness and control of leafy spurge and spotted knapweed. The effectiveness of the program was evaluated.

(2) Chemical control of spotted knapweed with 2,4-D and picloram was evaluated in an effort to determine the optimum herbicide rate necessary to control spotted knapweed.

(3) The longevity of viability of spotted knapweed seed in soil has not been determined. Studies were continued to determine the length of time spotted knapweed seeds remain viable in soil under natural and buried conditions.

PART 1

THE LEAFY SPURGE AND SPOTTED KNAPWEED
PUBLIC EDUCATION PROGRAM

CHAPTER 1

LITERATURE REVIEW

Introduction

Leafy spurge (Euphorbia esula L.) and spotted knapweed (Centaurea maculosa) are the two most troublesome range weeds in Montana. Leafy spurge currently infests over 221,632 ha of rangeland in the state (Noble et al., 1979) and can reduce cattle carrying capacity 50 to 75 percent (Alley et al., 1984). The extensive root system and vegetative buds of leafy spurge make it difficult to eradicate by chemical, cultural or mechanical means (Dunn, 1979; McIntyre, 1972).

Spotted knapweed currently occupies about 890,000 ha of rangeland in Montana (Harris and Cranston, 1979), and an additional 13.8 million ha are susceptible to spotted knapweed invasion (Bucher, 1984). The weed reduces carrying capacity by as much as 90 percent on severely infested sites and can spread rapidly because it contains an allelopathic chemical which inhibits the growth of competing plant species (Fletcher and Renney, 1963).

Factors which lead to an increase of weeds on range land are: 1) the inability of ranchers to correctly identify noxious weeds and 2) ignorance of the potential threat the invading plants pose to livestock production (Barreto and Fay, 1983). In addition, many ranchers in Montana do not have experience with herbicide application. The key to controlling both leafy spurge and spotted knapweed is to educate

landowners to the importance of early detection of invasion and subsequent treatment.

Extension Techniques

Effective educational programs help bridge the gap between agricultural producers and research results (Myren, 1964; Bradfield, 1966). The information presented must meet the needs and interests of all classes of producers from innovators to late adopters and laggards (Bohlen et al., 1962).

Audio -Visual Techniques

Mass media techniques, such as radio and television, are useful for reaching large numbers of people about agricultural concerns (Dale, 1954; Kelsey and Hearne, 1963; Awa and Van Crowder Jr., 1978). These techniques are suited to increasing overall public awareness of agriculture (Coleman et al., 1962), as well as providing specific information to agricultural producers (Brown and Collins, 1978; Rockwell, 1984). Changes in marketing, planting, and harvesting strategies have been attributed to specific radio and television programs (Kroetz and Cole, 1978; Rockwell, 1984).

Computers are useful educational tools. There are simplified computer programs which make current technical information readily available to county extension agents and agricultural producers (Chase, 1984; Harrison and Rades, 1974; Paisley, 1983). These programs provide easy access to current information on marketing, weather, and production technology. Computer-based videotext information delivery systems are suitable for problem-solving and decision-making tasks with specific information requirements (Paisley, 1983).

Computer programs have been developed which simulate agricultural situations (Amend, 1985). Some of these programs have been used to educate adults and young people about the value of agriculture.

Demonstration Plots and Group Meetings

Field Demonstration plots are effective tools to show new agricultural practices since visual comparisons of various treatments can be made easily (Barreto and Fay, 1983; Cunningham and Simeral, 1977; Witt, 1968). To be most effective, demonstration plots should be established at numerous locations since environmental conditions can effect results.

Group meetings such as symposiums, workshops, seminars, field tours, or formal classes offer an opportunity for farmers and ranchers to discuss specific problems with research and extension personnel (Barreto and Fay, 1983). Involving local producers increases interest and acceptance of new techniques (Witt, 1968). The quantity and quality of publicity that precedes a program has a major impact on the size of the audience (Barreto and Fay, 1983; Cunningham and Simeral, 1977; Bradfield, 1966).

Written Communication

Bulletins, flyers, newsletters, and circulars are an effective way to create interest, publicize events and dispense information (Bradfield, 1966; Myren, 1964; Awa and Van Crowder, 1978). To be effective, the written material must be concise and meet the needs and interests of the reader (Kelsey and Hearne, 1963; Reisbeck, 1980).

Printed media appears to be more effective than audio-visual communication for reaching specific audiences (Awa and Van Crowder, 1978). Bulletins, short pamphlets and newsletters were more effective than television and radio in reaching low income families (Awa, 1974). Dairy farmers in New York state ranked printed media higher than radio, television or interpersonal visits as the most effective extension communication effort (Awa and Van Crowder Jr., 1978).

Newsletters are a preferred form of written communication if concise, well written and pertinent (Brown and Collins, 1978; Kelsey and Hearne, 1963; Reisbeck, 1980; Harshman, 1981). Important articles in newsletters should be headlined to gain the attention of the reader (Harshman, 1981; Reisbeck, 1980).

Evaluation of Delivery Systems

Mailed questionnaires have become a popular method for collecting survey data. Not only are they cheaper than interpersonal surveys, but recent improvements in procedures for conducting mail surveys suggest that limitations of this method (such as low response rates and dependence on short questionnaires) can be overcome (Dillman, 1978).

The mail questionnaire must be well designed to obtain answers from survey participants. The content of the survey, rather than the length, paper color, or amount of personalization, appears to determine response rate (Dillman, 1978). Follow-up letters to mailed surveys have been used effectively to increase response rates (Kanuk and Berenson, 1975).

The effectiveness of various communication channels for transferring agricultural information has been measured by surveying

agricultural producers and researchers (Adams and Parkhurst, 1984; Awa and Van Crowder Jr., 1978). These surveys indicated that farming strategies would be improved if the most efficient delivery system was selected (Adams and Parkhurst, 1984).

The effectiveness of a given communication method varies according to the size of an individual farmer's production unit (Adams and Parkhurst, 1984). In addition, the means of communication which is most effective is dependent upon the type of subject matter being delivered (Brown and Collins, 1978). For example, the primary source of production information for large commercial farms is the Cooperative Extension Service and the university system. Radio was the most effective media for business and management information (Brown and Collins, 1978). Farm magazines were the most important source of agricultural information for farmers in Nebraska (Jaeger and Reifschneider, 1965; Adams and Parkhurst, 1984). However, those farming large acreages in Nebraska rated farm journals higher than those managing smaller acreage (Adams and Parkhurst, 1984).

Income level also affects communication channel effectiveness. Bulletins, flyers and newsletters were more effective than audio-visual media for low income families (Awa, 1974). Experiment station bulletins were rated higher as information channels for those in the middle and upper income levels (Adams and Parkhurst, 1984).

Summary

Spotted knapweed and leafy spurge are the most troublesome range weeds in Montana. The key to controlling both weeds is to educate

landowners so that early identification and control of pioneer infestations occurs.

A variety of techniques should be utilized to educate landowners. Audio-visual techniques including radio and television will increase public awareness of the problem. Field tours and demonstration plots will permit landowners to view and record the results of various practices and permit attendees to interact with researchers and extension personnel. Newsletters, extension bulletins and circulars can provide interested persons with accurate information about specific problems. Mail surveys can be utilized to obtain information about the effectiveness of various communication techniques. Utilizing the most effective communication methods can save money by allowing educators to key in on specific audiences.

CHAPTER 2

EXTENSION TECHNIQUES

Abstract

An on-going statewide weed education program was expanded in 1983. The objectives of the program were to continue the leafy spurge awareness effort started in 1980, and initiate a similar effort on spotted knapweed. Newsletters, herbicide demonstration plots, field tours and a ransom program were techniques utilized to meet the objectives. Leafy spurge and spotted knapweed newsletters provided information on current research programs and research results to agricultural producers, researchers, and extension specialists. Field plots were established at twenty-two locations to demonstrate herbicide efficacy. Field tours were held in twenty-six locations. The tours included information on the biology and control of leafy spurge and spotted knapweed, herbicide efficacy, and sprayer calibration. A ransom program on spotted knapweed was initiated in Stillwater County, Montana. The ransom program led to increased awareness of spotted knapweed, control of existing knapweed infestations, and compilation of a map delineating existing spotted knapweed infestations. The overall education program increased public awareness of leafy spurge and spotted knapweed, established long-term demonstration plots, and served as the catalyst for several localized weed action projects.

Introduction

Leafy spurge and spotted knapweed are major threats to the productivity of range and pastureland in Montana. The key to controlling both weeds is early detection and treatment. Thus, in 1983, an educational program was initiated to help decrease the rate of spread of leafy spurge and spotted knapweed in the state. The overall objective was to increase public awareness of spotted knapweed and leafy spurge. Specifically, the leafy spurge newsletter was continued and a newsletter on spotted knapweed was initiated, a ransom program was started, demonstration plots were established, and field tours were conducted.

Communication techniques must be effective to transfer technological advances to agricultural producers. Newsletters are a preferred form of written communication if they are concise and relate to the needs and interests of the receiver (Awa, 1974, Brown, 1978, Kelsey, 1963, and Reisbeck 1980. Barreto (1982) utilized a newsletter to increase public awareness, coordinate research and provide information to people interested in leafy spurge control.

Demonstration plots are an effective educational tool (Cunningham and Simeral, 1977), if the practices being demonstrated provide practical solutions to local problems (Kelsey and Hearne, 1963). This allows agricultural producers to view and record the results of various treatments under local environmental conditions (Witt, 1968). Field tours held at demonstration sites provide an informal setting where farmers and ranchers can discuss production problems with extension specialists and researchers (Barreto and Fay, 1983). However, field

tours must be carefully planned to meet the needs and interests of producers (Kelsey and Hearne, 1963) and be well advertised to be effective (Cunningham and Simeral, 1977).

Materials and Methods

Newsletters

Leafy Spurge Newsletter: Publication of the Leafy Spurge Newsletter was continued on a quarterly basis. The general format and methodology for printing the newsletter was described by Barreto (1982).

Knapweed Update: A letter was sent to researchers and extension specialists in Idaho, Washington, Oregon, Montana, British Columbia, and Alberta in September, 1983 to determine if there was a need for a newsletter about the knapweeds. These specialists provided suggestions for the format of the newsletter and names of extension agents, researchers, politicians, weed supervisors, and agricultural producers for the initial mailing list. A mailing list was stored on a computer disk and updated monthly as requests for the newsletter were received.

The art work for the letterhead and return address was developed and a silkscreen of the drawing was produced by the photographic department at Montana State University. The letterhead and return address was printed by the Multilith Department.

Researchers and extension specialists were contacted for contributions one month prior to printing the newsletters. The articles were summarized, typed, and sent to the Multilith Department for printing onto the letterhead paper.

Demonstration Plots and Field Tours

Herbicide treatments were applied to spotted knapweed or leafy spurge at twenty two sites in June, 1983 and 1984 (Figure 1). Site locations were selected by county extension agents, weed supervisors and chemical company representatives. The sites were easily accessible and located near population centers when possible. Picloram, (4-amino-3,5,6-trichloropicolinic acid), dicamba (3,6-dichloro-o-anisic acid) and 2,4-D [(2,4-dichlorophenoxy) acetic acid] were applied to plots at each site. The treatments were not replicated. Individual plot size varied from 6.6 X 26.6 meters to 6.6 X 36.3 meters. The herbicide rates and application timing were recommended by weed specialists at Montana State University, chemical company representatives, and county extension agents. Retreatments were made on a portion of the plots in 1984. A detailed description of herbicide demonstration plots at each location is shown in Appendix B. Twenty six field tours were held in 1983 and 1984 (Figure 1). Eighteen of the tours were held at herbicide demonstration locations established in 1983 and 1984. The remainder of the tours were held at locations which contained experimental plots that were previously established (Barreto, 1982).

Local landowners, county extension agents, weed supervisors, and state and federal employees helped plan and execute the educational program. This integrated approach helped improve public relations and increased the overall effectiveness of the program.

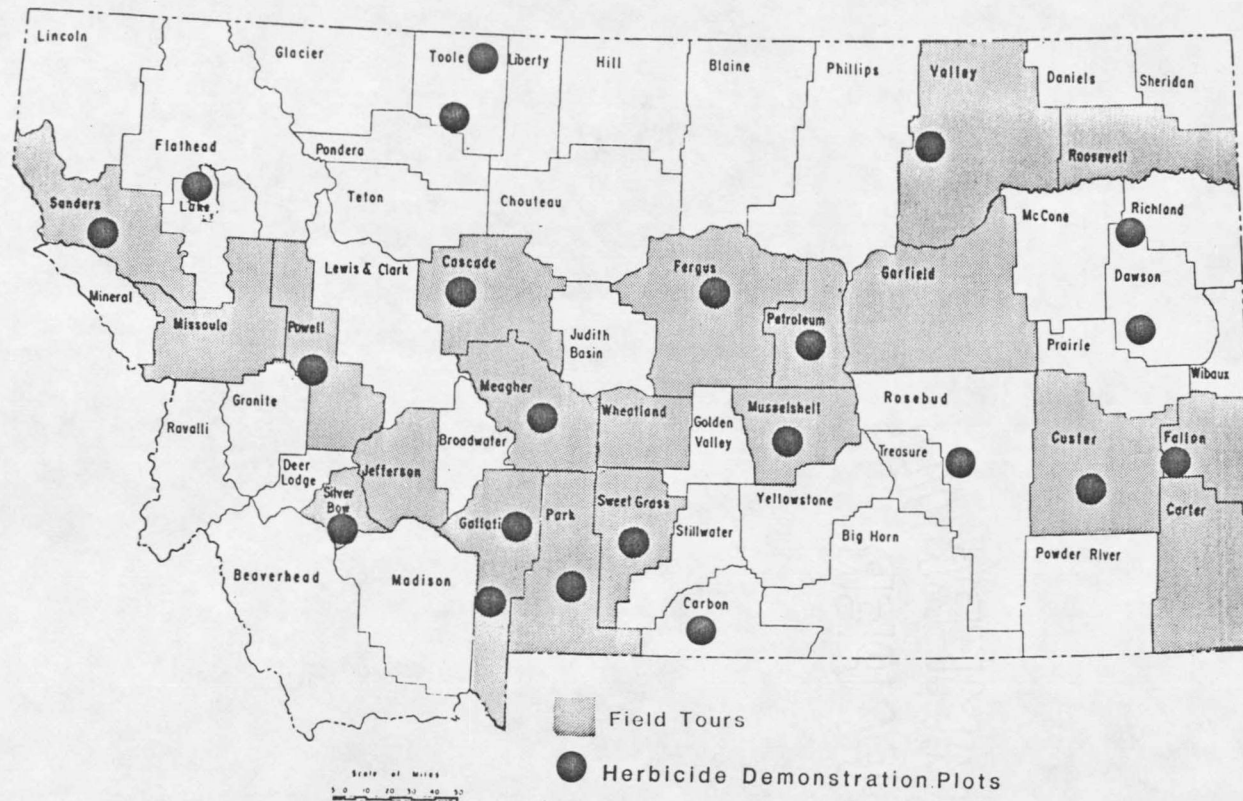


Figure 1: The Location of 1983 and 1984 Herbicide Demonstration Plots and Field Tours in Montana.

Information on the biology and distribution of both leafy spurge and spotted knapweed was presented at each tour. The educational programs emphasized: 1) An update and facts on biological control; 2) leafy spurge control with sheep; 3) economics of various control measures; 4) herbicide efficacy; and 5) current research programs. Sprayer calibration of hand held and field sprayers was demonstrated at tours held during 1984. Displays on county weed control equipment and the latest innovations in herbicide applicators for all terrain vehicles (Maxwell et al., 1984) were shown at the tours.

Radio programs, news articles, and flyers were utilized as publicity for the tours. Greg Northcutt, editor for the Montana Agricultural Experiment Station, conducted the radio interviews and coordinated news releases. County extension agents in several counties handled the news releases. Flyers were made and sent to ten counties holding weed tours. Picnic dinners or refreshments, and door prizes were provided at each field tour by Dow Chemical Company.

Ransom Program

The concept of a ransom program on spotted knapweed and leafy spurge was discussed with county extension agents. The objectives of a weed ransom program were to increase awareness of weeds among youth and help map county weed infestations. Young people participating in the program were encouraged to locate and report infestations of leafy spurge and spotted knapweed to their county extension agent or weed supervisor. Youth who reported new infestations, or infestations that had not been denoted on the existing county weed map, were awarded cash incentives. Guidelines for the program were made by county personnel

to best meet the needs of their respective county. The program was supervised by the county extension agent and/or weed supervisor.

Results and Discussion

Newsletters

Newsletters (Appendix A) were designed to provide information to a wide range of audiences. Information presented covered topics such as herbicide applicators, alternative uses for weeds, weed migrations, and biological, chemical and cultural control methods.

Newsletters appeared to be an effective method of communication between agricultural producers, researchers and extension personnel. The number of subscriptions to the Leafy Spurge Newsletter increased from 850 in October, 1981 (Barreto, 1982) to 1430 by October, 1984. Subscriptions to the Knapweed Update increased from 320 in October, 1983 to 793 in October, 1984 (Figure 2). The subscription list for both newsletters were compiled by request only which indicates the level of concern for spotted knapweed and leafy spurge.

There were less requests for newsletters from farmers and ranchers than from extension agents, weed supervisors and federal employees. However, since extension provides an effective link between agricultural producers and researchers (Awa and Van Crowder, 1978), the newsletter benefited the agricultural community indirectly. The cost of producing and mailing the newsletter is shown in Table 1. The total cost of the newsletter would have been much higher if student labor and bulk mailing rates had not been used.

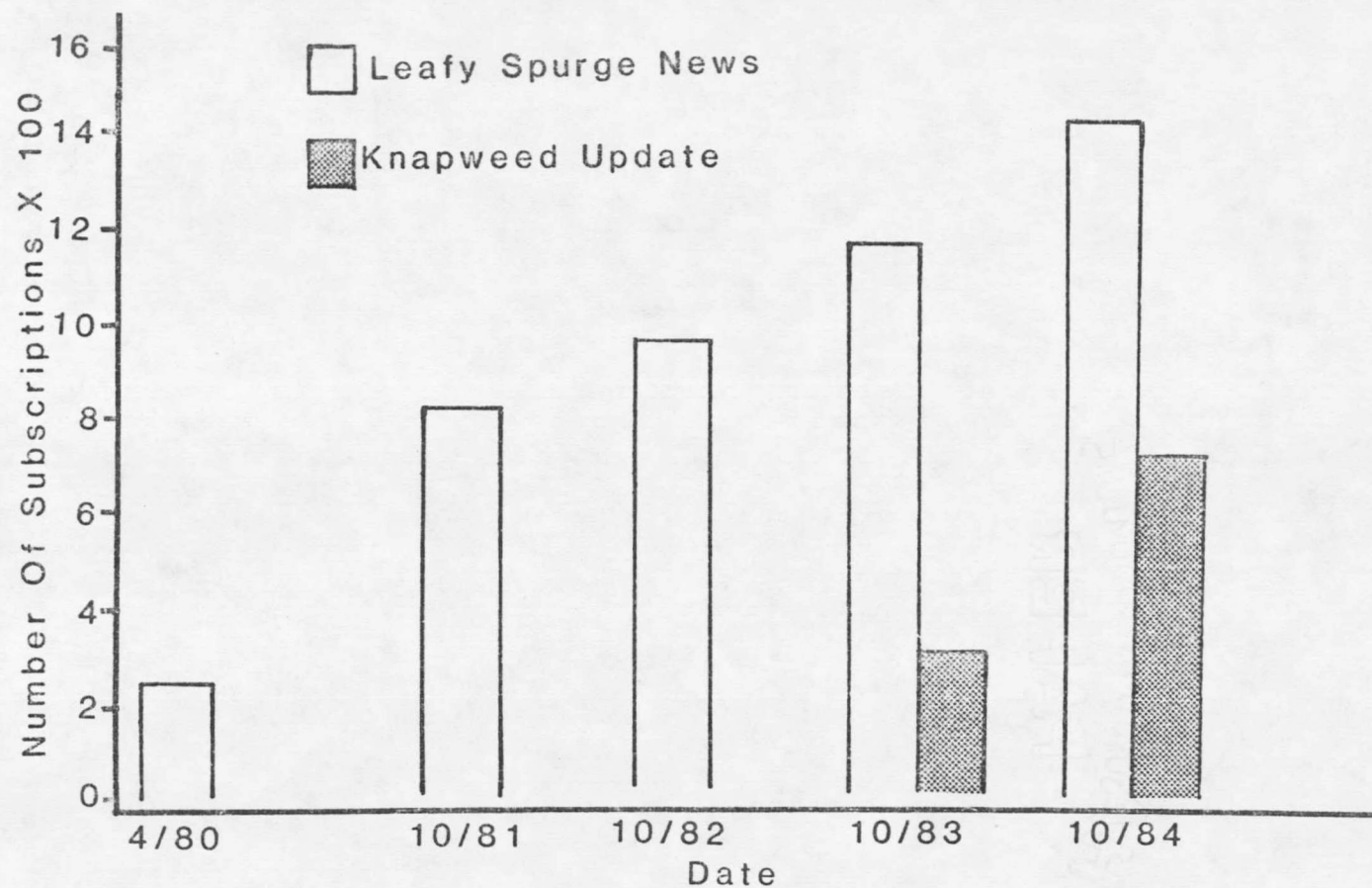


Figure 2: The Number of Subscriptions to the Leafy Spurge News and Knapweed Update from April, 1980 to October, 1984.¹

¹The Leafy Spurge News was initiated in April, 1980 and the Knapweed Update in October, 1983.

Table 1. The Cost of Publishing the Leafy Spurge News and Knapweed Update from April 1983 to December 1984.

Item	Cost (4/83 to 12/84)
Leafy Spurge News (7 issues)	
printing and paper	\$761.00
postage at \$0.072/newsletter	655.00
labor	56.00
Knapweed Update (4 issues)	
artwork	48.00
printing and paper	242.00
postage at \$0.072/newsletter	170.00
labor	24.00
Total Cost	1956.00

Demonstration Plots and Field Tours

Herbicide demonstration plots were an effective technique for evaluating the effectiveness of various herbicides for leafy spurge and spotted knapweed control (Table 2 and 3). Picloram provided the

Table 2. Herbicides Used for Leafy Spurge Demonstration Plots in Fourteen Locations in Montana.

Herbicide	Rate kg / ha
picloram	0.57*
picloram	1.14*
picloram	2.24
dicamba	2.24*
2,4-D	2.24*

* Indicates rates that were retreated on 1/2 of the plot in 1984

Table 3. Herbicides Used for Spotted Knapweed Demonstration Plots in Eight Locations in Montana.

Herbicide	Rate kg/ha
picloram + 2,4-D	0.14 2.24
picloram	0.14
picloram	0.28
dicamba	1.14*
2,4-D	2.24*

* Indicates rates that were retreated on 1/2 of the plot in 1984.

most effective control of both leafy spurge and spotted knapweed however, percent control varied according to location (Table 4 and 5). These differences were probably caused by variations in soil and/or climatic conditions. Results indicate the importance of establishing plots in a number of locations around the state.

Table 4. Percent Leafy Spurge Control With Various Herbicides at Selected Counties in Montana 12 Months After Application.

Percent Leafy Spurge Control							
Herbicide	Rate kg/ha	Pet.	Powell	Custer	Fallon	Dawson	Mean ² X
picloram	0.57	40	95	45	70	95	69 b
picloram	1.14	87	98	95	95	100	95 c
picloram	2.24	99	100	99	99	100	99 c
dicamba	2.24	25	60	10	10	25	26 a
2,4-D	2.24	30	55	15	15	25	28 a

¹ Petroleum county is abbreviated as Pet.

² Means followed by the same letter are not statistically different at the 5% level as determined by the LSD test of significance.

Table 5. Percent Spotted Knapweed Control With Various Herbicides at Selected Counties in Montana 12 Months After Application.

Percent Spotted Knapweed Control						
Herbicide	Rate kg/ha	County Location ¹				Mean ²
		Fergus	Musselshell	Meagher	Silver Bow	X
picloram	0.28	100	100	100	100	100 b
picloram + 2,4-D	0.14					
	2.24	95	95	90	95	94 b
picloram	0.14	95	93	90	95	93 b
dicamba	1.14	20	45	35	25	31 a
2,4-D	2.24	15	30	25	20	22 a

¹ Musselshell county is abbreviated as Mussel. and Silver Bow county is abbreviated as S.B.

² Means followed by the same letter are not statistically different at the 5% level as determined by the LSD test of significance.

Attendance at the field tours increased more than two fold from 1980 to 1984. Barreto and Fay (1983) reported an average of 28 persons per tour in 1980 and 1981. The average attendance per tour increased to 57 during 1983 and 1984 (Table 6). These results suggest that: 1) Agricultural producers viewed the field tours as effective educational tools; 2) An integrated approach which involved extension agents, local landowners, weed districts, and federal and state employees during the planning stage for tours increased interest and participation at field tours, and 3) It takes time to increase the awareness level for problems such as knapweed and leafy spurge. This was evident by the increased attendance at each of the five counties where repeat tours were held (Table 7).

Table 6. The Number of People Attending Spotted Knapweed and Leafy Spurge Tours During 1983 and 1984.

1983 Tours	
Location	Attendance
Park	42
Roosevelt	120
Valley	45
Wheatland	30
Fallon	60
Fergus	25
Jefferson	30
Sanders	60
Missoula	70
Silver Bow	30
Gallatin	120
Carter	110
Petroleum	41

Total	783

1984 Tours	
Location	Attendance
Musselshell	45
Petroleum	43
Garfield	50
Roosevelt	120
Valley	40
Fergus	30
Cascade	70
Park	20
Meagher	50
Bozeman	35
Fallon	90
Sweetgrass	100
Silver Bow	25

Total	718

Table 7. The Number of People Attending Weed Tours Held in 1980/1981 Compared to the Attendance at Weed Tours Held at the Same Locations in 1983/1984.

Location	Attendance	
	Date of Tour	
	1980/1981	1983/1984
Carter	6	110
Fallon	6	60
Missoula	30	70
Park	25	42
Roosevelt	53	120

Several factors were important in determining the attendance and success of a weed tour: 1) Attendance was greatest at tours that were well advertised. Radio tapes, news articles, and flyers should be sent to counties at least ten days in advance of the tours. 2) Attendance was greatest at late afternoon and evening tours, and lowest at morning sessions. 3) The date of the tour must not conflict with planting or harvesting seasons. 4) Tour sites should be easily accessible and located near population centers.

Ransom Program

The concept of a weed ransom program was rejected by all but one county because of lack of funding. The extension agent and weed supervisor in Stillwater County established a ransom program on spotted knapweed in June, 1984. They designed a ransom program where youth were paid \$5.00 for reporting an infestation and an additional \$50.00 if the infestation was controlled by the landowner. County spray equipment was available free of charge to landowners participating with

youth in the program which aided control efforts on the knapweed infestations.

The ransom program in Stillwater County was very successful. Approximately 65 people were directly involved with the weed control effort as a result of the program. Participants included 14 young people, in addition to parents, agricultural producers, and state and federal employees. Thirty-four spotted knapweed infestations were located and recorded on the county weed map which created an accurate base map for the county.

The program was very economical for the county. Total cost of implementing the program in 1984 was \$1170.00. However, by utilizing youth, rather than county employees to map and control infestations, the program actually saved the county weed control budget an estimated \$4500.00. There will also be long-term financial benefits achieved through the education and involvement of youth in the weed control effort. Overall results of the program were: 1) An accurate map of spotted knapweed infestations was developed 2) The level of weed awareness weed and control increased, and 3) The cost of weed control to the county decreased. Six additional counties plan to adopt a similar program in Montana in 1985.

Summary

Effective communication techniques are important when transferring research results to agricultural producers. Extension techniques such as field tours and demonstration plots can be utilized effectively at the county level. Newsletters were an effective method

for coordinating region-wide programs and provide current research information to educators. Innovative techniques such as a weed ransom program are an effective way to increase weed awareness and control especially among youth groups. These activities must be integrated with researchers and county , state, and federal entities to enhance the overall effectiveness of the program.

CHAPTER 3

PROGRAM EVALUATION

Abstract

A questionnaire was developed to evaluate the effectiveness of the weed education program. Three hundred and twenty questionnaires were mailed to producers that did and did not attend weed tours in four counties. Sixty eight percent of the surveys were returned. There was a higher degree of weed awareness among tour participants than among non-tour participants. The survey also provided information on various control methods currently being used for spotted knapweed and leafy spurge, major sources of weed information, reasons why weeds were not being controlled, and educational and research needs of producers in Montana.

Introduction

Educational programs must be evaluated to determine their effectiveness in communicating information. Programs can then be modified to best fit the needs of the agricultural community in an efficient and economic manner.

Mail surveys are a common method for gaining information from producers on the effectiveness of various communication techniques. Brown and Collins (1978) surveyed 1639 farmers to determine their priorities of need for various categories of information, and the

channels of communication they were using to obtain that information. Adams and Parkhurst (1984) sampled 2000 farmers in Nebraska to determine the importance of several communication channels. Jaeger and Reifschneider (1965), surveyed 2000 farmers to determine their sources of information. Results of these studies suggest that well designed surveys are an effective method for assessing various communication techniques.

The objective of this survey was to determine the effectiveness of communication techniques utilized in the weed education program. Additional information was obtained on landowners perception of weed control practices, herbicide use, and research and extension needs.

Materials and Methods

Four representative counties that held weed tours in 1983 were selected for the survey (Figure 3). Leafy spurge tours were held in Gallatin and Carter county while spotted knapweed tours were held in Sanders and Missoula county. Although information pertaining to the identification and biology of both weeds was presented at each tour, information regarding leafy spurge was stressed in Gallatin and Carter county, and spotted knapweed was stressed in Sanders and Missoula county.

A survey questionnaire was developed in October, 1983 (Appendix, C). County extension agents from the four counties and agriculture education specialists at Montana State University reviewed and edited a sample questionnaire. The questionnaire could be completed by a respondent in less than 12 minutes.

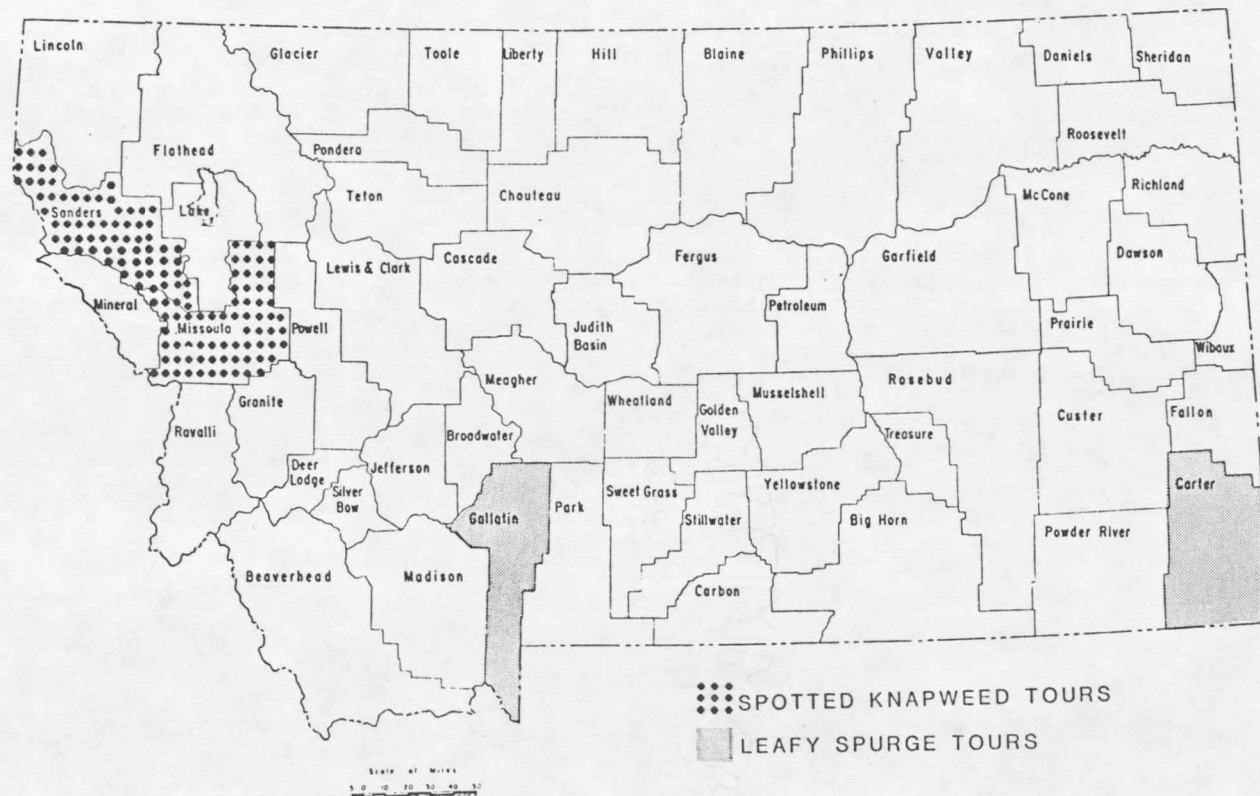


Figure 3. The Location of Four Counties in Montana That Were Selected for the Weed Survey.

The questionnaire was five pages long including a cover letter explaining the survey. The return address and postage permit number were printed on the back of the questionnaire to facilitate mailing. All questionnaires were marked with an identification number so responses could be grouped by county and tour attendance. A cover letter printed on Montana State University letterhead accompanied each questionnaire and explained the purpose of the survey.

Producers that attended each tour were mailed a questionnaire and cover letter. County agents within the four counties then selected an equal number of landowners that had not attended the weed tour. These people were selected from county ownership maps and/or extension mailing lists and owned land near known spotted knapweed or leafy spurge infestations. A survey questionnaire and cover letter was also mailed to this group.

In January, 1984, 320 questionnaires were mailed. A followup letter and questionnaire were mailed to producers that had not responded to the initial mailing after three weeks. The final deadline for receipt of the questionnaires was March 1, 1984.

Responses to the survey were assigned numerical values and entered into the computer with the participants identification number. Specific questions were analyzed using Chi Square analysis.

Results and Discussion

Sixty-eight percent of the questionnaires were returned. There was no difference in percent return between landowners that did and did not attend weed tours.

Weed Awareness

Weed awareness was significantly higher for tour participants than among non participants (Table 8). This suggests field tours increased public awareness of leafy spurge and spotted knapweed.

Table 8. Percent of Landowners Who Were Able to Recognize That Leafy Spurge or Spotted Knapweed Were Serious Problems on Their Property.¹

Plant Species	Landowners Attending Tour	Landowners Not Attending Tour
	%	%
Leafy Spurge ²	100a	55b
Spotted Knapweed	94a	65b

¹ Data based on information collected from 210 questionnaires returned by Montana landowners during January, 1984. About one-half of the respondents did attend a weed tour in 1983, while the remainder did not attend a weed tour in 1983.

² Percentages in the same row followed by the same letter not significantly different at the .005 level.

Weed Control

Survey participants were asked to indicate which control methods they used for spotted knapweed and/or leafy spurge. Thirty percent of the respondents had infestations of leafy spurge. Herbicides were the most important method of control for both groups of landowners (Table 9). However, more tour participants used herbicides for leafy spurge control than non-tour participants. About fifteen percent of all respondents were utilizing some method of control other than those listed on the questionnaire. The other methods included sheep (6%),

planting competitive grasses (1.5%), and spraying with diesel fuel (1.5%). This suggests that landowners attending the field tours considered leafy spurge to be a problem and were more likely to attempt to control it than those that did not attend tours.

Table 9: Treatment Methods Used by Landowners for Leafy Spurge Control in Four Montana Counties.¹

Control Method	Landowners Attending Tour ²	Landowners Not Attending Tour
	%	%
Mechanical	4.8	23.8
Biological	0.0	4.7
Herbicides ³	95.1a	66.6b
Other	9.7	4.7
None	2.4	23.8

¹ Data based on information collected from 210 questionnaires returned by Montana landowners. About one-half of the respondents attended a weed tour in 1983.

² Total percentage does not equal 100 because several respondents used more than one treatment method.

³ Percentages in the same row followed by the same letter are not significantly different at the .005 level. Percentages not followed by a letter indicate numbers that were too small for Chi Square analysis.

Spotted knapweed was listed as a problem by 44% of the respondents. There was no difference in the control methods used for spotted knapweed by producers that did and did not attend weed tours (Table 10). Herbicides were the most commonly used method of control.

The lack of difference in spotted knapweed control between tour participants and those who did not attend tours may be a reflection of the length of time the knapweed awareness program has been in effect. The intensive leafy spurge effort was initiated in 1980, however the

spotted knapweed program began in 1983. It may take several years before landowners are willing to adopt sound weed management practices. The lag period associated with adoption of new ideas has been well documented (Bohlen et.al., 1962).

Table 10. Treatment Methods Used by Landowners in Four Montana Counties for Spotted Knapweed Control.¹

Control Method	Landowners Attending Tours ²	Landowners Not Attending Tours
	%	%
Mechanical ³	25.5a	36.9a
Biological	19.1	28.3
Herbicides	57.0a	54.0a
Other	12.7	19.6
None	19.7	21.7

¹ Data based on information collected from 210 questionnaires returned by Montana landowners. About one-half of the respondents attended a weed tour in 1983.

² Total percentage does not equal 100 because several respondents listed two sources of information as being the most important.

³ Percentages in the same row followed by the same letter are not significantly different at the .005 level. Percentages not followed by a letter were too small for Chi Square analysis.

Survey participants were asked to rank five reasons for not controlling weeds in Montana. Four possible reasons were listed on the survey questionnaire. Room for a fifth measure was provided to permit respondents to list other choices. There was no difference in response between landowners that did and did not attend weed tours. Lack of available information was ranked as the most important reason for not controlling weeds (Table 11). This suggests that the weed

control effort would be improved if either more weed control information was available, or improved methods for distributing the information to landowners was adopted.

Other reasons listed by landowners as important for not controlling weeds included: High cost of herbicides (10%), apathy (8%), lack of awareness of the weed problem (5.5%), lack of cooperation between landowners (3.5%), and unacceptable results from prior attempts to control weeds (2.5%).

Table 11. The Relative Importance of Four Listed Reasons for not Controlling Weeds as Rated by Landowners in Four Montana Counties.¹

Reasons for not controlling weeds	% of total responses indicating that the reason was most important ²
Lack of information	41
Value of Land too Low	27
Lack of Application Equipment	19
Fear of Herbicides	15
Other	22

¹ Data based on information collected from 210 questionnaires returned by landowners during January, 1984. About one-half of the respondents attended a weed tour in 1983.

² Total percentage does not equal 100 because several respondents listed more than one reason.

Information Sources

Survey participants were asked to rank seven common sources of information pertaining to weeds according to their value to the landowner (Table 12). There was no difference in source of information

between those that did and did not attend weed tours. The cooperative extension service was chosen as the most important source of weed information by fifty-two percent of the respondents. Montana State University was ranked second by 25 percent of those responding to the survey. This suggests that personnel within the cooperative extension service and researchers at Montana State University should work together in presenting technical information. Radio or television was ranked as most important by only four percent of respondents. Other sources of weed information included weed supervisors (5%), federal agencies (4%), and personal trial and error (2%).

There is undoubtedly some bias in the results since half of the survey participants attended tours sponsored by the Cooperative Extension Service and Montana State University. Also, some participants that had not attended weed tours were receiving information from the Cooperative Extension Service.

Table 12. The Major Source of Weed Information for Landowners in Four Montana Counties.¹

Source of Information	% of Landowners
Cooperative Extension Service	52
Montana State University	25
Neighbor	11
Agricultural Business	10
Periodicals	9
Newsletters	5
Radio or Television	4

¹ Data based on information collected from 210 questionnaires returned by Montana landowners during January, 1984. About one-half of the respondents did attend a weed tour in 1983, while the remainder did not attend a weed tour in 1983.

Farm journals were a less important source of information in this survey (Table 12) than they were in Nebraska (Adams and Parkhurst, 1984; Jaeger and Reifschneider 1965). The sources of information listed in this questionnaire included farm magazines with periodicals which may have caused some confusion among survey participants. Responses may have been different if farm magazines had been listed separately.

Extension Strategies

Survey participants were asked to list strategies that the Cooperative Extension Service should utilize to improve weed control practices (Table 13). Sixty-nine percent of the respondents thought that more educational programs such as tours and seminars should be conducted. This indicates that survey participants found tours and meetings to be an effective communication technique. This conclusion is supported by an earlier survey conducted in Gallatin County (Crandell, Petroff, and Wolfe, 1983). Other strategies included publicizing weed problems in newspapers and magazines, establishing weed newsletters, providing a consultation service, and focusing weed control efforts on landowners with small acreages.

Research Needs

Survey participants were asked to list in order of importance what weed research should be conducted at Montana State University (Table 14). Sixty-two percent of the survey participants responded to this question. Research on biological control was ranked as the most important area by 43% of the respondents. Twenty seven percent would like to see more research on control of perennial weeds such as leafy

spurge, spotted knapweed and Canada thistle (Cirsium arvense) while 26 percent wanted more research conducted on herbicides. Research on weed physiology and alternative uses for weeds was ranked as most important by 2% of the respondents.

Table 13. The Most Important Strategies the Extension Service Should Utilize to Improve Weed Control Practices, as Perceived by Landowners in Four Counties.¹

Extension Strategies	% of Landowners ²
Conduct Tours and Seminars	69
Publicize Weed Problems	15
Publish Newsletter	10
Provide Consultation	9
Focus Education on Landowner with Small Acreage	5

¹ Data based on information collected from 210 questionnaires returned by landowners during January, 1984. About one-half of the respondents attended a weed tour in 1983, while the remainder did not attend a weed tour in 1983.

² Total percentage does not equal 100 because several respondents listed two strategies as being the most important.

Table 14. The Areas of Weed Research Needed at Montana State University as Perceived by Landowners in Four Montana Counties.¹

Research Needs	Landowners (%)
Biological Control	43
Perennial Weed Control	27
New Herbicides	26
Weed Physiology	2
Alternative Uses for Weeds	2

¹ Data based on information collected from 130 responses from 210 questionnaires returned by Montana landowners during January, 1984. About one-half of the respondents attended a weed tour in 1983.

Summary

It appears that the weed education program has been successful in Montana. Landowners that attended weed tours were more aware of the leafy spurge and spotted knapweed problems than those that did not attend. Also, attempts to control leafy spurge were significantly greater among tour participants than among non-participants.

The cooperative extension service was listed as the most important source of weed information by 52% of the respondents. The second most important source of information was Montana State University. Respondents felt that if more information on weed identification and control was available it would improve weed control practices. Weed tours and seminars were listed as important strategies for transferring weed information. Other important strategies included publicizing weed problems in newspapers and magazines, and publishing weed newsletters. Educators should utilize a range of communication techniques to develop a sound weed education program.

PART II.

BIOLOGY AND CONTROL
OF SPOTTED KNAPWEED

CHAPTER 4

LITERATURE REVIEW

Introduction

Spotted knapweed (Centaurea maculosa Lam.) is the most troublesome rangeland weed in western Montana (IPM Committee Meeting, 1981). The aggressive growth habit and lack of natural enemies has allowed spotted knapweed to spread rapidly.

Spotted knapweed was introduced to North America in 1893 in alfalfa seed from Asia Minor-Turkmenistan (Groh, 1940). Spotted knapweed was reported in Ravalli County, Montana by 1920 (Forcella and Harvey, 1980). The weed currently infests an estimated 800,000 hectares in the state (Maddox, 1979) and has been collected in every county. Approximately 13.8 million hectares of grazeable woodland and rangeland in Montana are susceptible to spotted knapweed invasion (Bucher, 1984).

Spotted knapweed is a biennial or short-lived perennial herbaceous plant that reproduces from seed. It has numerous ascending branches, 30-100 cm high, each bearing a single seed head (Moore and Frankton, 1974). The leaves are alternate, and much divided. The upper leaves are linear in shape. Each flower head has bracts that are marked with fine vertical streaks and tipped with a black fringe (Watson and Renney, 1974). The flowers are tubular and range in color from purple to white. Spotted knapweed is a tetraploid with $n=18$ chromosomes

seed, vegetative shoots can emerge from 2.5 to 7.5 cm from the mother plant. These shoots form rosettes which remain attached to the mother plant (Watson and Renney, 1974).

Spotted knapweed reproduces aggressively by seed. The number of viable seed produced per plant is directly related to the amount of available moisture (Schirmann, 1981). Individual spotted knapweed plants produce from 436 to 25,263 seeds under dryland and irrigated conditions respectively (Watson and Renney, 1974). The number of seeds produced per square meter ranges from 7000 to 90,000 (Schirman, 1984). Story (1976) estimated that spotted knapweed plants produce an average of 1000 seeds per plant in Montana. Seed dispersal begins two to three weeks after flowering. When movement of the stem occurs, the achenes are expelled with a flicking action from the head. Seeds may land up to one meter from the parent plant (Watson & Renney, 1974).

Spotted knapweed seeds germinate over a broad range of environmental conditions. Watson and Renney (1974) found that continuous light significantly reduced germination of spotted knapweed after six days. Optimum germination temperature was 10C to 28 C but germination occurred at temperatures from 7 C to 34 C.

The longevity of spotted knapweed seed viability has not been determined. However, preliminary work by Shirman (1984) and Chicoine (1984) indicates that buried spotted knapweed seed remain viable in the soil for more than five years.

Spotted knapweed is well adapted to a wide range of environmental conditions. The weed has been observed at altitudes ranging from 30 m to over 2700 m (Watson and Renney, 1974; Chicoine, 1984) and in annual

precipitation zones which receive less than 25.4 cm and more than 200 cm annually (Chicoine, 1984).

Spotted knapweed readily colonizes soils with a wide range of chemical and physical properties. The degree of soil disturbance rather than specific soil properties determines the density potential of spotted knapweed (Watson and Renney, 1974). Although open habitats are preferred by spotted knapweed, (Watson and Renney, 1974) it will invade disturbed forest soils which have an intermittent canopy cover (personal observation).

Spotted knapweed produces an allelochemical which helps the plant maintain stand densities (Fletcher and Renney, 1963). Preliminary studies have tentatively identified the allelochemical as cnicin (Kelsey, 1984) (Figure 4). The highest concentration of cnicin is found in the leaves (Fletcher and Renney, 1963).

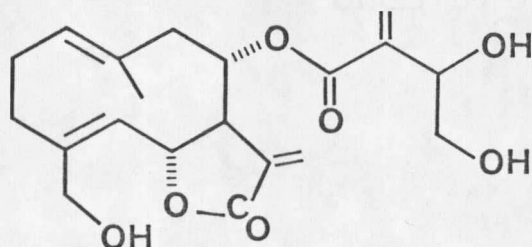


Figure 4. The Structure of Cnicin (from Kelsey, 1985).

Effect of Spotted Knapweed on Forage Production

The dense, spiny canopy of spotted knapweed reduces the availability of desirable forage species (Watson and Renney, 1974). Although spotted knapweed is rarely utilized for forage, the rosettes of spotted knapweed have some nutritive value. The protein content of spotted knapweed plants harvested in late May in Montana range from 9 to 18 percent depending on the site. Spotted knapweed mowed in late spring has also been found to produce a good quality silage with over 19 percent protein (Kelsey, 1985, personal communication). However, as the plant reaches maturity, the nutritional value decreases and fiber content increases (Kelsey, 1985, personal communication; Fletcher and Renney, 1963). Recently, Cox (1983) reported that sheep readily consume spotted knapweed in a pasture setting. This interesting finding merits further research to devise methods of sheep management as a control method.

The competitive nature of the knapweeds has been well documented. Watson and Renney (1974) found that knapweed invasion on a good condition bluebunch wheatgrass (Agropyron spicatum) - rough fescue (Festuca scabrella) rangeland in Canada reduced forage production 87.5 percent, from 896 kg/ha to 112 kg/ha. Similar results were reported in Idaho and Montana where spotted knapweed reduced perennial grass production from 80 to 90 percent (Wattenbarger et al., 1980; Chicoine, 1984).

Crested wheatgrass (Agropyron cristatum) and Russian wild rye (Elymus junceus) have been shown to compete with spotted knapweed and diffuse knapweed (Centaurea diffusa). There are also unsubstantiated

reports that sheep fescue (Festuca ovina) occurs in association with spotted knapweed (John Lacey, 1985, personal communication). The degree of knapweed suppression by grasses will vary according to the grass species and the climatic regime. Myers and Berube (1983) resampled plots established in 1967 to determine the effectiveness of crested wheatgrass and Russian wildrye in preventing reinfestation of diffuse knapweed. Results in 1978 (11 years following treatment) showed diffuse knapweed densities were high in non-seeded plots, moderate in Russian wild rye plots and very low in crested wheatgrass plots at one location. However, diffuse knapweed had completely reinvaded a similar experimental site in a higher rainfall zone. The ability of crested wheatgrass to utilize soil moisture early in the spring apparently depletes the soil moisture reserves which are critical for seedling establishment of diffuse knapweed (Hubbard, 1975; Myers and Berube, 1983).

Cattle carrying capacity is reduced as spotted knapweed replaces more desirable forage species. Cranston (1984) estimated stocking rate losses due to spotted knapweed were approximately \$1.5 million annually in British Columbia. The annual forage loss caused by spotted knapweed in Montana is estimated to be \$4.5 million (French and Lacey, 1983). Range livestock income could be reduced by \$155.7 million annually if all vulnerable range and grazeable woodland in Montana was infested (Bucher, 1984).

Effect of Picloram on Controlling Spotted Knapweed

Picloram (4-amino-3,5,6-trichloropicolinic acid) and 2,4-D ([2,4-dichlorophenoxy]acetic acid) have been used extensively for spotted

knapweed control on range and pastureland. These are selective herbicides which control broadleaf weeds with little damage to grass species. Picloram is the most effective herbicide for controlling spotted knapweed and provides from one to five years of complete control (Cranston, 1984; Chicoine, 1984). Liquid formulations of picloram are more effective than comparable rates of the granular formations (Wattenbarger et al., 1980). Renney and Hughes (1969) found that picloram applied at 0.42 to 0.56 kg/ha provided optimum control of Centaurea species. Picloram at 0.28 to 1.12 kg/ha provided 100 percent control of spotted knapweed one year following herbicide application (Wattenbarger et al., 1980). The addition of 2.24 kg/ha of 2,4-D to 0.28 kg/ha of picloram did not improve spotted knapweed control over 0.28 kg/ha of picloram alone (Chicoine, 1984).

The persistence and rate of picloram in soil determines the length of control for many weed species. The residual period of activity of picloram varies considerably at different locations. Goring et al. (1965) reported that decomposition of picloram applied at rates ranging from 1.57 to 4.7 kg/ha in four states ranged from 78 to 100 percent after two years. Keys and Friesen (1968) measured the residual activity of picloram three years after application on four soils in western Canada. The amount of picloram remaining in the soil was 10 percent of the original concentration after two years, and six percent after three years. Picloram residues were most often concentrated in the upper 15.2 cm of soil. Scifres et al. (1971) reported that picloram (0.28 kg/ha) dissipated within one year, and

usually within 90 days when applied to semiarid rangeland in west Texas.

Variation in the residual activity of picloram is attributed to differences in soil properties, elevation, climate, and initial herbicide concentrations. Picloram is more persistent in clay or sandy loam than sandy textured soils (Herr et al. 1966; Merkel et al., 1967). The rapid dissipation in light textured soils may be due to leaching (Burnside et al., 1971 ; Merkel et al., 1967) since the percent clay fraction had no significant influence on the rate of picloram decomposition (Youngson et al., 1967). Picloram decomposition rates are increased as soil organic matter content and temperature increases (Hunter and Stobbe, 1972; Youngson et al., 1967; Grover, 1968; Merkle et al., 1967). The rate of decomposition decreases with increasing depth in the soil profile (Hunter and Stobbe, 1972), and decreasing levels of soil moisture (Youngson et al., 1967).

Ultraviolet light decomposes picloram on plant and soil surfaces (Hall et al., 1968; Merkle et al., 1967). Photolytic degradation of picloram is greatest at high elevations since solar radiation increases with altitude (Johnson and Martin, 1983). Once in the soil, picloram is protected from photo-decomposition.

The rate of picloram dissipation is also related to initial herbicide concentration. Hunter and Stobbe (1972) determined that the percent of picloram degraded was greater at lower doses. This indicates that a lag period occurs in picloram degradation when high concentrations are applied (Grover, 1967).

Spotted Knapweed Response to 2,4-D

Spotted knapweed control with 2,4-D ((2,4-dichloro-phenoxy)acetic acid) is extremely variable. Chicoine (1984) found that the percent control of spotted knapweed after one year with 2.24 kg/ha of 2,4-D amine ranged from 21 to 100 percent at two locations. Results in Idaho were similar with spotted knapweed control ranging from 30 to 84 percent with 1.12 kg/ha of 2,4-D (Belles et al., 1978; Wattenbarger et al., 1980). Cranston (1984) reported that effective control of seedlings was obtained with 2,4-D, however, rosette plants recovered from the herbicide. Retreatment of 2,4-D is necessary to gain acceptable levels of control of mature spotted knapweed plants (Maddox, 1979). Variation in control of spotted knapweed with 2,4-D may be due to environmental conditions or differences in tolerance within the species.

Differential tolerance to 2,4-D within weed species has long been recognized. McCall (1954) and Hilton (1957) identified two strains of Commelina diffusa having differential tolerance to 2,4-D as early as 1950. One strain was easily controlled with 2,4-D at 1.12 kg/ha while 5.6 kg/ha were required to control the other. Whitworth (1964) reported differences in response to 2,4-D by strains of field bindweed (Convolvulus arvensis). Sexsmith (1964) found differences among 12 strains of whitetop (Cardaria chalepensis) in response to 2,4-D. There have also been reports of variation in sensitivity to 2,4-D within collections of kochia (Kochia scoparia) (Bell et al., 1972).

Differential response to a herbicide within a species often depends on factors that influence the amount of herbicide reaching the

phytotoxic site of action. This includes differences in uptake, translocation, and metabolism of the herbicide. The uptake of a herbicide can be influenced by growth habit, cuticle composition and thickness, or leaf surface pubescence. Hodgson (1973) reported that variation in cuticle thickness among Canada thistle (Cirsium arvense) ecotypes modified their response to 2,4-D. Hull (1964) reported an inverse correlation between cuticle thickness and activity of 2,4-D. Increasing thickness of isolated cuticle within a species has been shown to reduce 2,4-D penetration (Skoss, 1955). Norris (1974) reported that the quality and quantity of wax were more important than thickness in determining penetration of 2,4-D.

Translocation of 2,4-D is mostly symplastic with transport of the herbicide to active metabolic sites. Lack of phloem transport is an important mechanism in determining differential sensitivity to 2,4-D among plant species (Jenson, 1982).

Metabolism of 2,4-D to an inactive form is another factor regulating sensitivity to a herbicide. Detoxification of 2,4-D can occur by: (1) side-chain decarboxylation, (2) sugar conjugation, (3) conjugation with glutamine and aspartate, and (4) ring hydroxylation (Mullison, 1982) (Figure 5).

Luckwill and Lloyd-Jones (1960) found that the ability to decarboxylate 2,4-D varied widely between varieties of apples (Pyrus sp.) and strawberry (Fragaria sp.). Tolerant varieties could decarboxylate 59 percent of absorbed ¹⁴C 2,4-D compared to only 2 percent in a sensitive variety. However, inherent tolerance to 2,4-D appears to be more complex than decarboxylation alone. Luckwill and

Lloyd-Jones (1960) showed data from 17 species in which there was no association between tolerance and decarboxylation of 2,4-D.

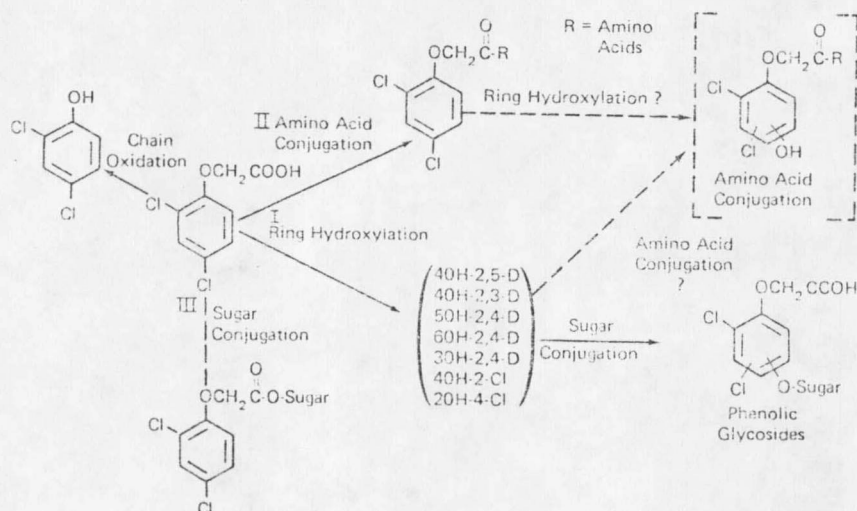


Figure 5. Summary of 2,4-D Metabolism by Plants (from Feung et al., 1978).

Whitworth and Muzik (1967) reported that differential response within field bindweed was not related to differences in leaf morphology, plant vigor, or adsorption and translocation of the herbicide. The differential response appeared to be through deactivation of 2,4-D within cells of the tolerant tissue by binding to nonactive sites. Adsorption to nonactive sites has also been proposed as the mechanism of tolerance within wild carrot (Daucus carota) (Whitehead and Switzer, 1963).

In general, it appears that differential response to 2,4-D within a plant species is based more on internal physiological factors rather than morphological characteristics. Rapid herbicide metabolism and its effect on translocation are often implicated when tolerance within a species is noted. The degree of tolerance within a species appears to be heritable (Jensen, 1982).

Summary

Spotted knapweed is an aggressive, introduced weed that has invaded over 800,000 hectares of grazeable woodland and rangeland in Montana. About 13.8 million hectares are highly susceptible to invasion by spotted knapweed in the state.

Spotted knapweed is well adapted and reproduces effectively by seed. Individual plants can produce from 436 to 25,263 seeds under dryland and irrigated conditions respectively. While the exact period of longevity of viability of spotted knapweed seed in the soil has not been determined, it has been found to exceed five years.

Spotted knapweed can establish and thrive under a wide range of environmental conditions. Once established, spotted knapweed spreads rapidly. The presence of an allelopathic chemical within the leaves of spotted knapweed suppresses the growth of surrounding vegetation. Grass production can be reduced 80 to 90 percent by invasion of spotted knapweed.

Picloram is the most effective herbicide for controlling spotted knapweed. One application of 0.28 kg/ha of picloram can control spotted knapweed for one to five years. The persistence of picloram in

soil determines the length of control of a given weed species. The residual activity of picloram will vary according to temperature, rainfall, soil properties such as percent clay and organic matter, elevation, and initial rate of herbicide applied.

Spotted knapweed control with 2,4-D is extremely variable. Variation in control between sites may be due to environmental differences, or inherent tolerance within strains of spotted knapweed. Morphological and physiological differences within a species can influence uptake, translocation, and metabolism of the herbicide.

CHAPTER 5

THE EFFECT OF REDUCED RATES OF PICLORAM
ON THE LONGEVITY OF CONTROL OF SPOTTED KNAPWEEDAbstract

Spotted knapweed (Centaurea maculosa Lam.) control with picloram and picloram/2,4-D combinations was measured at two locations in Montana. Picloram was applied at rates ranging from 0.07 to 0.28 kg/ha alone and in combination with 2.24 kg/ha of 2,4-D. Results showed that all rates of picloram significantly reduced mature and seedling spotted knapweed densities 26 months following herbicide application. The addition of 2,4-D to 0.07 kg/ha of picloram significantly reduced spotted knapweed density when compared to 0.07 kg/ha of picloram applied alone. Forage production increased 200 to 770 percent in response to the reduction in spotted knapweed density. Soil bioassays clearly indicated that persistence of picloram in soil is an important factor in maintaining long-term control of spotted knapweed.

Introduction

Spotted knapweed (Centaurea maculosa Lam.) is a short lived perennial weed which infests more than 800,000 ha of range and pastureland in Montana (Maddox, 1979). The plant reproduces by seed and spreads rapidly due to an allelopathic effect on surrounding vegetation (Fletcher and Renney, 1963). Carrying capacity can be

reduced 80 to 90 percent by invasion of spotted knapweed (Chicoine, 1984; Watson and Renney, 1974).

Herbicides are the most effective means of controlling spotted knapweed. Picloram at 0.28 kg/ha has been shown to provide from one to five years of control of spotted knapweed (Chicoine, 1984; Cranston, 1984). It has been suggested that the length of control is dependent either on picloram residues remaining in the soil or from competition from associated species (Chicoine, 1984; Harris and Cranston, 1979).

Length of control from picloram rates below 0.28 kg/ha has not been determined. The optimum rate of herbicide needed to control this weed must be determined because of ecological and economic concerns for rangeland.

The objectives of this study were: (1) To determine the optimum herbicide rate of picloram and picloram/2,4-D combinations needed to control spotted knapweed, (2) to measure the growth response of associated vegetation after removal of spotted knapweed, and (3) to measure the persistence of low rates of picloram under rangeland conditions in Montana.

Materials and Methods

Picloram Rate Study

Field trials were established in June, 1982 by Timothy K. Chicoine, former research assistant, Plant and Soil Science Department, Montana State University. Three sites were originally selected for the study however, the site near Stevensville, Montana was destroyed by building construction in 1983. The site characteristics of the remaining two locations are described.

Site 1 was located near Ovando, Montana on the Blackfoot-Clearwater Game Refuge. The study was established on gently rolling foothills characterized by a grassland community type. The site was dominated by timothy (Phleum pratense), smooth brome (Bromus inermis), and Kentucky bluegrass (Poa pratensis). The dominant forb was spotted knapweed. A detailed description of the plant community is shown in Appendix D (Table 35). The site had been cultivated in 1954 and seeded to timothy. There was no grazing use on the study location by either domestic animals or wildlife during the two year study period (Dan Neal, 1985, personal communication).

The elevation at the study site was 1837 m and average annual precipitation during the two year study period was 40 cm (Appendix D, Table 36). The soils were classified as loamy-skeletal, mixed, frigid Typic Haplustols (Appendix D, Table 38).

Site 2 was located approximately 15 miles south of Harlowton, Montana on a floodplain. The site consisted of a grassland vegetation community dominated by western wheatgrass (Agropyron smithii), Kentucky bluegrass (Poa pratensis), needle-and-thread (Stipa comata), and blue grama (Bouteloua gracilis). Spotted knapweed was the dominant forb. A detailed description of the plant community is shown in Appendix D (Table 35). The study area was located within a 245 hectare pasture that was stocked each year with 700 animal units from November through May. Although supplemental feed was provided, the area received heavy grazing pressure during the early spring months (Bill Jones, 1985, personal communication).

The elevation at the site was 2041 m and average annual precipitation was 37 cm during the study period (Appendix D, Table 36). The soil was classified as a loamy-skeletal, mixed, frigid Ustic Torrifluvent (Appendix D, Table 39). The thickness of the surface soil layer ranged from 5 to 20 cm.

Trials were arranged in a split block design with three replications per treatment. Picloram was the main plot treatment and was applied at rates of 0.0, 0.07, 0.11, 0.14, 0.21, 0.22, 0.25, and 0.28 kg a.i./ha. The subplot treatment was 2,4-D applied at the rate of 2.24 kg a.i./ha. Further details concerning the plot design and herbicide application were described by Chicoine (1984).

Mature and seedling spotted knapweed density counts and biomass measurements were taken in July, 1984. Two quarter meter square frames were placed at random locations within each subplot. Mature and seedling spotted knapweed density counts were made in each frame. Vegetation within the frame was clipped at ground level and the current years growth separated into perennial grasses, annual grasses, forbs, shrubs, and spotted knapweed. The vegetation was oven dried at 50 C for 48 hours to determine dry weight. The number of other forb species present in each treatment was determined in June, 1984. Three 0.09 square meter frames were randomly placed within each subplot and the number of forb species recorded.

Data collected may have been biased by earlier field techniques since plots clipped in 1982 and 1983 were not permanently marked or located along established transects. Although an attempt was made to avoid these areas while collecting 1984 density and biomass

The amount of picloram remaining in the soil was determined by bioassay. In preparation for the bioassay, 300 grams of soil from each picloram treatment and the untreated control was placed in 10 cm diameter by 7 cm deep styrofoam cups. Field beans (Phaseolus vulgaris) and spotted knapweed were used as bioassay indicator plants. Five beans and 10 spotted knapweed seeds were placed in each pot. The pots were arranged as a randomized complete block design with three replications per treatment. There were two pots in each replication which served as subsamples.

Plants were grown in the greenhouse at 16 C night and 21 C day temperatures. Supplemental fluorescent light was provided to extend the photoperiod to 16 hours per day. Pots were weighed three times per week and water added to maintain soil moisture at field capacity. After one week, the plants were thinned to three beans and five spotted knapweed per pot and grown for an additional three weeks. The beans were harvested one month after planting and oven dried at 50 C for 48 hours. Dry weights of the first two true leaves were measured. Spotted knapweed seedlings were grown for an additional month, harvested, and the oven dry weight of the seedlings was averaged for each pot. The experiment was conducted twice.

Standard reference curves were prepared using untreated soil from both locations. To determine the amount of picloram necessary to construct the standards, it was assumed that 7.6 cm of soil from an area of one hectare weighed 1.1 million kg. From this assumption, a 0.28 kg/ha application of picloram was equivalent to approximately 256 ppbw.

Standards were prepared by adding 300 grams of untreated soil to styrofoam pots. Solutions of picloram were added to the untreated soil at concentrations of 0, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, and 256 parts per billion by weight (ppbw). The herbicide was allowed to equilibrate in the soil for one week before planting. Field beans and spotted knapweed were used as bioassay plants and grown under the same conditions as described above for the field samples.

Simple linear regression analysis, $Y = a + bx$ (where $a = Y$ intercept and $b =$ slope), was used to analyze the effect of picloram concentrations (independent variable, X) on the weight of the bean leaves (dependent variable, Y) (Figure 5). The regression was used to determine the amount of picloram remaining in the field samples. An analysis of variance was used to test for differences between treatments.

Results and Discussion

Picloram Rate Study

All rates of picloram and picloram/2,4-D combinations significantly reduced mature and seedling spotted knapweed density 26 months after herbicide application (Table 15 and 16). Picloram alone at rates from 0.14 to 0.28 kg/ha continued to provide 100 percent control of mature spotted knapweed 26 months following herbicide application. Complete control of mature spotted knapweed plants was not obtained at picloram rates below 0.14 kg/ha alone or in combination with 2,4-D.

Mature spotted knapweed densities decreased from 35.7 plants in 1982 to 9.0 plants per quarter meter square in 1984 on plots treated

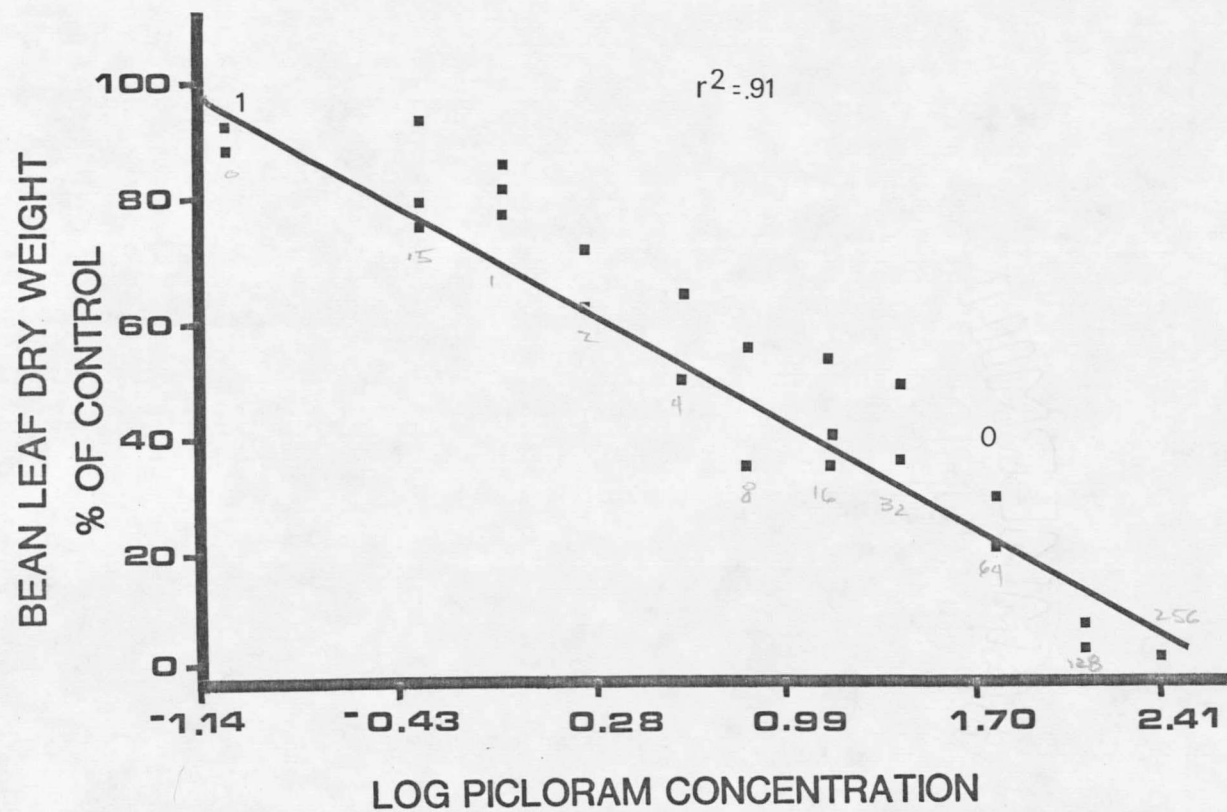


Figure 6. The Standard Curve Used for the Picloram Bioassay.

¹ Points on the Regression Indicate the Dry Weight of Bean Leaves as a Percent of the Control for each Picloram Concentration.

Table 15. Number of Mature Spotted Knapweed Plants per 0.25 m² in July 1983 and July 1984, 14 and 26 Months After Picloram Application at Harlowton and Ovando.¹

	<u>July 1983</u>				<u>July 1984</u>			
	Harlowton		Ovando		Harlowton		Ovando	
Picloram rate (kg/ha)	2,4-D amine rate	kg/ha	2,4-D amine rate	kg/ha	2,4-D amine rate	kg/ha	2,4-D amine rate	kg/ha
	0.00	2.24	0.00	2.24	0.00	2.24	0.00	2.24
0.28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.11	0.0	0.0	0.5	0.3	0.0	0.2	0.5	0.0
0.07	0.4	0.0	35.7	0.1	0.7	0.0	9.0	0.8
0.00	42.1	0.0	25.9	19.1	37.7	1.7	41.8	41.3
LSD.05	0.7		21.7		0.8		5.2	

¹Picloram rates were applied alone and in combination with 2,4-D on June 16 and 17, 1982.

Table 16. Number of Immature Spotted Knapweed Plants per 0.25 m² in July 1983 and July 1984, 14 and 26 Months After Picloram Application at Harlowton and Ovando.¹

	<u>July 1983</u>				<u>July 1984</u>			
	Harlowton		Ovando		Harlowton		Ovando	
Picloram rate (kg/ha)	2,4-D amine rate	kg/ha	2,4-D amine rate	kg/ha	2,4-D amine rate	kg/ha	2,4-D amine rate	kg/ha
	0.00	2.24	0.00	2.24	0.00	2.24	0.00	2.24
0.28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.14	0.1	0.0	0.1	0.0	0.0	0.2	0.5	0.0
0.11	0.5	0.1	0.2	0.1	0.0	0.2	0.7	0.0
0.07	0.4	0.0	48.5	0.1	1.0	0.0	3.2	1.0
0.00	725.0	2.4	510.0	47.1	638.5	2.5	526.5	552.0
LSD.05	89.9		206.2		98.6		66.4	

¹Picloram rates were applied alone and in combination with 2,4-D on June 16 and 17, 1982.

with 0.07 kg/ha picloram at Ovando. Mature spotted knapweed plants growing on these plots in 1983 exhibited picloram symptoms (epinasy and reduced biomass) (Chicoine, 1984). The decrease in spotted knapweed density from 1983 to 1984 was either the result of picloram residues in the soil and/or winter kill due to reduced vigor of the plants. The use of 0.07 and 0.11 kg/ha of picloram is not effective since complete control of mature spotted knapweed plants was not obtained.

Reinvasion by spotted knapweed seedlings occurred in both 1983 and 1984 on plots treated with less than 0.21 kg/ha of picloram (Table 16). Although the number of spotted knapweed seedlings in the treated plots was not significant, it is an important factor in determining the length of control of the weed on rangeland. Previous studies have shown that once seedling establishment begins, complete reinfestation occurs rapidly (Chicoine, 1984). Low seedling establishment in picloram treated plots is the result of either picloram residues in the soil, reduced seedling vigor (due to aging of the seed), and/or competition from perennial grass species.

The addition of 2,4-D with 0.07 kg/ha of picloram significantly reduced spotted knapweed density compared to 0.07 kg/ha of picloram alone at Ovando, however, this relationship was not observed at Harlowton. Picloram alone at rates above 0.07 kg/ha provided the same control of spotted knapweed as picloram in combination with 2,4-D. The application of 2,4-D alone significantly reduced mature spotted knapweed densities at Harlowton, but had no effect on plant density at Ovando in either 1983 or 1984 (Table 15).

Perennial grass production increased 200 to 770 percent on herbicide treated plots 26 months after application (Table 17). Combinations of 2,4-D amine and 0.07 kg/ha of picloram increased perennial grass production 37 percent when compared to 0.07 kg/ha of picloram alone at Ovando. Application of 2,4-D alone increased perennial grass production 200 percent at Harlowton but caused no significant increase in grass production at Ovando. The release of perennial grass growth is probably due to elimination of the allelopathic influence of spotted knapweed (Fletcher and Renney, 1963).

Table 17. Perennial Grass Production on July 20, 1984, 26 Months After the Application of Picloram to Control Spotted Knapweed at Harlowton and Ovando.¹

Picloram Rate kg/ha	Perennial Grass Production (kg/ha)			
	Harlowton		Ovando	
	2,4-D Amine kg/ha 0.00	2.24	2,4-D Amine kg/ha 0.00	2.24
0.28	807.2	627.2	2612.8	2877.6
0.25	795.2	705.2	2686.4	2928.8
0.22	841.6	702.8	2739.2	3086.4
0.21	747.2	656.0	3235.6	2658.8
0.14	702.0	665.6	2896.8	2427.6
0.11	640.4	754.0	2517.6	2726.8
0.07	659.6	568.0	1636.4	2594.4
0.00	256.7	542.0	418.4	482.8
LSD .05	222		371	
C.V. %	17		8	

¹ Picloram rates were applied alone and in combination with 2,4-D amine on June 16 and 17, 1982.

Perennial grass production was negatively correlated ($r=-.955$) to spotted knapweed density at Ovando (Figure 7). Grass production

decreased from 35 to 65 percent as spotted knapweed density increased from 5 to 18 plants per quarter meter square respectively. The correlation between forage yield and spotted knapweed density was -0.798 at the Harlowton site (Figure 8). Utilization of grass by cattle is responsible for the decrease in correlation at this site. These observations are consistent with results reported by Watson and Renney (1974) for diffuse knapweed.

There was no significant difference in the number or biomass of other forbs present on picloram or picloram/2,4-D treated plots compared to the control (Tables 18 and 19). Picloram applications did not cause a shift in forb species (Appendix D, Tables 40 and 41). The

Table 18. The Number of Forbs Other Than Spotted Knapweed Per 0.09 m² in June 1984, 24 Months After Herbicide Application at Harlowton and Ovando.¹

Picloram Rate (kg/ha)	Number of Other Forbs per 0.09 m ²			
	Harlowton		Ovando	
	2,4-D Amine Rate (kg/ha)		2,4-D Amine Rate (kg/ha)	
	0.00	2.24	0.00	2.24
0.28	0.53	0.88	0.11	0.00
0.25	0.22	0.11	0.11	0.00
0.22	0.44	0.33	0.22	0.44
0.21	0.33	0.33	0.00	0.22
0.14	0.66	0.44	0.55	0.88
0.11	0.99	0.99	0.44	0.33
0.07	1.33	1.11	0.33	0.22
0.00	1.22	0.44	0.00	0.11
LSD .05	0.64		0.44	
CV%	77		93	

¹ Picloram was applied alone and in combination with 2,4-D amine on June 16 and 17, 1982 respectively.

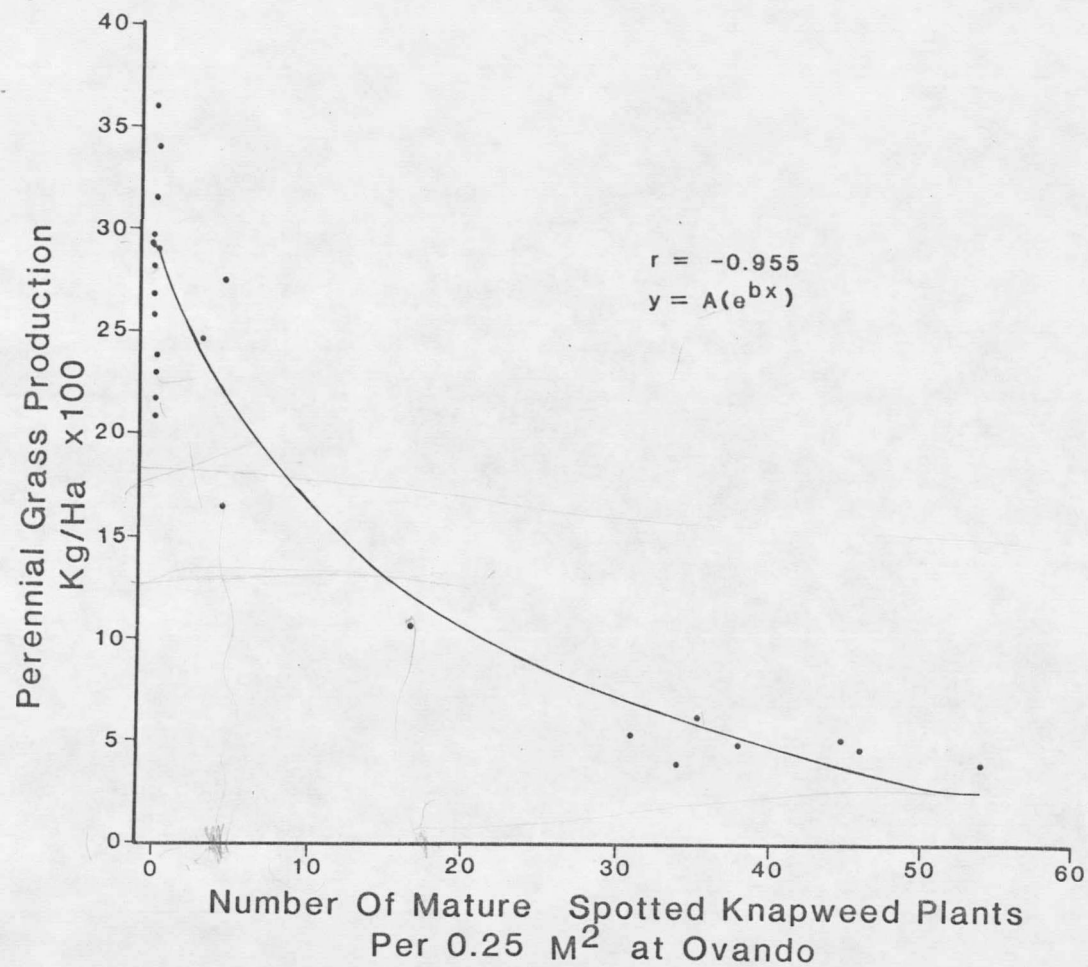


Figure 7. The Correlation Between Perennial Grass Production and Mature Spotted Knapweed Density at Ovando.

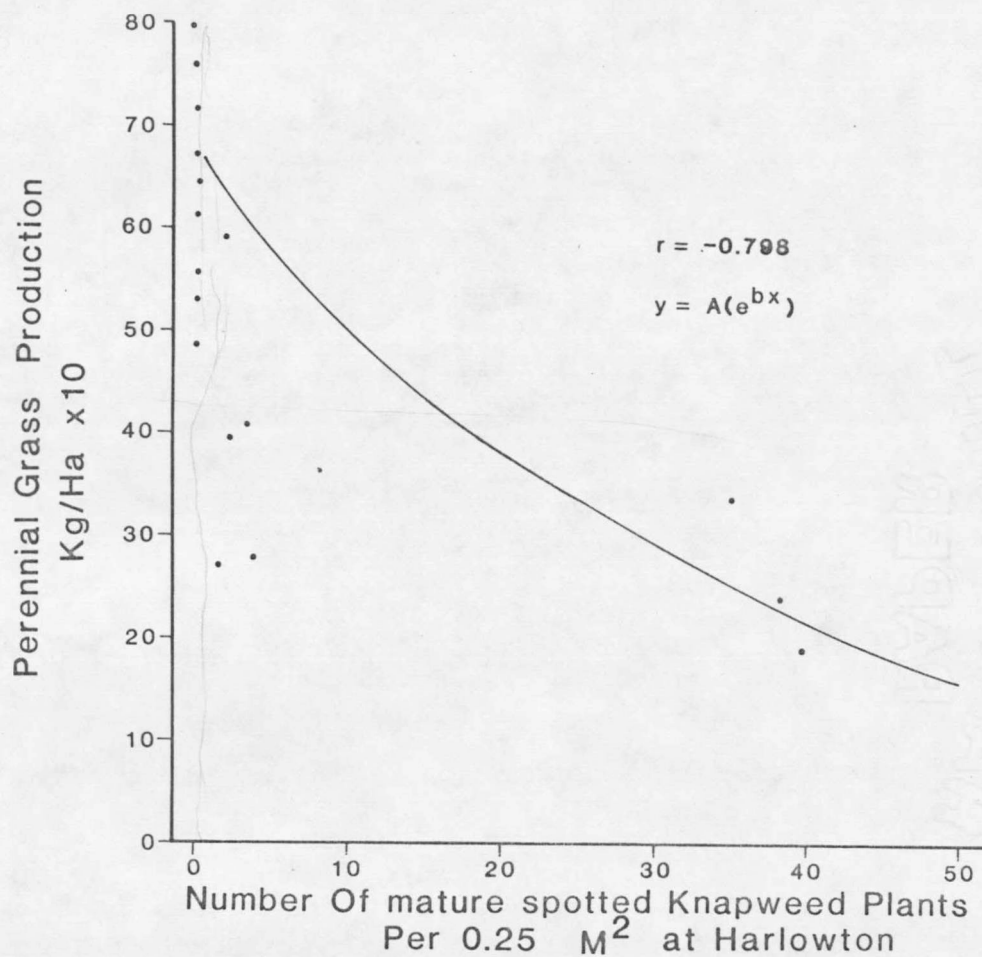


Figure 8. The Correlation Between Perennial Grass Production and Mature Spotted Knapweed Density at Harlowton.

low number of forbs present in untreated control plots indicates that spotted knapweed may suppress growth and establishment of forb species. These results suggest that low rates of picloram do not impair forb diversity on knapweed-infested rangeland.

Table 19. The Biomass of Forb Species Other Than Spotted Knapweed 26 Months After Herbicide Application at Harlowton and Ovando.¹

Picloram Rate kg/ha	Forb Biomass (kg/ha)			
	Harlowton		Ovando	
	2,4-D Amine kg/ha 0.00	2.24	2,4-D Amine kg/ha 0.00	2.24
0.28	19.2	50.8	6.8	0.0
0.25	28.4	43.6	5.2	8.9
0.22	63.6	17.3	12.8	0.0
0.21	22.0	76.0	0.0	14.4
0.14	104.0	83.2	16.4	9.4
0.11	53.2	78.4	0.0	0.0
0.07	96.0	106.8	6.8	0.0
0.00	92.8	104.0	0.0	15.3
LSD .05	102		21	
CV%	82		183	

Picloram Residue Study

Significant amounts of picloram remained in the soil 26 months after application. Data from both sites will be discussed concurrently since the amount of picloram in the soil was the same at both sites.

Approximately 12 ppbw of picloram was detected in soil after 26 months on plots which were originally treated with 0.28 kg/ha of picloram (Figure 9). This is equivalent to about five percent of the original concentration of picloram applied. There was a linear decrease in the amount of picloram remaining in the soil from 12 ppbw

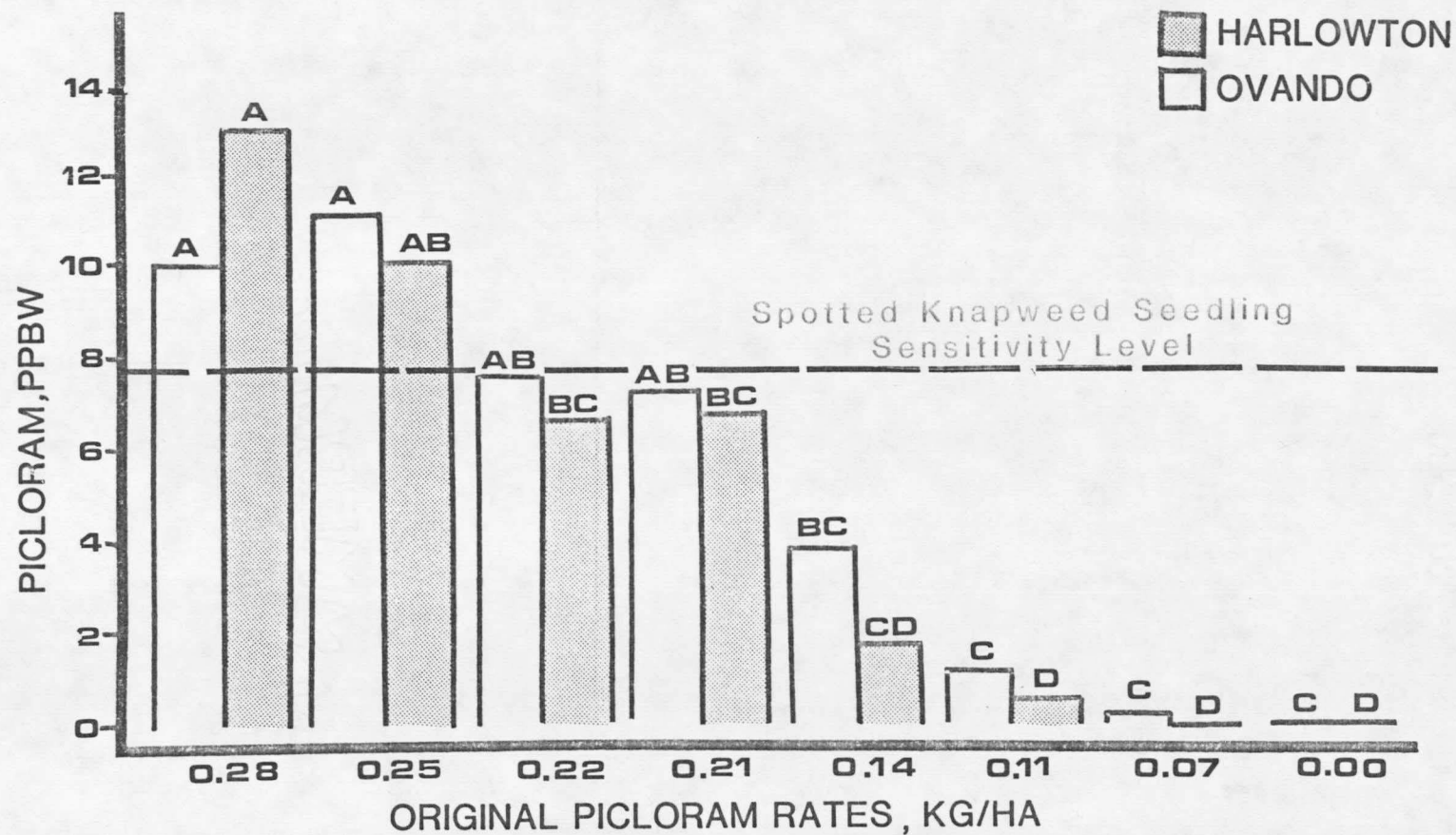


Figure 9. The Amount of Picloram Detected in Soil at Harlowton and Ovando 26 Months After Picloram Application.

for the highest rate applied (0.28 kg/ha) to less than 1 ppbw for the lowest rate applied (0.07 kg/ha).

The amount of picloram remaining in these soils is greater than that which would be predicted from published literature. Hamaker et al. (1967) used the following equation of half-order kinetics to calculate the persistence of picloram in soil:

$$\text{Months of Activity} = 2(\sqrt{C_0} - \sqrt{C})/K$$

where: C_0 = treatment rate oz ai/A

C = amount of picloram remaining after a specific time

K = half order constant

This equation was used to compare the estimated persistence of picloram for Montana soils to the recovered picloram in this residue study (Table 20). Results showed that picloram remained in rangeland soils in Montana 40 to 50 percent longer than is predicted by Hamaker et al. (1967).

Table 20. The Persistence of Picloram in Montana Soils as Estimated by Hamaker et al. (1967) and this Residue Study.

Picloram Rate kg/ha	Months to reach 0.6 ppbw in soil		
	Prediction by Hamaker		Present Field Study
	K values ¹		K value
	K=0.19	K=0.25	K=0.11
0.28	20.0	15.2	34.5
0.25	18.8	14.3	32.5
0.22	17.6	13.3	30.4
0.21	17.2	13.0	29.6
0.14	13.8	10.5	23.9
0.11	12.1	9.2	20.9
0.07	9.5	7.2	16.3
0.00	0.0	0.0	0.0

¹K values indicate half-order constants that were calculated to predict the persistence of picloram in soil.

The extended persistence of picloram in rangeland soils in Montana may be the result of several factors. First, cool summer and cold winter temperatures, which characterize both sites (Appendix D, Table 37), would slow the rate of microbial degradation of picloram (Grover, 1967; Goring et al., 1965; Keys and Frisen, 1968). Second, there was little or no loss of picloram by leaching because of the low rainfall regimes at the two study sites.

The results of the greenhouse bioassay indicated that spotted knapweed seedlings are injured by 8 ppbw of picloram in the soil (Figure 9). This indicates that picloram rates of 0.28 and 0.07 kg/ha would control spotted knapweed seedling growth for 29.7 and 11.5 months respectively (Table 21). Results also indicate that all rates of picloram applied in the field study will probably drop below the sensitivity level of spotted knapweed seedlings three years after application. Since most seedling establishment usually occurs during the spring of the year, 0.21 kg/ha of picloram will probably provide the same length of control as 0.28 kg/ha.

Table 21. Length of Time Necessary for Picloram Residues to Decrease Below the Sensitivity Level (8 ppbw) of Spotted Knapweed Seedlings.

Picloram Rate of application (kg/ha) (ppbw)		Estimated Months Required for Picloram Residues to Reach 8 ppbw
0.28	256	29.7
0.25	228	27.7
0.22	201	25.6
0.21	192	24.8
0.14	128	19.1
0.11	100	16.1
0.07	78	11.5
0.00	0	0.0

These results have important implications for management of spotted knapweed. The use of 0.21 kg/ha of picloram rather than the current recommendation of 0.28 kg/ha would reduce the cost of a control program in Montana by \$2.80 per acre (based on the present price of Tordon 22K at \$90.00 gallon). These results also indicate that the residual activity of all rates of picloram applied in this study will not persist beyond the longevity of viability of spotted knapweed seeds in soil. Therefore, at least one reapplication of picloram will be necessary to prevent reinvasion of this weed from an indigenous soil-borne seed population. This study should be continued to determine the optimum picloram rate needed as a retreatment in an attempt to eradicate spotted knapweed.

Summary

Spotted knapweed is the most troublesome weed of rangeland in western Montana. Picloram at rates of 0.14 to 0.28 kg/ha provided complete control of mature spotted knapweed plants for at least two years. Picloram rates below 0.14 kg/ha should not be recommended as a control alternative since spotted knapweed seed production was not completely stopped. Likewise, the addition of 2,4-D amine to picloram should not be recommended since it will not significantly improve control over an application of picloram alone. Reinvasion by spotted knapweed seedlings occurred 26 months following application of picloram at rates below 0.21 kg/ha.

Removal of spotted knapweed from the plant community with herbicides resulted in grass production increases of 200 to 770

percent. The increase in grass production was strongly correlated to spotted knapweed density; as spotted knapweed density increased, perennial grass production decreased. There were no adverse changes in plant diversity, plant number, or biomass production of other forb species on the two sites as a result of picloram applications.

Picloram residues are the most important factor in determining the longevity of control of spotted knapweed. Results of the residue study indicate that none of the picloram rates tested will remain in the soil long enough to exhaust the seed reserve of spotted knapweed. Therefore, at least one reapplication of picloram will be necessary in order to eradicate spotted knapweed from an infested site.

CHAPTER 6

THE EFFECT OF 2,4-D ON TWO
STRAINS OF SPOTTED KNAPWEEDAbstract

Differential tolerance to 2,4-D (2,4-dichlorophenoxy) acetic acid) was observed in spotted knapweed (Centaurea maculosa Lam.) in field experiments conducted at Harlowton and Ovando, Montana. Plants were collected from both locations and grown under identical conditions for field and laboratory evaluation. Experimental results indicated that there were no difference in response to 2,4-D applications between plants from the two locations when grown together. Application of 2,4-D at 2.24 kg/ha caused slight injury symptoms to both strains of spotted knapweed. Laboratory studies showed that there was no difference in uptake of ^{14}C 2,4-D between the two strains when leaf surface pubescence was intact. Twenty four percent of the applied ^{14}C 2,4-D was taken up by excised leaves in 48 hours. Uptake doubled when leaf surface pubescence was removed. Radiolabeled 2,4-D translocated throughout plants within one day following treatment. There was no difference between the two strains in the amount of 2,4-D that was translocated to different plant parts, 1, 4, and 8 days following application. However, the concentration of ^{14}C 2,4-D was 3.3 times greater in the crown of plants from Harlowton compared to Ovando plants 12 days following application. The observed tolerance to 2,4-D in the

initial field studies appears to be the result of differences in plant vigor rather than differences in uptake or translocation of the herbicide.

Introduction

Variations in interspecific tolerance to 2,4-D have been reported. Hodgson (1970) reported that ten ecotypes of Canada thistle (Cirsium arvense) responded differently to 2,4-D. Differences in response to 2,4-D have also been reported between strains of field bindweed (Convolvulus arvenses) (Whitworth, 1964), hoary cress (Cardaria chalapensis) (Sexsmith, 1964), wild carrot (Daucus carota) (Whitehead and Switzer, 1963), and kochia (Kochia scoparia) (Bell et al., 1972).

Field studies indicate that some strains of spotted knapweed may be tolerant to 2,4-D. Spotted knapweed control one year following application of 2.24 kg/ha of 2,4-D ranged from 21 to 100 percent at Ovando and Harlowton, Montana, respectively (Chicoine, 1984). Variation in the response of spotted knapweed to 2,4-D has also been reported by Wattenbarger et al., (1980).

Additional information concerning the variation in susceptibility of spotted knapweed to 2,4-D is needed to understand the potential of the weed to develop tolerance to the herbicide, and explain incidents of incomplete weed control. Specific objectives of this study were to: (1) evaluate the effect of 2,4-D on two strains of spotted knapweed when grown at one field location, and (2) measure 2,4-D uptake and movement between two strains of spotted knapweed.

Materials and Methods

Mature spotted knapweed plants which were not controlled by 2,4-D were collected on November 13, 1983 at Ovando, Montana from plots treated for two successive years with 2.24 kg/ha of 2,4-D. Mature plants were also collected from a population near Harlowton, Montana, on November 14, 1983. Although these plants had not been treated with 2,4-D, other plants growing at the site were found to be extremely sensitive to the herbicide. Plants from both sites were transported to Bozeman, Montana, for controlled field and laboratory studies.

Field Study

Fifty spotted knapweed plants from each location were planted at the Post Agronomy Farm, Bozeman, during November, 1983. Plants were spaced 0.9 meters apart with a three meter buffer strip separating the two strains. The soil at the study site was classified as Bozeman silt loam (Argic Pachic Cryoboroll) with three percent organic matter in the 0 to 20 cm depth. Average monthly temperature and precipitation data for the study area is shown in the Appendix D, (Tables 42 and 43). The soil had been fallowed for one year prior to planting.

Plants were evaluated on April 13, 1984 for winter injury. Plants that were winter killed were replaced with greenhouse-grown plants from the respective locations.

Plant height, number of stems, and date of flowering was recorded for each plant during the summer. Bolt height was measured on June 17 and 29, and July 11 and 26. The number of stems per plant was recorded

on July, 26. Date of flowering was recorded on July 11, 15, 26, and 30, and on August 2 and 9, 1984.

Herbicide treatments of 0.0, 1.12, and 2.24 kg a.i./ha of the diethanolamine salt of 2,4-D were applied on June 29, 1984. Plots were arranged in a randomized complete block design with three replications per treatment. There were five plants per plot. Plant height at the time of herbicide application averaged 50 cm for plants from Ovando, and 24 cm for plants from Harlowton. The 2,4-D was applied with a CO₂ pressurized backpack sprayer in 167 l/ha of water. Plant injury was evaluated visually, using a 0 to 10 scale, where 0 and 10 indicated no injury, and death of a plant respectively. Injury ratings were taken on July 7 and August 2, 1984. Above ground biomass was harvested on August 9, oven dried at 50 C for 48 hours, and weighed.

Plants were allowed to regrow after harvest and 2,4-D was applied in the fall to plants in the rosette growth stage. The diethanolamine salt of 2,4-D was applied at rates of 0.0 and 2.24 kg a.i./ha to each strain on September 3, 1984 as described above. Plant injury was evaluated on September 5, and 15, and on October 12, 1984 using the method described above for the June herbicide application.

Uptake Studies

Spotted knapweed plants used for the laboratory studies were potted in 1.8 liter containers in November, 1983. They were grown in the greenhouse for six months with 16C day temperature and 21C night temperature. Fluorescent lights were used to extend the photoperiod to 16 hours per day.

Six spotted knapweed plants from Harlowton and six plants from Ovando were selected for the study. Four leaves were taken from the basal rosette of each plant. This sampling scheme allowed one leaf from each plant to be represented in each treatment. The leaves were excised while the whole plant was submersed in water to minimize xylem plugging (Richard and Slife, 1979). Each leaf was placed in a 2 cm diameter by 15 cm long test tube containing 35 mls of glass-distilled, de-gassed water. While submersed, 0.5 cm of leaf tissue was removed from the cut end of the leaf. The leaves were placed in the dark at 21 C. After 45 minutes, the leaves were removed from the dark and placed under 234 uE/m²/sec of light intensity at 21 C for a one-hour equilibration period. Relative humidity of the leaf surface was measured with a Licor autoporometer to determine if the leaf was actively transpiring. Only leaves that were actively transpiring were used in the study.

The surface pubescence on the adaxial surface of 12 leaves from each spotted knapweed strain was removed by rubbing the leaf ten times between the forefinger and thumb. Twelve leaves from each strain were not rubbed and served as controls. Uniformly ring labeled 2,4-D (0.08 uCi) was applied in four, 0.5 ul drops to the adaxial surface of each leaf.

Radiolabeled 2,4-D was received as (2,4-dichlorophenoxy)acetic acid ring UL-¹⁴C labeled (100 uCi) with specific activity of 9.0 uCi/mmole. The ¹⁴C 2,4-D was dissolved in 500 ul of 50 percent ethanol. A 150 ul aliquot was removed from this solution and combined with diethanolamine in a 1:1 molar concentration. The diethanolamine

salt of ^{14}C 2,4-D was diluted with 50 percent ethanol and 90 ul of a solution containing commercially formulated diethanolamine salt of 2,4-D (0.28 kg a.i./ha) to provide a total volume of 600 ul with 28.8 uCi of activity.

Uptake was measured at 24 and 48 hours after application of ^{14}C 2,4-D. At the end of each uptake period, six rubbed and six unrubbed leaves from each strain were removed from the de-gassed water. Each leaf was placed in a 35 ml test tube and rinsed three times for 30 seconds with 10 ml of 50 percent ethanol by agitating on a vortex mixer. This technique ensured removal of unabsorbed ^{14}C 2,4-D from the leaf surface. The wash solutions were combined and brought to a total volume of 30.0 ml with 50 percent ethanol. A 1.0 ml aliquot was removed and placed in a scintillation vial with 15 ml of Hydrocount Scintillation Fluid ¹. Total volume of the de-gassed water solution was recorded and a 1 ml aliquot was placed in a scintillation vial with 15 ml of Hydrocount Scintillation Fluid. The radioactivity in the vials was measured for 10 minutes by liquid scintillation spectrometry ². All treatments were replicated six times in a completely randomized design. The experiment was conducted twice, and the data shown in for both experiments combined unless otherwise stated.

¹ Hydrocount is manufactured by J.T. Baker Chemicals B.V., Deventer, Holland.

² Tri-Carb model 2002, Packard Instrument Co., Downers Grove, IL

Translocation Studies

Mature spotted knapweed plants were grown in the greenhouse as described above for uptake studies. Plants of uniform size and growth stage were selected for the study. A broadcast application of commercially formulated diethanolamine salt of 2,4-D was applied to each plant at 0.28 kg a.i./ha in 196 l/ha of water using a greenhouse belt sprayer. Immediately after application, ^{14}C 2,4-D acid (0.485 μCi) was applied in 10, 1 μl drops to the adaxial surface of one leaf. The treated leaf was located on the lower portion of the rosette and marked with a paper tag.

The plants were placed in a growth chamber with a 16 hour photoperiod with a day/night temperature of 22/20 C, respectively. Light was provided by fluorescent and incandescent tubes and the intensity at the base of the plant crown was 234 $\mu\text{E}/\text{m}^2/\text{sec}$.

Plants were harvested 1, 4, 8, and 12 days after application of ^{14}C 2,4-D. The treated leaf was removed and washed three times in 50 percent ethanol to remove the radioactive 2,4-D as described under the uptake studies above. The remaining plant was sectioned into the following parts: leaves with the treated leaf, other leaves, crown, upper root system, and lower root system (Figure 10). Each plant part, including the treated leaf, was immediately frozen with dry ice, lyophilized, and weighed. Plant parts were homogenized with mortar and pestle. Samples (100 mg) were taken from the homogenized material and oxidized in a biological material oxidizer ³ for three minutes. The

³ Harvey Oxidizer, Ox 300, Harvey Instrument Co., 123 Patterson St., Hillsdale, N.J.

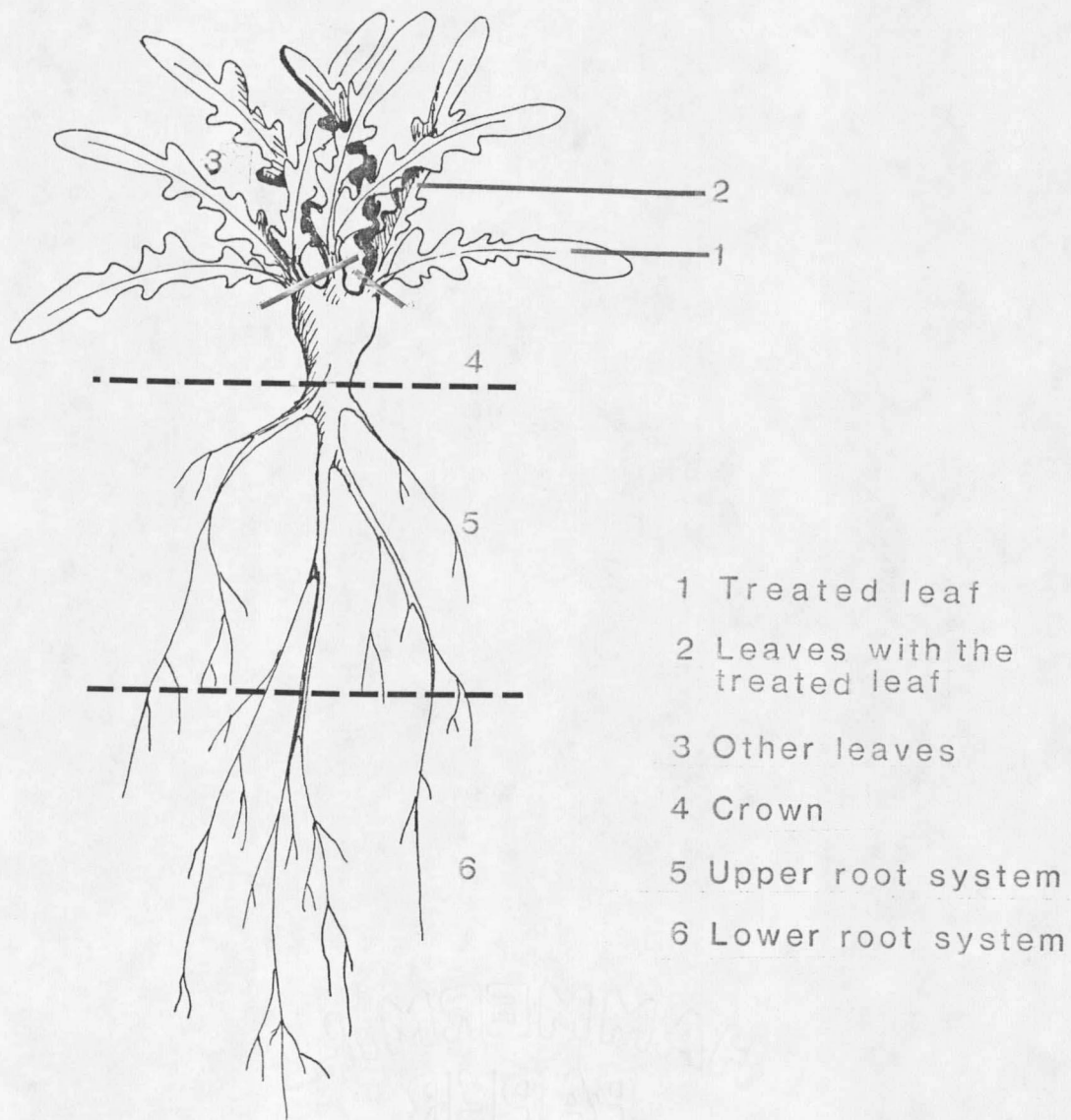


Figure 10. Spotted Knapweed Plant Parts That Were Collected to Determine Regions of ^{14}C 2,4-D Accumulation.

oxidizer efficiency data is shown in Appendix D, (Figures 18 and 19). The ^{14}C was trapped in Carbon 14 Cocktail ⁴as ^{14}C CO_2 . The ^{14}C content was then measured for 10 minutes in a liquid scintillation spectrometer. All treatments were replicated four times in a completely randomized design.

Results

Field Studies

There was a significant difference in growth rate and date of flowering between plants collected at Harlowton (susceptible strain) and Ovando (tolerant strain) (Figures 11 and 12). Plants from Ovando had a faster growth rate and began flowering earlier than plants from Harlowton. The number of stems per plant was the same for the two strains.

There were significant differences between the two strains of spotted knapweed in response to the June application of 2.24 kg/ha of 2,4-D (Table 22). Plants from Ovando showed more injury symptoms than plant from Harlowton, however, the level of injury for both strains was very low. None of the plants grown in the study were killed by the herbicide application in June.

A major problem with the June application was that the two strains of spotted knapweed were in different growth stages. Plants from Ovando were growing more rapidly and averaged 50 cm in height compared to 24 cm for plants from Harlowton. Actively growing plants are more

⁴ Carbon 14 Cocktail is manufactured by R.J. Harvey Instrument Corp.

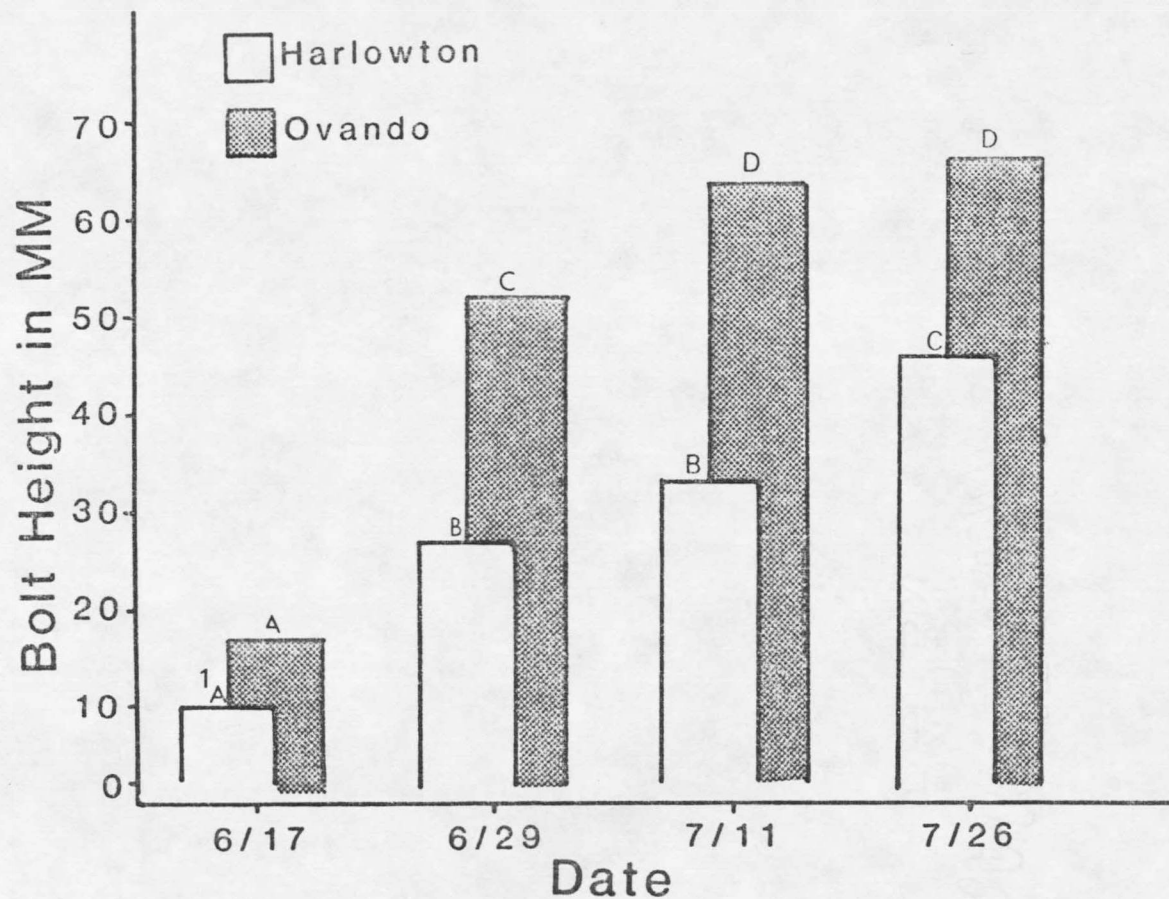


Figure 11. The Bolt Height of Spotted Knapweed Plants Collected From Harlowton and Ovando, Montana from June 17 to July 26, 1984.

¹ Bars with the same letter are not significantly different at the 5 percent level using the LSD test.

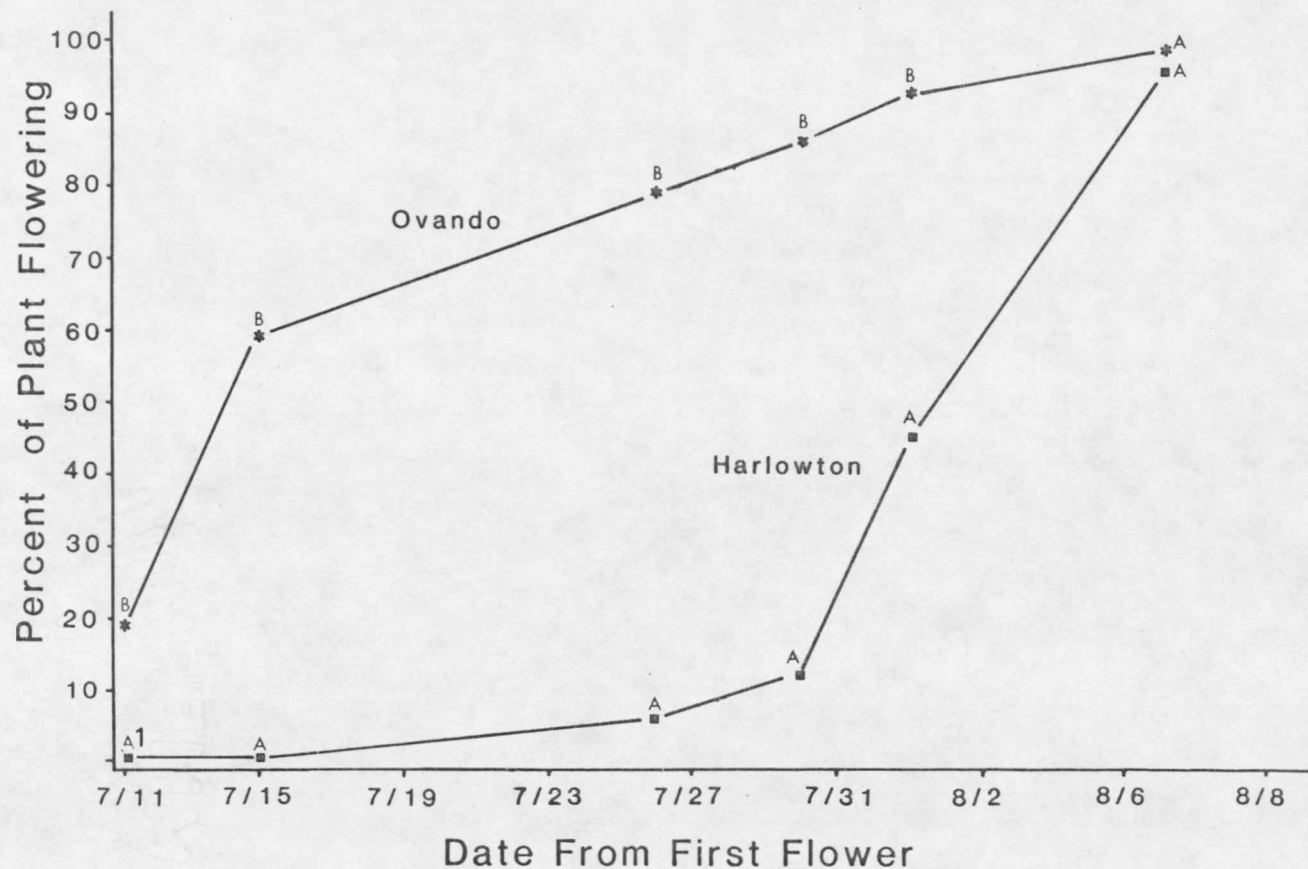


Figure 12. The Percent of Spotted Knapweed Plants Collected From Harlowton and Ovando That Were Flowering from July 11 to August 8, 1984.

¹ Points at the same date followed by the same letter are not significantly different at the 5 percent level using the LSD test.

Table 22. Injury Ratings for Spotted Knapweed Plants Collected at Ovando and Harlowton 40 Days After Foliar Treatment With Diethanolamine Salt of 2,4-D.¹

2,4-D kg/ha	Date of 2,4-D Application			
	6/29/84		9/3/84	
	Ovando	Harlowton	Ovando	Harlowton
0.00	0.00a ²	0.00a	0.00a	0.00a
1.12	1.00b	0.80b	-	-
2.24	4.40d	2.10c	4.60b	6.10b

¹Injury Ratings are based on visual observations where 0 = no injury and 10 = death of plant.

²Means in columns for each date followed by the same letter are not significantly different at the 5% level using the LSD test.

susceptible to 2,4-D (Bell et al., 1972), which could explain the differences in response to the 2,4-D applications. The application of 2.24 kg/ha of 2,4-D reduced above-ground biomass 50 and 45 percent in plants from Ovando and Harlowton, respectively (Table 23). There was no significant reduction in biomass with the application of 1.12 kg/ha of 2,4-D in plants from either location. The difference in plant height and relative vigor between the two strains is evident in the above-ground biomass measurements. Plants from Harlowton weighed an average of 65 percent less than plants from Ovando in both treated and untreated plots (Table 23).

Plants receiving a fall application of 2,4-D exhibited injury symptoms two days after herbicide application. In contrast to the June application, plants from Harlowton treated in the fall were injured more than plants from Ovando, however, the differences were not statistically significant (Table 22). The difference in response of the two strains to spring and fall applications of 2,4-D suggests that

Table 23. Above Ground Dry Weight Biomass of Spotted Knapweed Strains Collected from Harlowton and Ovando. Plants were Treated with 2.24, 1.12, and 0.00 kg/ha of 2,4-D on 6-29-84 and Harvested on August 8, 1984.

2,4-D (kg/ha)	Dry Weight Biomass (g/plant)	
	Ovando	Harlowton
0.00	178.7b ¹	61.0a
1.12	178.7b	41.4a
2.24	90.4a	33.8a

¹ Means followed by the same letter are not significantly different at the 5 percent level using the LSD test.

growth rate is a factor which affects the sensitivity of spotted knapweed to the herbicide.

Results of these field studies indicate there is no difference in response to 2,4-D between the two strains of spotted knapweed when grown under identical environmental conditions. Differences in the rate of growth and date of flowering between the two strains may be due either to genetic differences between plants from the two locations or differences in plant vigor.

Uptake Studies

There was no difference in uptake of 2,4-D between the two strains of spotted knapweed over a 48 hour period in leaves with the pubescence intact. However, the uptake was significantly greater in leaves excised from Ovando plants when the surface pubescence was removed (Table 24). Uptake was also 50 percent greater in leaves with the leaf pubescence removed compared to leaves with the pubescence intact. Uptake continued to increase in rubbed leaves after 24 hours.

The percent ^{14}C 2,4-D recovered in rubbed leaves increased from 41 to 47 percent respectively 24 and 48 hours following application (Table 25).

Table 24. Total DPM's of ^{14}C 2,4-D Recovered Over a 48 Hour Period in the Leaf Wash, Solution, and Leaves Excised From Spotted Knapweed Plants Collected From Harlowton and Ovando.²

	Total DPM's			
	Pubescence Intact		Pubescence Removed	
	Harlowton	Ovando	Harlowton	Ovando
Leaf Wash ²	136000c	135700c	108500b	97990a
Solution	116a	159a	202a	300a
Treated Leaf	34220a	34520a	61690b	72100c
Total DPM's ¹	170336	170379	170392	170390

¹170,400 DPM's were applied to the leaf surface.

²Means within the same row followed by the same letter are not significantly different at the 5 percent level using the LSD test.

Table 25. The Percent of ^{14}C 2,4-D That was Absorbed in Leaves With Pubescence Removed and Pubescence Intact 24 and 48 Hours Following Application.²

Hours After Treatment	^{14}C Absorbed			
	Pubescence Intact		Pubescence Removed	
	%	(DPM)	%	(DPM)
24 ¹	19.9	(33910)c	40.7	(69353)b
48	23.4	(39874)c	46.8	(79747)a

¹ Means followed by the same letter are not significantly different at the 5% level using the LSD test.

² Data shown are for one experiment with Harlowton and Ovando plants combined.

³ 170,400 DPM's were applied to the leaf surface.

Surface pubescence appears to be important in regulating uptake of 2,4-D into spotted knapweed leaves especially in plants collected from Ovando. The amount of ^{14}C 2,4-D taken up by pubescent leaves was only 23 percent compared to 47 percent for leaves with the pubescence removed. Although care was taken in removing pubescence from the leaf surface, it is possible that additional damage may have occurred to the leaf cuticle. This could have influenced the amount of 2,4-D absorbed. Ineffective uptake of 2,4-D may be a major factor which explains the unacceptable control often achieved with field applications.

Translocation Studies

Results from the translocation studies indicate that radiolabeled 2,4-D is translocated throughout both strains of spotted knapweed one day following application (Table 26) (Appendix, Table 46). The concentration of ^{14}C 2,4-D recovered in leaves with the treated leaf was significantly greater in plants from Ovando compared to plants from Harlowton one day following application. However, there was no difference in the amount of ^{14}C 2,4-D translocated to other plant parts between the two strains 1, 4, and 8 days following application. The highest concentration of ^{14}C 2,4-D remained in the treated leaf throughout the study period.

Significant differences in translocation patterns were detected for the two strains 12 days after application (Table 26). The amount of ^{14}C 2,4-D recovered from the plant crown was greater for Harlowton plants. However, based on the results of the field studies, this difference in translocation between the two strains does not appear to be great enough to cause a differential response to 2,4-D.

Table 26. The Concentration of ^{14}C 2,4-D (expressed as DPM's per gram of dry tissue) That Was Recovered in Different Parts of Spotted Knapweed Plants from Harlowton (H) and Ovando (O), Montana, 1, 4, 8 and 12 Days Following Application.

Plant Part	DPM's per gram dry weight ²							
	Days After application							
	1		4		8		12	
treated leaf ¹	713600a	685100a	498700a	477100a	438300a	580300b	406100a	473200a
leaves with treated leaf	11440a	5841b	20020a	18200a	12890a	8962a	7555a	14800b
other leaves	1793a	757a	1452a	1507a	2131a	987a	1697a	1183a
crown	6009a	5191a	9844a	11620a	9860a	9289a	20690b	6194a
upper root	2462a	971a	2996a	3828a	5134a	4855a	5657a	2914a
lower root	443a	295a	1757a	1836a	3011a	1949a	3568a	2059a

¹Means in rows for each date followed by the same letter are not significantly different at the 5 percent level using the LSD test.

²A total of 1,067,000 DPM's were applied to each plant.

Discussion

Field observations of herbicide trials at Ovando and Harlowton, Montana, indicated that control of spotted knapweed with 2,4-D was erratic. Controlled field and laboratory studies showed no difference in response to 2,4-D between strains from each location when grown together. Both strains exhibited tolerance to 2,4-D under optimum growing conditions.

The differential response to 2,4-D in original field studies may be due to differences in the relative vigor of the plants growing at the two locations. Data from the field locations shows that above ground biomass of spotted knapweed was 37 percent greater at Ovando than Harlowton (Chicoine, 1984) (Table 27). Plants from Ovando also appear to be more winter hardy than plants from Harlowton. Winter kill of the Ovando and Harlowton plants, when grown at Bozeman, averaged 16 and 40 percent respectively.

Table 27. The Density and Above Ground Biomass of Mature Spotted Knapweed Plants Growing at Harlowton and Ovando, Montana.¹

Location	Plant Density per 0.5 m ²	Biomass kg/ha
Harlowton	47	2100
Ovando	46	3264

¹ Data were collected on August 4, 1982.

Soil fertility levels at the two sites may explain the differences in plant vigor. Nitrate levels in the surface foot averaged 76 and

1.8 ppm and phosphorus levels were 26 and 6 ppm at Ovando and Harlowton, respectively (Table 28). The extremely low soil fertility levels at the Harlowton site may be responsible for the decreased vigor evident in these plants.

Table 28. The Amount of Nitrogen, Phosphorus, and Potassium in the Surface Foot of Soil from Harlowton and Ovando, Montana.

Location	Nppm	Pppm	Kppm
Harlowton ¹	1.8	6	325
Ovando	76.0	26	294

¹ Data for Harlowton is based on the average of composite samples taken from both the eastern and western portion of the study site.

The more favorable growing conditions encountered in the greenhouse and in the field studies conducted at Bozeman increased the vigor of plants from Harlowton. This increased vigor may have made the plants more tolerant to 2,4-D. Limited uptake of 2,4-D by spotted knapweed may also reduce the phytotoxic effects of the herbicide within the plant. These results suggest that under optimum growing conditions, spotted knapweed is somewhat tolerant to 2,4-D.

Summary

Field and laboratory studies were conducted to measure the response of two strains of spotted knapweed to 2,4-D. There was a significant difference in average bolt height, date of flowering, and above-ground biomass for the two strains. There was no difference between the two strains in response to application of 1.12 and 2.24

kg/ha of 2,4-D knapweed. Uptake and translocation of ^{14}C 2,4-D was the same in both strains of spotted knapweed up to 8 days following application. Leaf surface pubescence appears to interfere with the uptake of 2,4-D. The amount of ^{14}C 2,4-D absorbed into excised leaves was 24 percent in normal pubescent leaves compared to 47 percent when leaf pubescence was removed.

The differential response of spotted knapweed to 2,4-D observed in field studies at Ovando and Harlowton may be due to differences in plant vigor. When grown at the same location under optimum growing conditions, plants from both locations exhibited tolerance to 2,4-D.

CHAPTER 7

SEED LONGEVITY OF SPOTTED KNAPWEED
IN MONTANA SOILSAbstract

Spotted knapweed (Centaurea maculosa Lam.) is a short-lived perennial that reproduces by seed. Two experiments were established in 1982 to determine the longevity of viability of spotted knapweed seeds. Results from the first experiment, a seed burial study, showed that less than 50 percent of the seed had germinated 24 months following burial. Viability of the remaining seed averaged 94 percent. Seed germination rate and seedling vigor was significantly reduced in seeds buried at the Bozeman location.

The second study measured the longevity of seed viability under natural field conditions. Approximately 60 seeds per 0.5 m² remained viable in soil 26 months after seed production had been stopped. There was no significant decrease in the number of viable seeds from April, 1983 to October, 1984. The projected longevity of viability of spotted knapweed seed in natural populations is 144 months, assuming a linear rate of decline of 48 percent every 18 months.

Introduction

Spotted Knapweed (Centaurea maculosa) currently infests over 800,000 hectares of grazeable woodland, rangeland, and pastureland in Montana (Maddox, 1979). The plant reproduces by seed, and individual

plants can produce an average of 1000 seeds (Story, 1976). Approximately 90 percent of the seed produced by spotted knapweed plants is viable (Schirman, 1981).

The longevity of viability of spotted knapweed seed has not been determined. Chicoine (1984) predicted that it would take 60 to 75 months to completely exhaust soil seed reserves under natural conditions in Montana. Preliminary results reported by Schirman (1984) indicate that 40 percent of buried spotted knapweed seed remain viable in the soil for at least five years. The length of time seed remain viable in soil is important when developing herbicide treatment programs for spotted knapweed control. Objectives of this study were to determine the length of time spotted knapweed seed remain viable in soil.

Materials and Methods

Seed Burial Study

The seed burial study was conducted at two locations in Montana. Site 1 was located at the Post Agronomy Farm near Bozeman, Montana. The soil was classified as Bozeman silt loam. Site 2 was located on the Dale Folkvord Farm near Three Forks, Montana on native range. Both soils are deep and well drained. Monthly temperature and precipitation records for the two sites are shown in Appendix D, (Tables 42 and 43).

In preparation for the burial study, fifty polyvinyl-chloride (PVC) rings (7.6 cm diam. by 2.5 cm depth) were cut from PVC pipe. Nylon window screen (16 mesh) was cemented to the bottom of each ring. The containers were filled with soil gathered from the respective burial sites. One hundred spotted knapweed seeds were placed on the

surface of the soil in each container and nylon window screen was cemented to the top surface of each ring. The PVC containers were buried 1.5 cm deep at both locations on September 22, 1982. The rings were arranged in a randomized complete block design.

Five seed containers were recovered at each location on 11-11-82, 4-7-83, 5-2-83, 5-16-83, 6-2-83, and 10-10-83. The number of seeds which had germinated while buried, and the percentage of viable dormant seed was determined for each collection date. Because of low in-field germination and high viability of the dormant seed, the study was revised so that three containers were recovered once per year at each location after 1983. This modified design will permit the burial study to continue through 1989 and provide a better indication of spotted knapweed seed longevity.

Containers were recovered October 15, 1984. Seed was separated from the soil by screening through a 10.02 and 3.10 mm² mesh screen. The remaining seed and soil mixture was placed on 0.55 mm² screen and gently washed with running water for three minutes to remove the fine soil particles. Seeds were removed from the remaining material by hand.

The number of seeds that germinated during burial were determined by counting empty seed hulls. Germination tests were performed on 25 of the ungerminated seed from each PVC ring by floating them in distilled water for seven days at 21 C. The percent germination of seed was measured daily over the seven day period. A speed of germination index was calculated using the method described by McGuire (1962) where:

$$\text{Speed of germination} = \frac{\text{number of germinated seedlings}}{\text{day of observation}}$$

Comparisons of seedling vigor were made between seeds from the original seed lot which were stored in a dry condition at 21 C, and seeds recovered from both locations in May, 1983 and October, 1984. Seedling vigor tests were performed on germinated seed by placing them in 16 X 15 X 4 cm germination boxes fitted with moistened blotter paper. The boxes were placed on an 85 slant in a dark germinator at 20 C. Radicle length was measured daily for 6 days. Speed of elongation index was calculated using the formula described by Carleton et al. (1968):

$$\text{Speed of elongation} = \frac{\text{change in radicle length}}{\text{day of observation}}$$

Data were analyzed by analysis of variance.

Cultural Practice Study

The longevity of viability of a natural soil reserve of spotted knapweed seed was studied at two locations in Montana. The study was established at the same sites (near Harlowton and Ovando) as the picloram rate study in Chapter 5. Climatic conditions of the study areas are shown in Appendix D, (Tables 36 and 37).

Five treatments were applied to plots at each site to determine their effect on the longevity of seed viability. Treatments included rolling, harrowing, burning, mowing, a 2,4-D application, and an untreated control. Treatments were applied in 1982 as described by Chicoine (1984). Plots were arranged in a split block design with three replications per treatment. All plots except the untreated

control were sprayed annually in June with 2.24 kg/ha of 2,4-D to prevent seed production.

The population of mature and seedling spotted knapweed plants was measured by taking plant density counts in six randomly selected 0.09 m² locations in each plot in June, 1983 and 1984 prior to the 2,4-D application. The amount of ungerminated seed remaining in soil was measured by taking six 5.6 cm² diameter soil cores (to a depth of 7.6 cm) within each plot with a tapered tulip bulb planter in April and October, in both 1983 and 1984. The location of each soil core was selected randomly, however, if the random location chosen for a sample site was on a rodent burrow, a new location was selected. Rodents are believed to consume spotted knapweed seeds and may be a source of seed contamination on the plot areas (personal observation; Silvertown, 1982). Soil was separated from the seed through a series of screening, washing, and air cleaning steps (Chicoine, 1984). Seed from each core were floated on distilled water at 21 C for seven days. The number of germinated spotted knapweed seed were counted daily.

Results and Discussion

Seed Burial Study

Seed recovery from buried soil cores averaged 99 and 98 percent for Bozeman and Three Forks, respectively (Table 29). In-field germination of seed averaged 20 percent at Bozeman and 45 percent at Three Forks 24 months after burial (Table 30). The number of seeds germinated after 24 months was significantly greater than at 2.5 months after burial.

Table 29. Recovery of Buried Spotted Knapweed Seed Samples in the Seed Burial Study Established on Sept. 21, 1982 at Bozeman and Three Forks.

Months of Burial	Seed Recovery (%)	
	Bozeman	Three Forks
2.5	100a ¹	100a
7.0	99a	100a
8.0	100a	98a
8.5	99a	99a
9.0	98a	98a
12.5	97a	95a
24.0	100a	99a
X	99	98

¹Means within a column followed by the same letter are not significantly different at the 5% level using the LSD test

While in-field germination reduced seed populations after two years, more than 50 percent of seed did not germinate in the soil. A high percentage of germination was measured in several PVC containers at Three Forks which was caused by micro-climatic conditions created during the burial of the PVC rings (Chicoine, 1984). The rings settled following burial creating a depression in the soil which collected precipitation. The increased moisture may have stimulated higher than normal levels of germination.

Viability of the ungerminated seeds was 96 and 92 percent at Bozeman and Three Forks respectively (Table 30). There was no significant difference in viability between buried and unburied seed. The ability of the seeds to germinate in a favorable environment indicates that enforced dormancy rather than innate or induced dormancy may be responsible for lack of germination (Cook, 1980).

There was no significant difference in speed of germination between seed buried for 24 months at Three Forks and the unburied

control. However, seed buried 24 months at Bozeman germinated at a significantly slower rate than seed buried at Three Forks or seed from the original seed lot which were stored at 21 C. There was no difference in total percent germination between the three seed lots after five days (Figure 13).

Table 30. Percent Germination During the Burial Period, and the Viability of Dormant Spotted Knapweed Seed in the Seed Burial Study Established Sept. 21, 1982 at Bozeman and Three Forks.

Months of Burial	Percent Germination During Burial		Percent Viability Ungerminated Seed	
	Bozeman	Three Forks	Bozeman	Three Forks
2.5	1a ¹	1a	99a	99ab
7.0	20bc	13a	98ab	98ab
8.0	13ab	7a	97ab	100a
8.5	17bc	8a	98ab	99ab
9.0	12ab	7a	87c	95bc
12.5	11ab	34b	91bc	95bc
24.0	20bc	45b	96ab	92c
unburied	-	-	99a	99ab

¹Means within a column followed by the same letter are not significantly different at the 5% level using the LSD test.

Seedling vigor (expressed as speed of radicle elongation) was the same between seeds buried for 9 and 24 months at Three Forks and the unburied control. Radicle elongation was slower with seeds buried for 9 and 24 months at Bozeman compared to either Three Forks or the unburied control (Figure 14).

Decline in seedling vigor is expressed by speed of radicle elongation and speed of germination indexes shown in Table 31. Speed of germination indexes were not calculated for seed buried at Bozeman

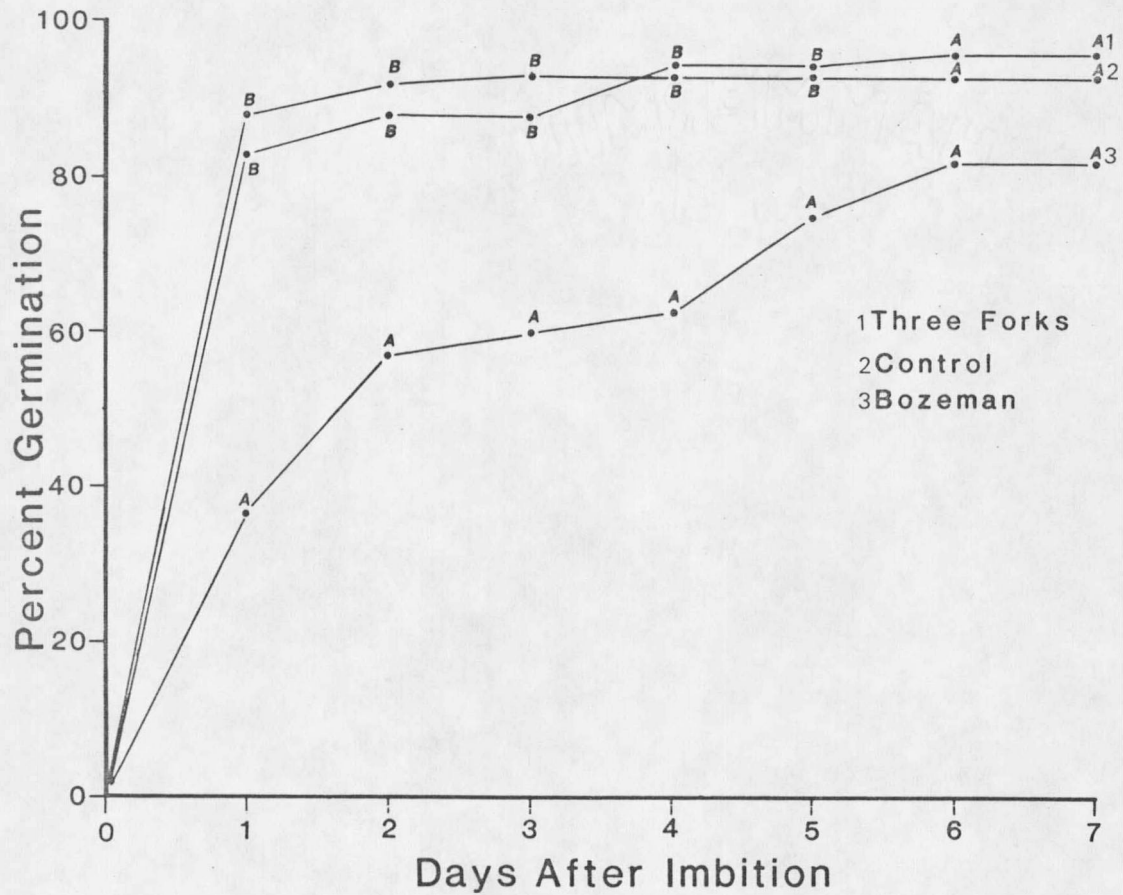


Figure 13. Percent Germination of Seed Buried for 24 Months at Three Forks and Bozeman and the Unburied Control.

¹Point in the same date followed by the same letter are not significantly different at the 5 percent level using the LSD test.

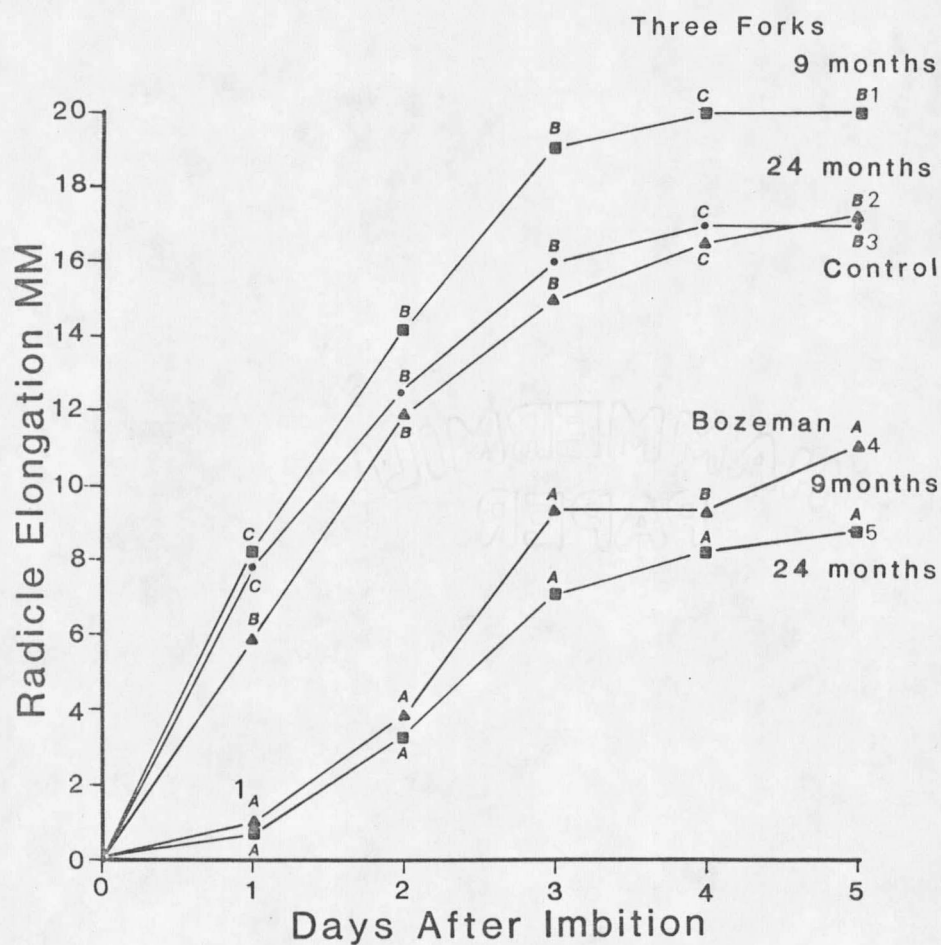


Figure 14. Rate of Radicle Elongation in Seeds Buried for 9 and 24 Months at Bozeman and Three Forks, and the Unburied Control.

¹ Points in the same date followed by the same letter are not significantly different at the 5 percent level using the LSD test.

for 9 months because of the small amount of seed saved in 1983. The lower index values for seed buried at Bozeman compared to seed from Three Forks may be due to accelerated aging of the seed. Visual symptoms of aging included deterioration of the pappus and the micropylar plug. The accelerated aging of the seed at Bozeman may be due to increased microbe and fungi populations as a result of higher precipitation (Bewley and Black, 1978) (Figure 15).

Table 31. Speed of Germination and Speed of Elongation Index Numbers for Seed Recovered From Bozeman and Three Forks 24 Months After Burial.

Location	Index Numbers			
	Speed of Germination		Speed of Elongation	
	1983	1984	1983	1984
Bozeman	-	12.9a ¹	0.54a	0.31a
Three Forks	-	22.5b	0.89b	0.98b
Unburied	-	23.0b	0.91b	0.91b

¹Means within a column followed by the same letter are not significantly different at the 5 % level using the LSD test.

Cultural Practice Study

The number of viable seed remaining in soil decreased 91 and 88 percent at Ovando and Harlowton respectively in a 28 month period following the termination of seed production (Figures 16 and 17; Appendix D, Tables 44 and 45). Seed reserves declined 87 percent at Ovando and 72 percent at Harlowton the first 10 months after seed production was stopped. However, the rate of decline averaged only 47 percent the following 18 months at both locations. An average of 34 and 97 viable seeds remained per 0.5 meter square at Ovando and

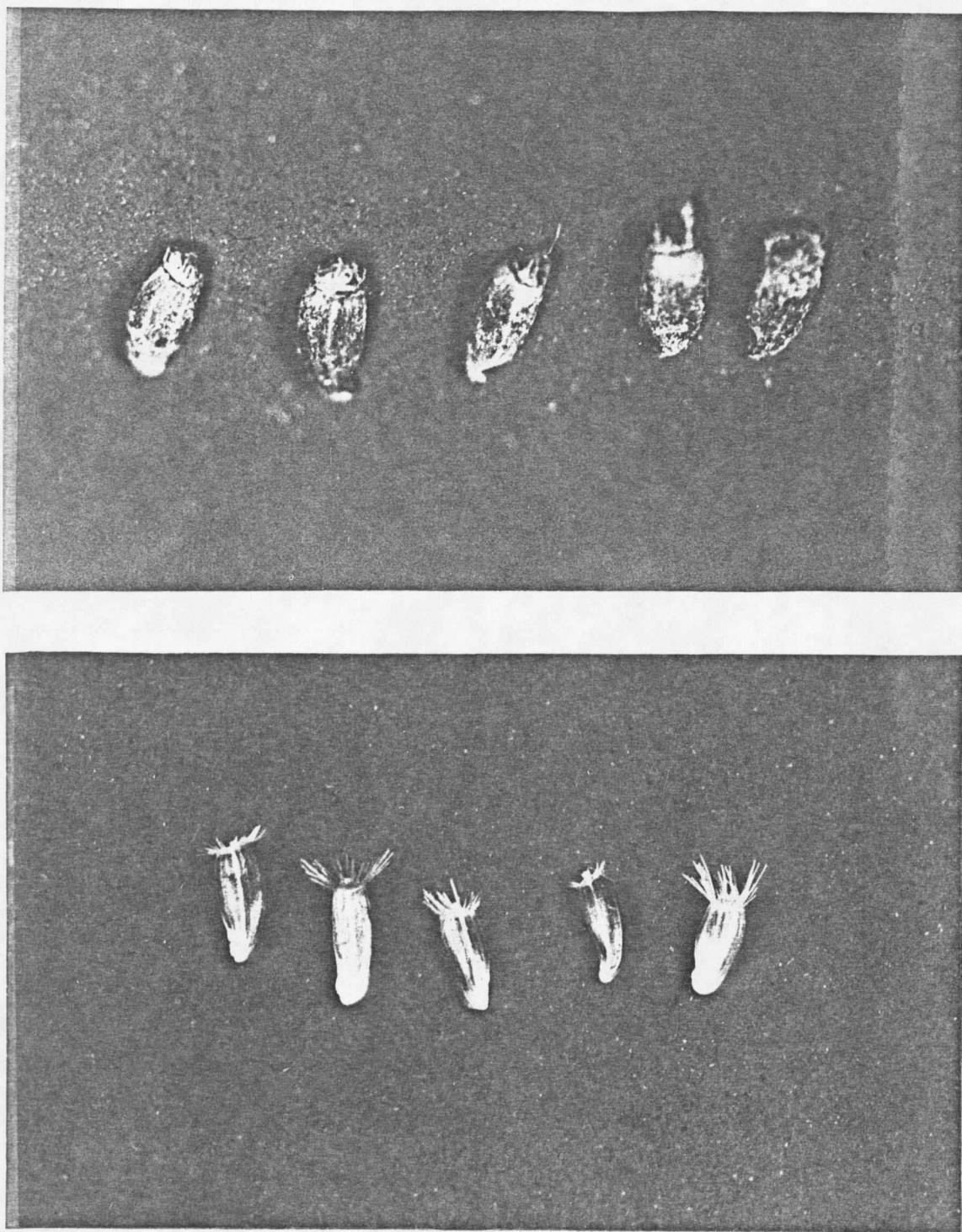


Figure 15. Photographs Showing the Effect of Aging on Bozeman Seed (Top) Compared to the Unburied Control (Bottom).

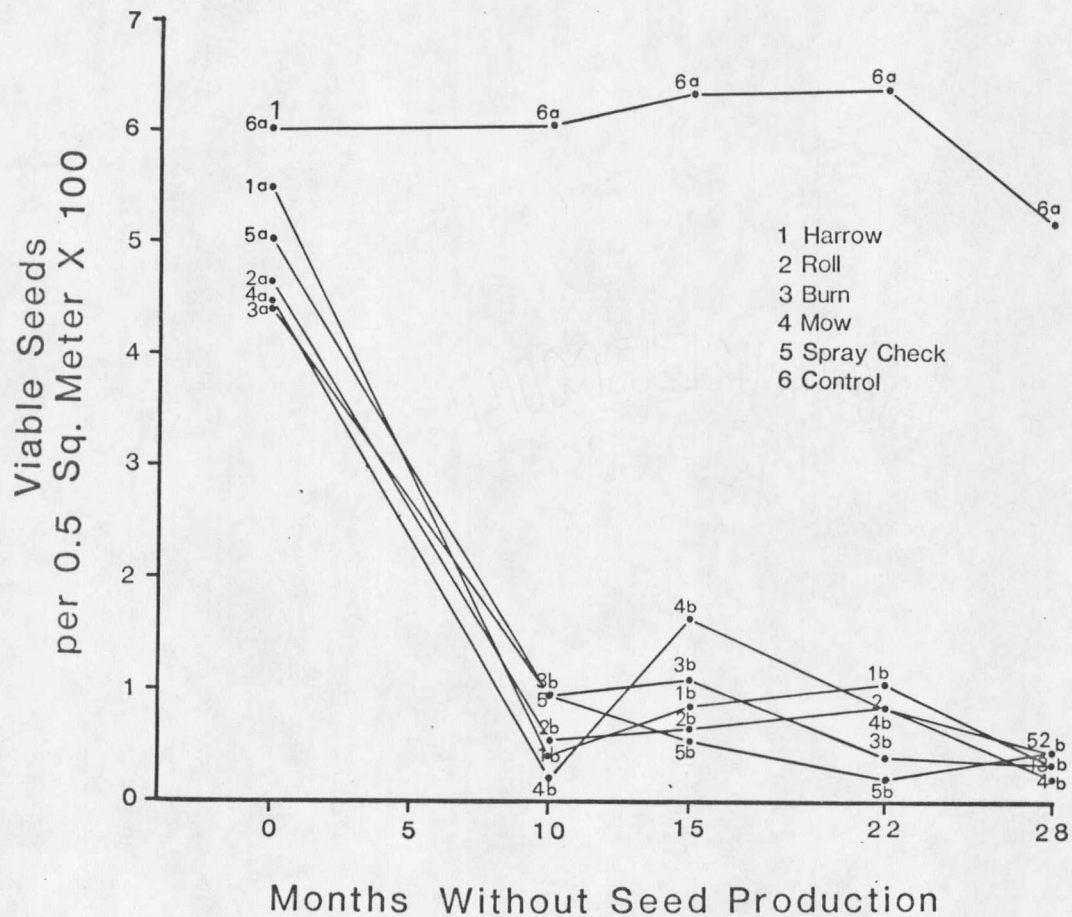


Figure 16. Changes in Spotted Knapweed Seed Reserves with Various Cultural Practices from 0 to 28 Months After Seed Production Was Stopped at Ovando ¹.

¹Points in the same month followed by the same letter are not significantly different at the 5 percent level using the LSD test.

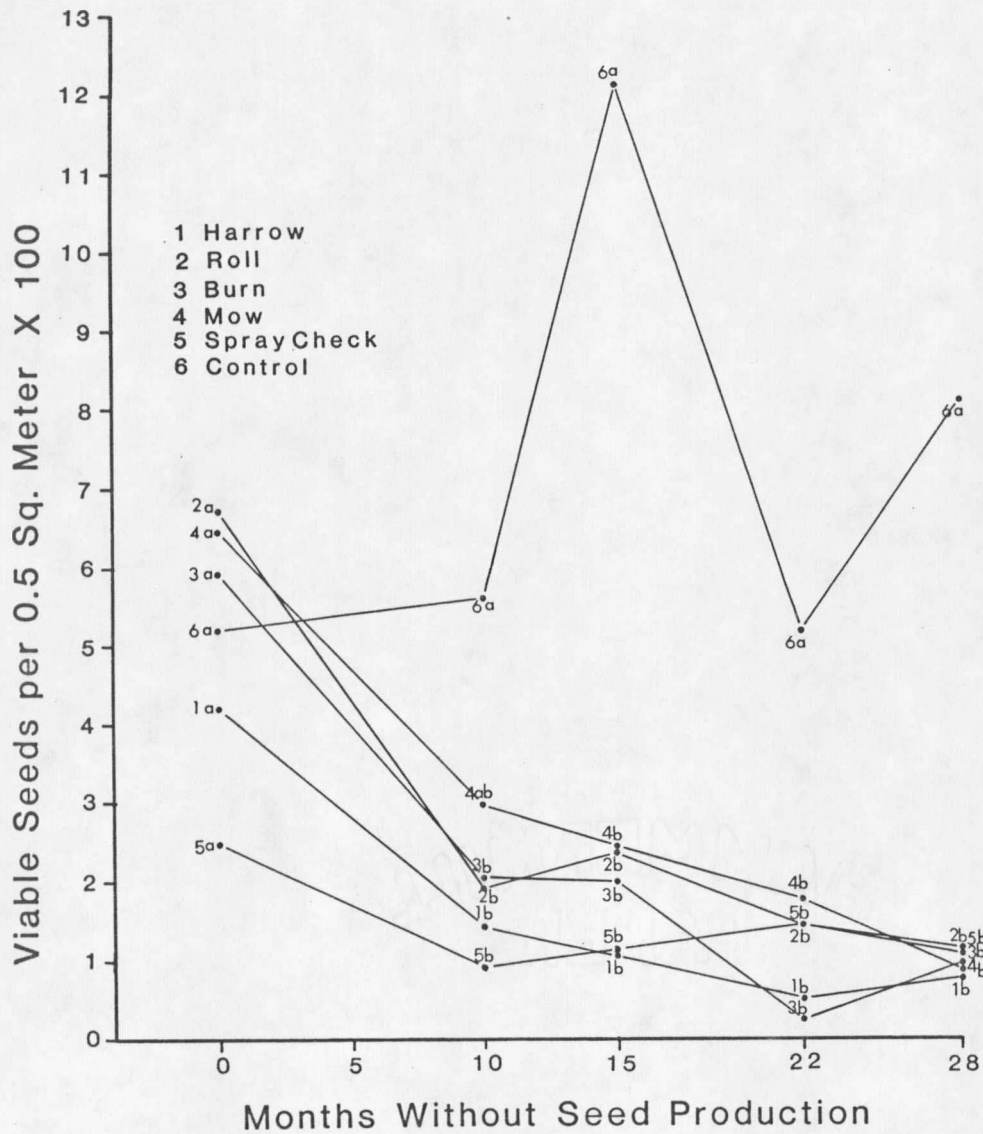


Figure 17. Changes in Spotted Knapweed Seed Reserves with Various Cultural Practices from 0 to 28 Months After Seed Production Was Stopped at Harlowton ¹.

¹ Points in the same month followed by the same letter are not significantly different at the 5 percent level using the LSD test.

Harlowton, respectively, 28 months after seed production was halted. There was a significant decline of viable seeds from April, 1983 to October, 1984 at Harlowton. However, no decline in viable seeds was measured at Ovando. The cultural practices tested which were designed to improve seed to soil contact did not influence the rate of decline of seed reserves.

Figure 18 shows the decline in seed reserves for both locations and all cultural practices combined. Following the initial rapid decline in soil seed reserves, the number of viable seed declined slowly. This response suggests that a portion of spotted knapweed seed in the soil is regulated by enforced dormancy. The mechanisms that prevent spotted knapweed seed from germinating under normal field conditions appear to be important in extending the longevity of seed in the soil. The gradual decline of seed in the soil may be caused by germination of the seed when environmental conditions are optimal. Other factors which could reduce soil seed reserves include predation or senescence (Radosevich and Holt, 1984).

The long term rate of decline of viable spotted knapweed seed in soil can be estimated by calculating the rate of decline from April, 1983 to October, 1984. This provides a more accurate prediction of seed longevity than was made by Chicoine (1984) since it eliminates the initial rapid decline in seed reserves which occurred between June, 1982 and April, 1983. The soil reserve of viable seed decreased 49 and 45 percent at Harlowton and Ovando respectively from April, 1983 to October, 1984. Assuming a constant rate of decline, it will take 144

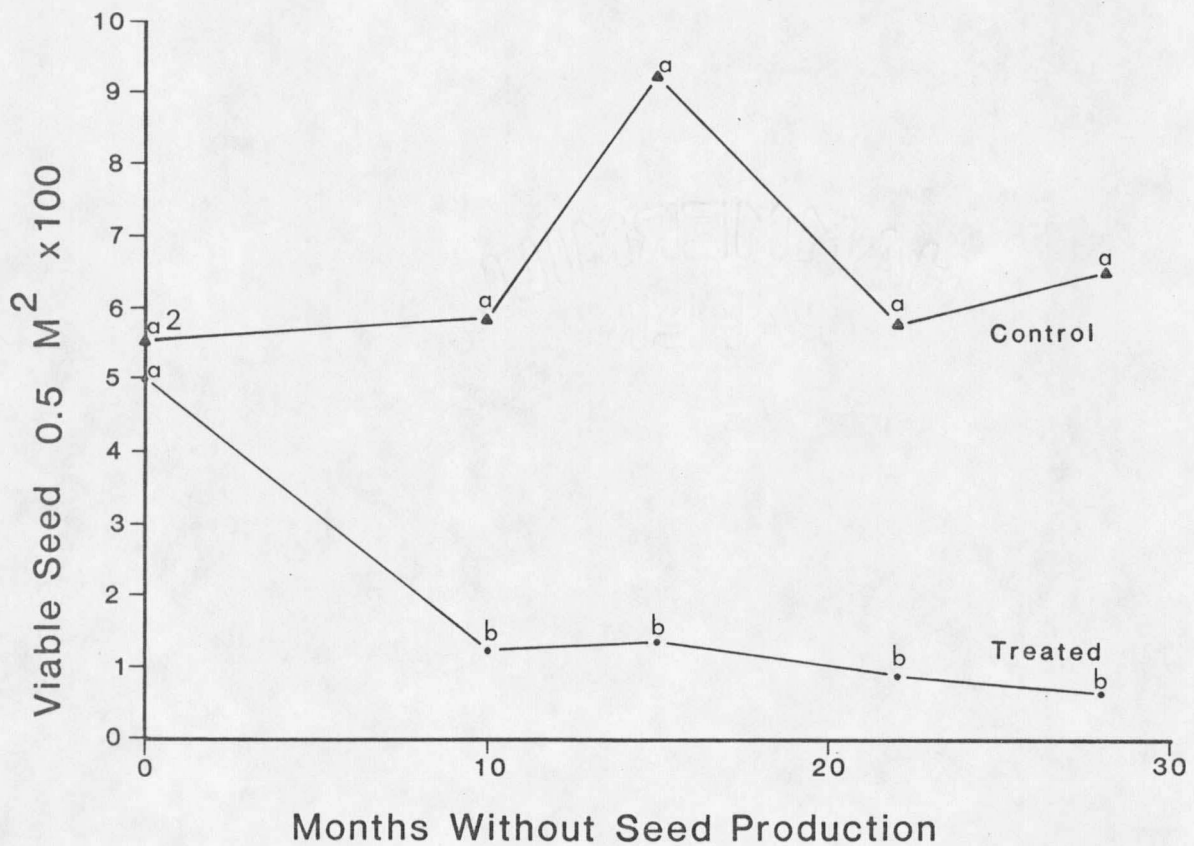


Figure 18. The Decline of Viable Spotted Knapweed Seed Reserves from 0 to 28 Months After Seed Production was Stopped.¹

¹ Data are for averages of all cultural practices from Harlowton and Ovando combined.

² Points in the same month followed by the same letter are not significantly different at the 5 percent level using the LSD test.

months to reduce the number of viable seed reserves to less than one seed per 0.5 meter square at both locations (Table 32).

The predicted rate of decline (Table 32) does not take into account the reduction in seed vigor observed in the burial study (Table 31). A decline in seed and seedling vigor could hinder both seed germination and seedling establishment. The breakdown of dormancy mechanism within the seed could also result in unsuccessful germination and death (Radosevich and Holt, 1984). The inability of viable seeds to germinate and establish would decrease the effective length of time that the population could reestablish from endogenous soil seed reserves.

Table 32. The Predicted Rate of Decline of Spotted Knapweed Seed Based on the Rate of Decline Measured from April, 1983 to October, 1984 at Harlowton and Ovando.

Months After Seed Production is Stopped	Number of Viable Seed per 0.5 m ²	
	Harlowton	Ovando
10	186	61
28	95	34
36	48	19
54	24	10
72	12	6
90	6	3
108	3	1.7
126	1.5	1
144	<1	<1

Since cultural practices did not influence spotted knapweed seedling or mature plant density, data was averaged for all treated plots. Spotted knapweed seedling densities decreased from June, 1983 to June, 1984 (Table 33). An average of one and twelve percent of the

viable seed in the treated plots at Harlowton and Ovando respectively germinated and became established seedlings in 1984. The decline in seedling establishment may reflect either a decrease in seedling vigor or a change in favorability of environmental conditions from 1983 to 1984. There was no difference in mature plant density from 1983 to 1984.

Table 33. The Plant Density of Spotted Knapweed Seedlings in Treated and Control Plots in June 1983 and June 1984 at Harlowton and Ovando.

Year	Harlowton		Ovando	
	control	treated	control	treated
1983	489a ¹	22a	933a	24a
1984	272a	1b	733a	4b

¹ Means within a column followed by the same letter are not significantly different at the 5% level using the LSD test

The number of viable seed (650 per 0.5 m²) in the control plot in 1984 at Ovando is approximately the same as the number of established seedlings (733 per 0.5 m²). This suggests a static population, where deposits of seed from seed production and dispersal is about equal to withdrawals from the soil seed reserve by germination. This static population is not observed in Harlowton where the amount of viable seed in the soil exceed the number of seedlings established in 1984. Environmental conditions at Harlowton may not have been optimum for seedling establishment.

Summary

Spotted knapweed seeds which do not germinate remain viable in soil for 24 months following burial. Field germination of buried seed was less than 50 percent and the viability of ungerminated seed was 94 percent. Speed of germination and speed of radicle elongation indexes were lower in seed buried at Bozeman than seed buried at Three Forks or unburied seed. This suggests a decline in seed vigor for seeds buried at Bozeman. The decrease in seed vigor may indicate that accelerated aging of seed has occurred as a result of higher precipitation at Bozeman.

The number of viable seed in natural seed populations decreased 48 percent from April, 1983 to October, 1984. Less than 15 percent of the viable seed in soil germinated and became established in 1984. Various cultural practices designed to increase seed to soil contact had no effect on percent seed germination or seedling establishment.

Approximately 25 percent of spotted knapweed seed in natural populations appears to be regulated by enforced dormancy. Dormancy mechanisms are important in extending the longevity of viability of spotted knapweed seed in soil.

The projected longevity of viability of seed in natural populations is 144 months, assuming a linear rate of decline of 48 percent every 18 months. However, reductions in seed and seedling vigor from natural aging could decrease the length of time required to stop seedling establishment on a site. These studies will be continued determine the exact period of longevity of viability of spotted knapweed seeds in soil.

SUMMARY

Leafy spurge and spotted knapweed are the two major weed problems on rangeland in Montana. Extension and research programs were initiated in an effort to stop the spread of the two weeds. They included: an educational program on leafy spurge and spotted knapweed, the effect of reduced rates of picloram and picloram/ 2,4-D combinations on control of spotted knapweed, the effect of 2,4-D on two strains of spotted knapweed, and the longevity of viability of spotted knapweed seed in Montana soils.

Newsletters, herbicide demonstration plots, field tours, and a ransom program were effective in increasing public awareness and control of leafy spurge and spotted knapweed in Montana. The effectiveness of the overall program was enhanced by utilizing an integrated approach which involved researchers, extension specialists, and federal and state entities.

Picloram is the most effective herbicide for controlling spotted knapweed. Picloram rates as low as 0.14 kg/ha will provide up to two years of control of mature spotted knapweed plants. The residual period of picloram determines the length of control of spotted knapweed. The addition of 2,4-D to picloram does not significantly improve control over picloram alone. The removal of spotted knapweed from the plant community results in an increase in grass production of 200 to 770 percent.

Differential tolerance of spotted knapweed to 2,4-D observed in field trials at Ovando and Harlowton was examined. There was no difference in response to 2,4-D between plants from both locations when grown under identical conditions. The tolerance of spotted knapweed to 2,4-D observed in the initial field studies was probably due to differences in plant vigor rather than differences in uptake or movement of the herbicide.

Spotted knapweed seed remain viable in the soil for at least 28 months under buried and natural conditions. Less than 50 percent of the buried seed had germinated 24 months following burial. There was an average of 65 viable seeds per 0.5 m² remaining in a natural seed population 28 months after seed production was stopped. Based on the current rate of decline, the longevity of viability of spotted knapweed seed in the soil is 144 months.

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APPENDICES

APPENDIX A

NEWSLETTERS



Leafy Spurge News

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
BOZEMAN, MONTANA 59717

Volume IV

May 1983

Issue 2

Newsletter continues with a new editor!

Hi, I'm the new editor of the Leafy Spurge Newsletter. My name is Celestine Lacey and I just started working on a Master's degree in Weed Science with Dr. Pete Fay at Montana State University. A large part of my work will involve a leafy spurge extension program.

Bruce Maxwell is continuing to work on his Master's, but will concentrate his efforts on leafy spurge research. We appreciate the excellent job that Bruce did editing the newsletter, and will keep you updated on the progress of his research.



Maw....with leafy spurge it's not always what you spray but how you pray!

LEAFY SPURGE SYMPOSIUM

The most important spurge event of the year will be held in Sundance, WY on June 21 and 22, 1983. There will be something on the program for anyone interested in leafy spurge. Speakers will include researchers, weed supervisors, and ranchers from Colorado, Wyoming, North Dakota, South Dakota, Montana, Maryland, and California. A detailed agenda of the symposium follows.

SEE YOU IN SUNDANCE!

Leafy Spurge Symposium
Sundance, Wyoming
June 21-22, 1983

<u>June 20, 1983</u>	5:00-8:00 pm, Registration, Lobby of the Bear Lodge
<u>June 21, 1983</u>	County Courthouse Basement
8:00 am	Future direction of leafy spurge research in Great Plains area. <u>Dr. Don Anderson</u> - Administrative Advisor of Great Plains Agricultural Council.
8:20 am	Future direction of leafy spurge research from a University viewpoint. <u>Dr. Harold Luna</u> - Dean, College of Agriculture, University of Wyoming.
8:40 am	State leafy spurge program from a legislative viewpoint. <u>Wyoming State Senator</u> .
9:00 am	State leafy spurge program from State Weed and Pest Coordinator viewpoint. <u>George Hittle</u> - Weed and Pest Coordinator - Wyoming State Department of Agriculture.
9:20 am	COFFEE BREAK
10:00 am	State leafy spurge program from a Weed and Pest Supervisor's viewpoint. <u>Bob Benjamin</u> - Weed and Pest Supervisor, Sheridan.
10:20 am	State leafy spurge program from a rancher's viewpoint. <u>Jess Driskill</u> - Rancher, Hulett.
10:40 am	Leafy spurge program from Weed and Pest board member's viewpoint. <u>John Dorrance</u> - Board Member, Crook County.
11:00 am	Research Reports, North Dakota. <u>Cal Messersmith</u> - Chairman.
11:45 am	LUNCH
<u>Afternoon - June 21, 1983</u>	
1:15 pm	Montana Research Reports - <u>Peter Fave</u> - Chairman. Nutritional value of leafy spurge as a forage component for ewes and lambs. <u>S. J. Bartz, K. M. Hustad and E. L. Avres</u> .
1:30 pm	Herbicide application accessories for all terrain vehicles. <u>Lee Coble, Bruce Maxwell and Peter Fave</u> .

June 21, 1983

- 1:45 pm Update on leafy spurge research at Montana State University. Bruce Maxwell and Peter Faye.
- 2:00 pm Leafy spurge awareness programs in Montana. Part II. Celestian Lacy and Peter Faye.
- 2:15 pm Nebraska - Alex Martin, Chairman. Research on leafy spurge control in Nebraska. Alex Martin.
- 2:30 pm Wyoming Research Reports - H. P. Alley, Chairman. Leafy spurge, a production thief. Slide-tape Series. Tom Whitson.
- 2:45 pm Soil residue and leafy spurge root studies. Ron Vore.
- 3:00 pm COFFEE BREAK
- 3:15 pm Evaluation of growth regulator/herbicides. Mark Ferrell.
- 3:30 pm Repetitive herbicide treatments for leafy spurge control. H. P. Alley.
- 3:45 pm Forage production - leafy spurge control comparisons. Tom Whitson.
- 4:00 pm USDA-USFS. Mapping leafy spurge committees from aerial photos. Richard Myhre - U.S.F.S., Ft. Collins.
- 4:15 pm European rust fungi evaluated for leafy spurge control at the Plant Disease Lab. William L. Bruchardt - Plant Disease Lab, Maryland.
- 4:30 pm Does 2,4-D follow assimilate translocation in leafy spurge. S. E. Lingle and J. C. Suttle - USDA Metabolism and Radiation Research Lab, Fargo.
- 4:45 pm Preliminary investigations on the efficacy of compounds of natural origin and experimental herbicides on greenhouse grown leafy spurge plants. David G. Davis - USDA-ARS, Fargo.
- 5:00 pm Chemotaxonomy of leafy spurge. Kenneth L. Stevens - USDA-ARS, Berkeley.
- 5:15 pm Chemistry and allelopathy of leafy spurge. Gary D. Manners - USDA-ARS, Berkeley.
- 6:00 pm Barbecue - Fairgrounds
- 8:30 pm Business Meeting, County Courthouse Basement.

June 22, 1983

7:30 am - 4:30 pm Field tour will include:

- (1) Comparisons of herbicide treatments on leafy spurge applied five years previously.
- (2) Leafy spurge root sampling techniques.
- (3) Aerial application demonstration.
- (4) Growth regulator, herbicide combinations and new herbicide introductions.

Registration costs of between \$15 and \$20 will include all meals with the exception of breakfast on June 21st. Progress reports and proceedings will be provided for participants at the meeting.

For more information please contact Dr. Harold Alley or Dr. Tom Whitson Plant Science Dept. P.O. Box 3354 University Sta., Laramie, Wyoming 82071.

MONTANA

Leafy Spurge Extension Program

An extension program has been reinitiated to increase public awareness and disseminate information on leafy spurge. Herbicide demonstration plots will be established at 20 locations this year and tours and meetings will be conducted throughout Montana. A one-to-one consultation service will also be offered to land owners to help solve their spurge problem. A leafy spurge monograph on the biology and control of the plant will be published by December.

SPURGE TOURS

Leafy spurge tours will be held around the state in June and July. The tours should be informative and fun. A tentative schedule follows.

June 14 Roosevelt County (Snowden Bridge)
 June 15 Valley County (Hinsdale)
 June 28 Toole County (Shelby)
 July 6 Fergus County

For more information about the tours contact your county extension agent.

THIRD ANNUAL WEED FAIR

Fight Weeds and Win! The third annual weed fair will be held in Stillwater County on July 23, 1983. The weed fair will include tours for farmers, ranchers, and small landowners; information booths; goat barbeque; crowning of King Thistle and Miss Morning Glory; old-time fiddling; and a Weed Fair Dance. Register before July 15 and pay only \$5.00 per family. For more information contact Stillwater County Extension Service in Columbus, Montana (406)322-5334.

Join us for a lot of fun and learn some valuable new methods of plant management!

Just clip out the following registration form and send it to Stillwater County Extension Agency.

Name _____	
Name of Spouse _____	
Names/Ages of Children _____	

Address _____	
_____ Zip _____	
Please check choice of tours, developed for:	
_____ Rancher	_____ Legislator/
_____ Farmer	County Commissioner
_____ Small landowner	_____ Spouse
_____ Pilot/Flying Farmer	_____ Children
Will you be joining us for the barbeque, entertainment, and dance? _____ Yes _____ No	
Mail before July 15 with check or money order for \$5.00 to:	
Stillwater County Extension Agency	Make checks payable to
Box 507	Stillwater Co. Extension Agency
Columbus, MT 59019 322 5334	

WEED BILL PASSES, BUT.....

The 1983 Montana State Legislature recently passes a bill that provides approximately \$87,000.00 per year for weed research. However, the bill will not be enacted until 1984. The old saying "better late than never" certainly applies in this case!

SHEEP ON SPURGE

Research initiated in the summer of 1982 on weight gains of lambs grazing on leafy spurge will continue this summer. Sue Bartz, a graduate student in range science at Montana State University is recording lamb gains from pastures with 3 different treatments: 1) leafy spurge controlled with chemicals; 2) light levels of leafy spurge infestation (10% plant composition) and; 3) heavy levels of spurge infestation (20% or greater plant composition). In addition, exclosures will be placed in each pasture to determine ewe and lamb use of spurge.

NORTH DAKOTA

FUNDS FOR SPURGE

Congressman Marlenee's office indicated that part of the program effort at the USDA Research Station at Sidney, MT will be directed toward noxious weed research. In addition, funding will also be available to Montana State University for research on leafy spurge.

LEAFY SPURGE SPREADS

A 1982 survey of leafy spurge in North Dakota has been completed and indicates there are over 860,000 acres of spurge in the state. This is an increase of over 150,000 acres compared to the 1981 estimate and because of a very wet fall, leafy spurge growth should be vigorous this spring reported Dr. Rod Lym. The major areas of increase are in the North Central and South Eastern parts of the state, but nearly all 53 counties reported at least some increase in spurge acreage. In addition, the North Dakota Highway Department estimates over 87,000 miles of state and county roads have leafy spurge growing along them. This is up from 55,181 miles reported in 1979.

WEED FUNDS VETOED

The 1983 North Dakota State Legislature introduced a bill to appropriate \$500,000.00 for cost share on leafy spurge control in the state. The bill was passed by the Senate and House, but was vetoed by the Governor. This money, along with revenue available to local weed boards, would have helped to fund a large program to stop the spread of leafy spurge in the state.

WYOMING

OBEREA UPDATE

Oberea erythrocephala, a root-boring beetle, was released in 1980 and 1981 in Fremont County and in 1982 in Lincoln County. The status of the release program follows.

- 1980 - (Release site on Popo Agie Ranch) The site was visited on July 1, 1982 but no adults were found. Only four plants were located on the site with possible Oberea scars. One larva was dissected from a stem in May, 1982.
- 1981 - (Release site at Lander) The site was visited on July 21 and Aug. 16, 1982. No adults were found on either occasion. In July, 300 stems of leafy spurge were examined and 31 scars found. In August, of 400 stems examined, 118 scars from Oberea were located.
- 1982 - (Release site at Afton, 10 miles N.) On July 4, 1982, 302 adults were released on leafy spurge plants dominating a hillside (86 flowering stems/m²). Male and female Oberea began copulating immediately. Some females, presumably mated in transit, began chewing holes in stems as soon as they were released.

BIOLOGICAL CONTROL

CANADA

Dr. Peter Harris, Agriculture Canada, reported that releases of adult Aphthona flava and A. cyparissias (spurge root-feeding beetles) were made in Alberta, Saskatchewan, Ontario, Quebec and Manitoba. No breeding occurred in field cages in the former three provinces and the latter two remain to be checked. The beetle did breed on well-watered plants in the laboratory and it is thought that they would fare better in the field with an early spring release since the eggs require moist conditions. Late fall releases of larvae were made but cannot be checked until the ground thaws.

On cypress spurge in Ontario, Hyles euphorbiae, (spurge hawkmoth) in some places reached densities of up to 27 larvae/m² which led to complete defoliation of the weed in the spurge stand. In Saskatchewan, the root-boring beetle Oberea erythrocephala continues to survive at low densities. The problem relates to lack of oviposition but the reasons for this are unclear.

Currently host specificity tests funded by Alberta are being concluded on the root-beetle Aphthona cwalinae and have been started on the root-gall fly Pegomya argyrocephala. Saskatchewan is funding a search for the defoliating moth Biston fiduciaris and the leaf-tying moth Lobesia euphorbiana. At Regina, Saskatchewan, L. euphorbiana is being increased in the greenhouse for release in the spring of 1983 as well as A. flava and A. cyparissias for further attempts at establishment. Also, screening is underway on the defoliating moth Minoa murinata and two aphids, Acyrtosiphum cyparissiae and Aphis esula.

* * * *

If anyone would like extra copies of this newsletter, to be added to the mailing list, or more information on leafy spurge, please contact:

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Leafy Spurge News

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
BOZEMAN, MONTANA 59717

Volume IV

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WYOMING

Leafy Spurge Symposium

Congratulations to the University of Wyoming for hosting an informative and enjoyable Leafy Spurge Symposium!

The first day of the symposium was highlighted with research reports which gave a good overview of the current research on leafy spurge. A social hour and barbecue hosted by Dow, Velsicol, Union Carbide, and Jirdon Chemical Companies followed the reports in the evening.

The second day included a bus tour through the Jess Driskill ranch where an active leafy spurge control program has been conducted. The control obtained and the cost of such a program was discussed. The group also viewed the extensive research program being conducted on leafy spurge in the area, including the repetitive herbicide program started in 1978; a helicopter Tordon 2K pellet application demonstration and root sampling techniques used to evaluate root kill were observed.

An extensive herbicide research plot area was toured in the afternoon. The most interesting research plots were where the leafy spurge had been mowed and regrowth sprayed with low rates of Banvel, Tordon 22K and 2,4-D LV ester. The treatment of the 2,4-D LV ester was excellent, indicating a need for more research in this area.

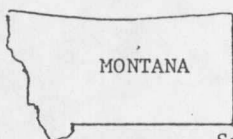
We appreciate all of the hard work and time that everyone in Wyoming contributed to make the symposium a success.

Moving On

Dr. Tom Whitson, who has been very active in the leafy spurge research program accepted a position as Extension Weed Specialist at Oregon State University. He reported July 1, 1983. We will miss Tom's expertise and hard work in Wyoming, but wish him well in his new position. Mr. Mark Ferrell, a Ph.D. candidate in Weed Science, will assume Tom's responsibilities until the vacated position is filled.

More Funds for Spurge

The Wyoming State Department of Agriculture recently awarded the Weed Science Section at the university a \$10,000 grant to assist in leafy spurge research.



Spurge Saves Lives

Leafy spurge is credited with saving lives at Montana's Third Annual Weed Fair! Goats that were destined to be the main course of the barbecue for the fair were spared their lives when they proved how effectively they could control leafy spurge along the Yellowstone River. Although a few goats contributed to the dinner, several pairs were spared to continue their spurge control effort.

The Weed Fair was a great success with about 500 people attending the event. The fair started at 12:30 p.m. July 23rd with weed tours for everyone including youth, spouses, ranchers, farmers, weed supervisors and legislators. Highlights of the tours included control for field bindweed, Canada thistle, wild oats, leafy spurge and spotted knapweed; range improvement demonstration plots on seeding, mechanical treatments, and fertilization; sagebrush control with mowing, herbicides and controlled burning; establishment of a grass nursery; and a historical tour of Columbus.

King Thistle, Wilber Holmes, and Miss Morning Glory, Mary Peterson, were crowned in a ceremony following the barbecue. Wilber Holmes was one of the ranchers who was instrumental in using sheep for controlling leafy spurge in Montana, and Mary Peterson has been a "weed fighter" for many years. Congratulations to our winners for their help with the WEED BATTLE.

A special thanks to Chuck Egan, Wayne Pearson, John Lacey, Pete Fay, Herb Uhrich, and all of the other people who worked so hard to make the Weed Fair a success.

BLM Purges Spurge

The Bureau of Land Management in Montana is using herbicides to treat approximately 995 acres of their land that is infested with leafy spurge. This includes land in the Lewistown, Billings, Miles City, Powder River, and Big Dry Resources Areas.

The Dillon Resource area is controlling spurge on 240 acres by allowing sheep grazing with a no-cost license.

For more information about BLM's weed programs, contact Fred Batson, Montana State Office 406-657-6655.

Spurge Tours

The 1983 Leafy Spurge tours had a record turnout, with over 570 people attending the 9 tours held in June and July. It was great to see so many people concerned about leafy spurge control programs. Their enthusiastic support of extension and research efforts is essential to developing a viable spurge control program.

Thanks to all of the county agents, soil conservation service personnel, soil conservation districts, and weed supervisors who worked so hard to make these tours a success. We also appreciate the help and support from Dow Chemical Company who sponsored the tours.

Two fall tours are planned for this year:

Sept. 6	Petroleum Co.	Contact: Celestine Lacey 994-4601
Sept. 8	Carter Co.	contact: Pam Castleberry 778-2891

NORTH DAKOTA

Carbohydrates Effect Herbicide Movement?

In 1981 and 1982 leafy spurge root samples were taken weekly to a 6-inch depth from early April to late October. Analysis of the soluble sugars indicated sucrose as the major carbohydrate present with a slight amount of glucose and fructose also present. The soluble carbohydrate reached maximum levels in late fall just prior to freeze-up and constituted 16% of the leafy spurge root material on a dry weight basis. Carbohydrate levels fluctuated greatly during midsummer in both growing seasons. It was found that carbohydrate levels decreased as the average weekly temperature increased; conversely, root carbohydrate levels increased as the average weekly temperature decreased. These fluctuations in carbohydrate movement could affect herbicide translocation and thus leafy spurge control. Root samples are being taken twice weekly in 1983 so that a more precise prediction of periods of increased carbohydrate and perhaps herbicide translocation to the root system can be made.

Dollars & Sense

Economical control of leafy spurge has been a major goal of the leafy spurge program in North Dakota. Annual application of Tordon plus 2,4-D at 0.25 plus 1.0 lb/A for 2 years has resulted in greater forage production and similar leafy spurge control compared to Tordon applied once at 2.0 lb/A after 3 years (Table 1). Banvel at 2.0 lb/A has given fair forage production, but only 39% leafy spurge control. Banvel has generally given better leafy spurge control in western versus eastern North Dakota. Annual applications of 2,4-D have not resulted in long-term leafy spurge control, but does kill the top growth long enough to allow increased forage production.

Table 1. Leafy spurge control from various annual herbicide treatments or a single application of picloram.

Herbicide	Rate (lb/A)	Control		Total forage production (lb/A)	Net return (\$/A)
		1982	1983		
------(X)-----					
Annual treatments (1981-82)					
Picloram	0.25	14	50	4,090	23
Picloram + 2,4-D	0.25+1.0	20	68	4,086	19
Dicamba	2.0	5	39	3,501	-12
2,4-D	2.0	4	22	3,349	15
Single application (1980)					
Picloram	2.0	84	76	2,548	-72
Control		...	...	2,114	
LSD (0.05)		24	16	448	

¹ Economic return estimate by converting forage production to hay at \$48/T minus herbicide and application cost. 2,4-D at \$2.17/lb, dicamba at \$10.30/lb, picloram at \$40.00/lb. Application cost at \$2.05/A.

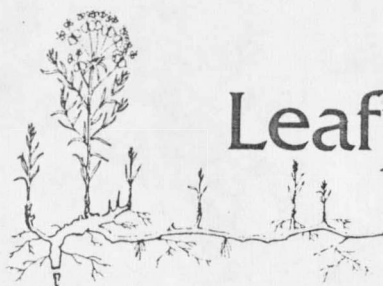
CANADA

Dr. Peter Harris, Agriculture Canada, reported that the larvae of Apthona flava and A. cyparissias released in November of 1982 were recovered in the spring of 1983. This indicates that the larvae are capable of overwintering in Saskatchewan.

* * * * *

If anyone would like extra copies of this newsletter, to be added to the mailing list, or more information on leafy spurge, please contact:

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Leafy Spurge News

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
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Volume IV

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Issue 4



NORTH DAKOTA

Program Receives Boost

Dr. Calvin Messersmith reported that the leafy spurge control program received a significant boost July, 1983. Program enhancement funds were provided by the 1983 N.D. Legislature and in addition, there was redirection of some scientists on staff by the Dir. of the Ag. Exp. Sta. The program enhancement adds a significant biological control and basic plant physiology program and stabilizes the chemical control program. Dr. C. Messersmith, is the overall leafy spurge control project coordinator; Dr. D. Galitz, is in charge of the plant physiology research; Dr. L. Littlefield, directs the disease control component; Dr. R. Lym, coordinates the chemical control projects; and Dr. Carlson, covers leafy spurge control with insects.

Research Supports Recommendations

The recent recommendation of adding 2,4-D with low Tordon rates for leafy spurge control is being supported by additional experiments across N.D.

Figure 1: Percent Leafy Spurge control with Tordon and 2,4-D applied singularly and in combination.

Tordon lb a.i./A	2,4-D lb a.i./A			
	0.0	1.0	1.5	2.0
0.0	0.0	30*	19*	30*
0.25	42	68	71	61
0.38	61	74	81	60
0.50	75	85	84	78

LSD 0.05 (for Tordon X 2,4-D)=18

* 2,4-D rates applied both spring and fall annually

Tordon at 0.25 lb/A plus 2,4-D at 1.0 lb/A applied annually provided enhanced control over either herbicide alone. This treatment gradually reduces a leafy spurge stand while providing a net positive income of about \$15.00/A. 2,4-D at 1.0 to 2.0 lb/A applied both spring and fall resulted in 30% or less leafy spurge control after 2 years. Leafy spurge control was not enhanced by increasing the 2,4-D rate above 1.0 lb/A either along or with Tordon. Increasing the Tordon rate to 0.38 or 0.5 lb/A with 2,4-D improved leafy spurge control compared to Tordon at 0.25 lb/A plus 2,4-D, but the net economic return from improved forage production was near 0 or negative. Annual applications of Tordon plus 2,4-D for 3 to 5 years will gradually reduce a leafy spurge stand until the remaining isolated patches can be spot treated with high Tordon rates.

Pathogens on Spurge

Dr. Larry Littlefield reported that several pathogens are being studied for their effect on leafy spurge at N.D.S.U.

Uromyces striatus: Spurge plants infected with the rust U. striatus are severely dwarfed, Chlorotic and exhibit distortions such as thickened, curled leaves, shortened internodes and flattened stems. Infected plants invariably die within 3 to 4 weeks of emergence. Unfortunately, the stage of the rust present in leafy spurge is nonrepeating, thus infection cannot be spread from one spurge plant to another. Also, the alternate host which bears the repeating uredial stage is alfalfa. Consequently there is little chance the rust can become a biocontrol agent for spurge.

Uromyces dictyosperma another rust has been obtained from MT on a close relative of leafy spurge, E. dictyosperma. Its effectiveness on leafy spurge will be tested as soon as a sufficient supply of urediospores can be obtained.

Microspheera euphorbiae causes powdery mildew but does little damage in the field. Some ecotypes of spurge are more severely affected than others. This pathogen might prove useful in characterizing different ecotypes of spurge.

Alternaria tenuissima f. sp. euphorbiae is the most promising pathogen for spurge biocontrol identified to date. Studies by Dr. Joe Krupinsky, have shown that this pathogen causes severe leaf spotting, cankers that girdle the stem, die-back of aerial portions, fruit decay, and reduction in seed set. The Alternaria pathogen is widespread but seems to do greatest damage in protected areas such as the shelterbelts, within clumps of buffalo berry bushes and under trees along streams. Greenhouse tests of virulence of many different Alternaria isolates will begin in mid Oct. 1983. Limited field tests of the virulent isolates will be made in N.D. and MT. during summer of 1984.

Studies on Sclerotium rolfsii, a soil borne pathogen, are being expanded. The potential problems associated with the wide host range of the pathogen might present major barriers to its use in biological control programs.

COLORADO

Mapping Leafy Spurge

Dick Myhre, USDA-FS at Ft. Collins, CO reported that a research study looking at the inventory and analysis of leafy spurge sites has been in progress at the U.S.F.S. Rocky Mtn. Forest and Range Exp. Sta. The study utilizes ground data and remote sensing techniques to: 1) Develop a quantitative approach to leafy spurge community description; 2) Determine the feasibility of mapping areas for leafy spurge infestations; and 3) Determine select soil-site relationships of leafy spurge. Mr. Myhre is working on the techniques for using aerial photography to locate and map leafy spurge infestations.

The test is comparing photo scales, film types, and seasons (peak flowering and fall coloration) to determine the combination(s) best suited for large area surveys. The aerial photography and ground data used in the study were acquired in the Devils Tower, WY area.

Results of this study will be used to recommend scale/film/season combinations for inventories, accuracy and cost tradeoffs between medium and small scale photo surveys, and the amount of accuracy that can be obtained for acreage estimates. The anticipated final product should be a users guide/handbook covering aerial photo specifications, photo interpretation techniques, training aids, etc.

MONTANA

Fall Tours

Approximately 155 people attended leafy spurge tours held in Carter and Petroleum Counties during September. A special thanks to Everett Brady, Dave Phillips, Darryld Kautzman, Pam Castleberry, Norman Campbell and others who worked hard to make the tours a success. We also appreciate the help and support of Dow Chemical Co., who sponsored the tours.

Pulling Together

Bruce Maxwell reported that experiments have been conducted to determine if pulling leafy spurge could control regrowth. Plots were hand pulled every two weeks throughout the 1982 growing season. Regrowth was measured on June 12, 1983 and Sept. 1, 1983.

The June rating showed no significant decrease in leafy spurge stems per square foot on any of the pulling dates, but visual ratings indicated up to 70% control due to the stunted nature of the regrowth. Visual ratings taken on Sept. 1, 1983 showed a maximum of 25% control over all the pulling dates. This indicates that the best time to pull leafy spurge for maximum control of regrowth is mid to late June.

During the 1983 growing season machines were used to pull leafy spurge. Machine pulling was compared with mowing, 2,4-D applications, Tordon application, and 2,4-D treatments following pulling and mowing. Preliminary results from this fall indicated that a single spring application of 2,4-D amine at 2 lbs/A and machine pulling with a follow-up treatment of 2,4-D regrowth after pulling provided the best control of leafy spurge. The 2,4-D treatment alone provided the greatest amount of perennial grass production, however grass weights were only significantly greater than the mowing treatments. The untreated check produced the most perennial grass on a biomass basis.

CANADA

New Insects?

Dr. Peter Harris has submitted a proposal to screen six new insects for the biological control of leafy spurge and Cypress spurge in Canada. The insects are: Aphona czwalinae, larvae feed on roots of spurge; Acyrtosiphon cyparissiae, an aphid; Minoa murinata, a moth, larvae feed on flowers and leaves; Aphis euphorbiae, an aphid; Pegoma agryrocephala, larvae mine through shoots, galls are formed at the base of the shoot; Lobesia occidentis, a stem borer.

WYOMING

Shoot/Root Control Study

Mark Ferrell reported that past studies attempting to correlate the shoot/root ratio of various herbicide treatments on leafy spurge have not been as successful as desired.

In 1983, core samples from the 0-18 inch soil depth were extracted from selected herbicide plots established in 1978. The plots which were selected for sampling ranged from 78 to 100% leafy spurge shoot control (evaluated 1982). Original treatments of Tordon and Banvel were retreated with Tordon, 2,4-D amine, Banvel, and a combination of Banvel/-2,4-D amine in 1979, 1980, 1981, 1982, and 1983. The Tordon treatments were terminated with the 1981 application.

Total vegetative root biomass was screened from the respective core samples, transplanted into greenhouse soil and moved to the greenhouse for regeneration evaluations.

The root regeneration study showed leafy spurge regrowth from the original/-retreatment combinations of: Banvel 4L/2,4-D amine at 4+2 lb ai/A, Banvel 4L/Tordon 22 K at 4+0.5 lb ai/A, Tordon 22K/Tordon 22K at 0.5+ 0.5 lb ai/A, Tordon 22K/Banvel 4L+ 2,4-DA at 1+1+2 lb ai/A and Tordon 22K/Banvel 4L+2,4-DA at 2+1+2 lb ai/A.

No original/retreatment plots maintaining 100% shoot control in 1982 showed any leafy spurge regrowth from the 0 to 18 inch depth. These treatments were Tordon 22K/Tordon 22K at 0.5+1 lb ai/A, Tordon 22K/Tordon 22K at 1+1 lb ai/A, Tordon 22K/Tordon 22K at 2+1 lb ai/A, Tordon 22K/Banvel 4L at 2+2 lb ai/A, Banvel 4L/Tordon 22K at 4+1 lb ai/A, and Check/Tordon 22K at 0+1 lb ai/A.

Although the shoot or root biomass was not measured it appears that the regeneration study initiated in 1983 may be a method of determining the recovery ability of leafy spurge under various original/repetitive herbicide treatments.

For more information or to be added to the mailing list, contact:

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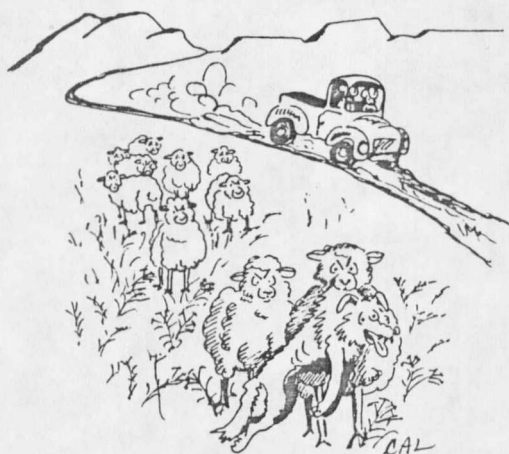
Leafy Spurge News

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
BOZEMAN, MONTANA 59717

VOLUME V

FEBRUARY 1984

ISSUE I



WHOOEE ... THOSE LAMBS OF OURS SURE GREW BIG AND TOUGH
ON THIS LEAFY SPURGE PASTURE !

MONTANA NEWS

Lambs Gain on Leafy Spurge

Sue Bartz reported that during the summer of 1982 and 1983, field research was conducted to determine the nutritional value of leafy spurge as a forage component for ewes and lambs. Data collected during these two periods are currently being analyzed and some interesting preliminary observations have been noted:

- * Lambs grazing leafy spurge infested pastures showed a significantly

higher weight gain than those lambs grazing only native grasses during the six-week data collection period. Weight gains of lambs grazing spurge averaged 5 pounds heavier than weight gains of lambs grazing only grass.

- * Breeding records of those ewes having eaten leafy spurge (the summer prior to breeding) showed absolutely no rebreeding problems or lambing difficulties due to the ingestion of leafy spurge.

- * Utilization data are still being analyzed to determine the percent "disappearance" of grass and spurge as a result of selective grazing by sheep.

Preliminary results are showing that sheep ate a significant amount of the spurge that was available to them, thereby supporting previous research which showed that after a 2 to 3 week adjustment period, sheep would selectively consume 40 to 50% of their diet as leafy spurge.

Do Doves Spread Spurge?

Bruce Maxwell reported that a cooperative study between Montana State Univ. and David Blockstein of the Bell Museum of Natural History, U. of Minn., has been undertaken to determine if leafy spurge seed is dispersed by mourning doves.

Preliminary results indicate that all leafy spurge seeds that have passed through the doves' intestines are not viable. Seed material was also collected from the gizzard and crop of seven doves. No viable leafy spurge seeds were found in the gizzards and only one viable seed was found in the crop.

These data indicate that mourning doves may not be important in the dispersal of leafy spurge seeds.

Biocontrol Update

Dr. Bob Nowierski & Jim Story reported that the spurge hawk moth Hyles euphorbiae was collected on a hillside north of Bozeman during 1982 & 1983. These insects are propagated during the winter for redistribution to other areas. In 1983, approximately 350 larvae, pupae & adults were released at two sites in Gallatin and Teton Counties.

Feeding tests are being conducted this winter to identify the types of leafy spurge preferred by the spurge hawk moth. Plant types that are preferred by Hyles and offer survivorship of the moth will be targeted for releases this spring.

NORTH DAKOTA NEWS

Leafy Spurge Symposium

Mark your calendar for the 1984 Leafy Spurge Symposium to be held on June 27 and 28 at Dickinson, ND. This year's program will highlight biological control with an updating on current research and actual control efforts. Part of the program will cover research on taxonomy of the leafy spurge complex and its importance in development of control programs. Chemical control work will be covered in short updating reports. A half-day tour is also planned.

Dickinson is close to Medora and Roosevelt Parks, so plan on bringing your family and spend some time in this beautiful area of North Dakota before or after the meeting. If you plan to fly commercial airlines, arrange to fly to Bismarck and provide Dr. Russell Lorenz with your arrival time so shuttle service to Dickinson can be arranged. Dickinson does have an excellent airstrip for private aircraft.

Pre-registration information will be provided automatically to GPC-14 committee members and those who have attended regularly. Others who wish to have their names on the mailing list or for additional information concerning the meeting please contact Dr. Russell J. Lorenz at 701-663-6445 or write to him at Box 459, Mandan, ND 58554.

SEE YOU IN JUNE!

Leafy Spurge Nursery

Dr. Rod Lym reported that the leafy spurge nursery, started by Dr. Melvin McCarty in 1978, has been removed from Lincoln, NE and will now be maintained at Bozeman, MT and Fargo, ND. Before his retirement, Dr. McCarty collected 39 leafy spurge specimens from 16 states, 2 Canadian provinces and Austria. This collection will be added to the current nursery at NDSU which consists of specimens from several areas of ND and MN. Any differences in the specimen's growth patterns or biological composition must be identified before biological control can become a reality.

Economical Spurge Control

Dr. Ron Lym reported that annual applications of Tordon or Tordon plus 2,4-D for 3 years have gradually reduced leafy spurge stands and are much more economical than single Tordon treatments at high rates. Tordon at 0.5 lb/A provided 75% leafy spurge control after three annual treatments. Tordon at 0.25 lb/A averaged only 42% control after three applications, but when tank mixed with 2,4-D at 1.0 and 2.0 lb/A control averaged 71%. The cost of the annual treatments is \$15 to \$20/year or a total of \$45 to \$60 after 3 years compared to Tordon at 2.0 lb/A which costs \$80 to \$90/A and must be reapplied every 3 years to maintain satisfactory control in ND. No Tordon residue was found in the soil after three annual applications thus the general increase in leafy spurge control was due to a gradual stand reduction and not to an increased Tordon level that would prevent reestablishment.

Pathogen Update

Dr. Larry Littlefield reported that emphasis during the past 4 months has been on Alternaria tenuissima euphorbiae as a possible pathogen for biocontrol. Isolates obtained from Wisconsin, Minnesota, Montana, North Dakota, and South Dakota have been tested. So far only one isolate from North Dakota has caused serious damage to inoculated plants. That isolate (SS-4) was obtained from J. M. Krupinsky (Mandan, ND) and was the one used in his earlier studies. Three different spurge ecotypes have been tested; two are severely damaged by SS-4, but one is not. However, following death of the spurge leaves and stems, healthy lateral branches usually arise from the stem below the dead area. Field tests of the SS-4 Alternaria are planned for summer 1984 in Montana and North Dakota.

Sclerotium rolfsii, obtained from D. E. Mathre, Montana State Univ., will kill all above ground portions of spurge plants growing in vermiculite. However, healthy young shoots begin to emerge, and within 60 days after inoculation the pot is again full of vigorous spurge plants.

Sclerotinia sclerotiorum, the northern counterpart to Sclerotium rolfsii, has not shown any pathogenicity on spurge. Experiments testing different methods of inoculation are still underway with this fungus.

WYOMING NEWS

Mowing Sets Up Herbicide Treatment!

Dr. Harold Alley reported that plots were established near Hulett, WY to determine the effectiveness of mowing, prior to treatment with herbicides, on controlling leafy spurge shoot regrowth.

Leafy spurge plants were mowed within 1 to 2 inches of ground level on June 30,

1982, 21 days prior to treatment with herbicides. Treatments included applications of liquid formulations of Banvel at 1.0 lb/A, Tordon at 0.5 lb/A, and 2,4-D LVE at 1.0 lb/A.

Shoot counts made May 19, 1983 (one year after treatment) indicated that mowing prior to herbicide treatment may have potential for reduced rates of chemical for leafy spurge shoot control. The treatment of 1.0 lb/A of 2,4-D LVE was as effective as 0.5 lb/A of Tordon resulting in 19 and 86% shoot control, respectively. However, more data are necessary to fully evaluate the value of mowing a setup treatment for controlling leafy spurge. Additional experiments are planned for the summer of 1984.

2,4-D LVE Treatments Prior to Tordon!

Dr. Alley reported that an experiment was established June 16, 1982, 5 miles south of Hulett, WY, to evaluate the use of 2,4-D LVE as a setup treatment prior to application of light rates of Tordon on leafy spurge.

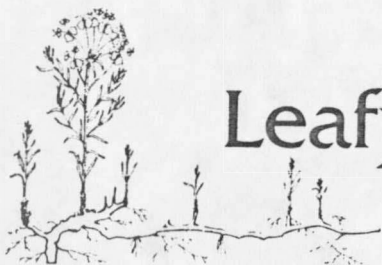
Setup treatments with 2,4-D LVE were made 1 day and 17 days prior to application of liquid formulations of 0.5 and 1.0 lb/A of Tordon.

Shoot counts made May 18, 1983 (one year after treatment) showed all Tordon/2,4-D LVE setup combinations gave 100% shoot control. There was no difference in leafy spurge shoot control between the 1 day and 17 day setup treatments with 2,4-D LVE.

These results would indicate that 2,4-D LVE as a setup treatment, followed by low rates of Tordon, may be an effective means of controlling leafy spurge shoot growth. Further experiments are planned for the summer of 1984.

* For additional information or to be added to the mailing list, please contact:

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Leafy Spurge News

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
BOZEMAN, MONTANA 59717

VOLUME V

APRIL 1984

ISSUE 2



CORRECTION

We apologize for an error made in the Feb. 1984 issue of the Leafy Spurge News. The error was made in the Wyoming section under Mowing Sets Up Herbicide Treatments. The percent shoot control with 1.0 lb/A of 2,4-D LVE should be 91% rather than 19%. Please make this correction in your February newsletter!

LEAFY SPURGE SYMPOSIUM

Mark your calendar for the biggest spurge event in 1984! The Leafy Spurge Symposium will be held on June 27 and 28 at Dickinson, N.D. Speakers will include researchers from Canada, Montana, Utah, Indiana, North Dakota, South Dakota, Idaho, Washington, Oregon, Nebraska, and Minnesota. A detailed agenda of the symposium follows.

LEAFY SPURGE SYMPOSIUM
Dickinson, N.D.
June 27-28, 1984

Tentative

- | | |
|--------------------------|---|
| <u>June 26</u> 6:00 p.m. | Tour of Leafy Spurge Plots |
| <u>June 27</u> | Ramada Inn |
| 6:30-7:30 a.m. | Group breakfast |
| 8:00-8:15 a.m. | Welcome & Introduction - Dr. Russell Lorenz |
| 8:15-12:00 | Leafy Spurge Taxonomy - Dr. Alina Stahevich (Moderator) |
| 8:15-9:00 a.m. | Cytogenetics
- Dr. Alina Stahevitch, Ottawa, Ontario
- Dr. Schaeffer, Montana |
| 9:00-10:30 a.m. | Chemotaxonomy
- Dr. John Evans, Utah
- Dr. Paul Mahlberg, Indiana
- Dr. Dave Davis, ARS, Fargo
- Dr. Don Galitz, North Dakota |
| 10:30 a.m. | Break |
| 10:45-12:00 | Discussion Groups - Taxonomy |
| 12:00-1:00 p.m. | Noon lunch - Group |
| 1:00-3:15 p.m. | Biological Control of Leafy Spurge -
Dr. Robert Nowierski, Moderator

Montana - Nowierski, Rees
Wyoming - Levine
North Dakota - Carlson, Littlefield
Canada - Harris
Idaho
Washington
Oregon |
| 3:15-3:30 p.m. | Break |
| 3:30-4:45 p.m. | Discussion Groups - Biological Control |
| 4:45 p.m. | Announcements |
| 5:30 p.m. | No host social |
| 6:30 p.m. | Banquet (Group Meal) - speaker
Dr. Robert Nowierski |
| <u>June 28</u> | |
| 6:30-7:45 a.m. | Group breakfast |
| 7:00 a.m. | Business Meeting (breakfast program) |
| 8:00-9:00 a.m. | Reports from Discussion groups |
| 9:00-11:30 a.m. | Chemical and Cultural Control - update**
Dr. Calvin Messersmith, Moderator

Montana - Dr. Peter Fay, et.al.
Wyoming - Dr. Harold Alley
North Dakota - Dr. Rod Lym, Dr. Cal Messersmith
Nebraska |

10:00 a.m. Break
 South Dakota
 Canada
 Utah
 Minnesota - Dr. David Biesboer

11:30 a.m. Check out of Motel

11:45-12:45 Noon Lunch - group meal

1:00-6:00 p.m. Bus tour to spurge problems and research plots West of Dickinson and in the badlands

6:00 p.m. Evening meal at Medora

Other speakers that may attend:

- Bill Bruckardt, Frederick, MD - Pathology
- Ken Stevens, ARS-USDA, Berkely Lab - Chemistry
- Gary Manners, ARS-USDA, Berkely Lab - Chemistry
- Duane Ebke, Nebraska

** May be limited to one speaker per state or to 15 to 20 minutes per state if all wish to report.

The registration fee will include two breakfasts, two noon lunches and the evening meal on June 27. Costs for breakfast is \$3.95 each, lunch \$3.50, and the evening meal is \$6.20.

For more information, please contact Dr. Russ Lorenz, USDA, ARS Box 459 Mandan, ND 58554 701-663-6445

NORTH DAKOTA

SPURGE TOURS

Dr. Rod Lym reported that field tours will be held at three N.D.S.U. leafy spurge research sites in June. The public will be updated on both biological and chemical control data. Those scheduled to be present are: Dr. Calvin Messersmith (Group leader), Dr. Robert Carlson (Entomology), Dr. Don Galitz (Botany), Dr. Larry Littlefield (Plant Pathology), and Dr. Rod Lym (Agronomy). The field days will be held in Sheldon on June 21 at 7:30 p.m., Minot on June 25 at 7:30 p.m. and in Dickinson on June 26 at 7:00 p.m. Those interested in the latest information on leafy spurge control are urged to attend.

MONTANA

BIOLOGICAL CONTROL

Dr. Robert Nowierski reported that 1200 adult beetles, *Oberea erythrocephala*, were released in four field cages in Bozeman during 1982. Plants sampled in 1983 indicate that 40% to 50% of the stems contain *Oberea* larvae, however two years will be required for larval development.

The flea beetle, *Aphona flava*, was received by the USDA Rangeland Insect Lab, Bozeman, in fall 1982. The insect is currently being held in cold storage until further testing is performed on *Euphorbia robusta*.

LEAFY SPURGE TOURS

Mark your calendar for the summer leafy spurge tours to be held in Montana. The tours should be informative and fun, with current updates on cultural, chemical, and biological control of leafy spurge. A tentative schedule follows:

June 7 - 4:00 p.m. Petroleum County
 located at Don Kimmel Ranch
 Contact: Everett Brady 424-7571
 Dave Phillips 538-3919
 Darryld Kautzmann 323-2704

June 11 - Powell County
 Contact: Dave Streufert 846-3680

June 14 - Roosevelt County
 Contact: Roger Ashley 787-5312

June 15 - Valley County
 Contact: Rick Stellflug 228-2457
 Verlin Koenig 228-2456

June 21 - Cascade County
 Contact: Jim Freeman 727-2804
 Doug Johnson 727-2804

June 22-24 STATE WEED FAIR - Toole Co.
 Contact: Kevin Laughlin 434-5351

Sept. 5 - Fallon County
 Contact: Pam Castleberry 778-2891

SOUTH DAKOTA

ECONOMICS OF SPURGE CONTROL IN PASTURE

Steve Gylling, assistant in the Plant Science Dept., S.D.S.U. reported that several herbicide treatments were applied for six growing seasons to spurge infested pastures in east central S.D. The treatments increased forage production up to

2800 lb/A when compared to untreated plots. Added return over treatment costs ranged from \$26.00/A benefit to \$18.00/A loss from the chemical applications. Treatments which provided the most economically beneficial control of leafy spurge are shown in Table 1.

Table 1:

	lb a.i./A	time*	% control	added return/A
2,4-D ester	3.0	S&F annually	98	\$22
2,4-D ester	1.5	S&F annually	93	\$19
2,4-D ester	1.5	S annually	75	\$17
2,4-D ester	3.0	S annually	82	\$15
Banvel + 2,4-D ester	0.5+1.0	S annually	87	\$19
Tordon + 2,4-D ester	0.25 + 1.5	S annually F annually	95	\$15
Roundup + 2,4-D ester	3.0 + 1.5	S first year S succeeding years	88	\$26

* S= spring application

F= fall application

LSD(0.05) 15

\$ 9

Splitting the 2,4-D applications into spring and fall treatment was generally beneficial as compared to a single spring application. However, when applied with Banvel, the best control was from a single spring application as a tank-mix. The single spring Roundup application appeared to suppress Kentucky bluegrass growth in the pasture, thereby favoring warm-season grasses. In general, leafy spurge control was feasible in this study, and repeated applications of herbicide were necessary to achieve long-term control.

CANADA

WELCOME

Dr. Alec McClay has recently accepted a position as weed scientist responsible for biocontrol at the Alberta Environmental Centre. Dr. McClay will be conducting follow-up studies on releases of Apthona and Oberea erythrocephala. He will also be working with the release of additional species which are being screened by the CIBC in Switzerland.

We welcome Dr. McClay to the staff in Alberta, and look forward to his contributions to the Leafy Spurge News.

WYOMING NEWS

ACTIVITY OF GROWTH REGULATORS & HERBICIDES ON LEAFY SPURGE

Mr. Mark Ferrel reported on the results of a greenhouse screening study and field study of selected growth regulators and herbicides on leafy spurge control. Banvel and Tordon were applied to leafy spurge at 1/8 the recommended rates with the following growth regulators: AGB-3034, a synthetic cytokinin; mixed cytokinins; 2,4-D; gibberellic acid; glyphosate; naphthaleneacetic acid; and PP333, an experimental anthigibberellin compound.

Evaluations of both the field study and greenhouse screening study showed that the growth regulators were ineffective in aiding Tordon and Banvel in controlling leafy spurge.

PROGRAM EVALUATION

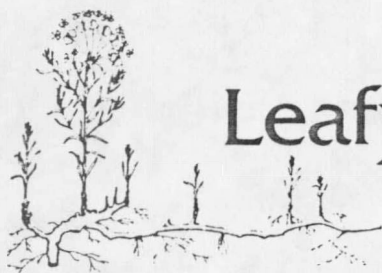
George Hittle, state weed coordinator, reported on the State Evaluation Committee's (SEC) review of the 1983 Leafy Spurge Program. The S.E.C. members include: Gary Orr, Wyoming Weed & Pest Council; Jim Whalen, State Land Office; Dr. Harold Alley, Univ. of WY; John Orton, Commissioner of Agriculture; M. F. Gowin, State Board of Agriculture.

The committee visited four counties in 1983: Lincoln, Crook, Weston and Sheridan plus attending the Leafy Spurge Symposium in Sundance. The committee concluded that all 4 counties were doing a very efficient job of controlling leafy spurge. Approximately 3,237 acres was initially treated and 16,193 acres was re-treated in 1983. Approximately 47,641 acres have been initially treated and 61,986 acres have been retreated from July 1, 1978 thru Dec. 31, 1983.

* * * * *

For additional information or to be added to the mailing list, please contact:

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Leafy Spurge News

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VOLUME V

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ISSUE 3



WELL, I KNOW I SHOULD TREAT THIS SPURGE....,
BUT IF I KILL IT HERE, IT'LL JUST
COME UP OVER YONDER!

MONTANA NEWS

Pulling Spurge

Bruce Maxwell reported that a study to develop cultural control practices for leafy spurge was initiated in 1983. Machine pulling was compared with mowing, 2,4-D (2 lb/A), Tordon (.5 lb/A), and 2,4-D treatments following pulling and mowing. Results from the fall of 1983 indicated that single spring application of 2,4-D amine at 2 lbs/A and machine pulling with a follow-up treatment of 2,4-D to regrowth provided the best control of leafy spurge. The 2,4-D treatment alone provided the greatest perennial grass production, however, it was observed that cows tended to graze pulled plots more readily than plots treated with 2,4-D.

None of the machine pulled, mowed, herbicide, or combination treatments significantly decreased the density of leafy spurge one year after application.

Results from this study showed that hand pulling could be an effective way to control small infestations of leafy spurge for one year. Seed production can be eliminated and regrowth is severely stunted which will slow the advancing infestation. This method of control would be best suited to small patches along waterways where herbicide use is restricted and where leafy spurge seed production must be eliminated to prevent dispersal by water. If a soil borne pathogen can be developed as a biological control agent on leafy spurge the pulling may be an effective way to increase infection in the plant.

Moving On

B. I. Maxwell recently completed his MS degree at Montana State University. Bruce was a great asset to our spurge program in Montana and we will miss his dedication and hard work. Bruce plans to attend Oregon State University as a Ph.D. candidate, working with Dr. Steve Radosevich. We will continue to publish results of the research that Bruce conducted in the next several newsletters. Bruce's mailing address is:

129 NW 35th Street
Corvallis, OR 97330

Spurge Tours

Approximately 435 people attended 9 tours held in June and July. The tours provided information on identification and control of both leafy spurge and spotted knapweed. A special thanks to all of the county agents, soil conservation service personnel, soil conservation districts, and weed supervisors who worked so hard to make these tours a success. We also appreciate the help and support of Dow Chemical Company who sponsored the tours.

Two fall tours are planned this year:

Sept. 11 Fallon County
Contact: Pam Castleberry
778-2891

Sept. 12 Sweetgrass County
Contact: Jim Roller
932-5146

NORTH DAKOTA NEWS

Successful Symposium

Congratulations to NDSU and USDA, ARS for hosting an informative and enjoyable Leafy Spurge Symposium.

The first day of the symposium was highlighted with research reports on cytogenetics, chemotaxonomy, and biological control. The second day featured an update on chemical control of spurge and a bus tour to spurge problem areas and research plots west of Dickinson and in the Badlands.

A special thanks to Dr. Rod Lym, Dr. Russ Lorenz, Dr. Cal Messersmith, Dr. Robert Nowierski and others for planning and organizing the symposium.

Weed Research Nursery

Dr. Rod Lym reported that a perennial weed control area is being established at the NDSU Experiment Station in Fargo. A 25 acre area has been set aside for the establishment of a leafy spurge nursery as well as field bindweed, perennial sowthistle and quackgrass. These perennial weeds are being planted to provide an area where experiments requiring daily observation and treatment can be conducted. In the past such experiments were impractical because of the travel time and expense. It will also provide a site for controlled release of pathogens or

insects that may become available for biological control. It will take approximately 5 years to establish solid stands of the perennial weeds on the 25 acre site.

Pathogen Update

Dr. Larry Littlefield, Plant Pathology Dept., NDSU, reported that the results of 1984 summer field studies in North Dakota have not been very promising. Leafy spurge plots in 2 locations were inoculated with Alternaria tenuissima f. sp. euphorbiae, the fungus which has given excellent control in greenhouse studies. Very little, if any, damage was done to leafy spurge under field conditions by these inoculations.

A new graduate student will join the project in September. Two new temperature and humidity controlled growth chambers are now operational and studies are underway to induce mutations to higher virulence in the pathogen. Now all that is needed is a bit of cooperation from Euphorbia esula!

One bright note is that a Fusarium sp. has been isolated from dead Russian Knapweed. Therein may lie a potential biocontrol for another serious weed. Greenhouse studies will be made during the coming winter on that host-pathogen combination.

Native Insects on Spurge!

Joe Julian recently completed his MS degree at NDSU. His masters program was to conduct a native insect survey on leafy spurge. The results of his research showed that although native insects were not observed to cause major damage to leafy spurge, a few of the insects may play a part in controlling the weed either directly or indirectly. Sparganothis sulfureana was found feeding on the leaves and seed pods in various parts of eastern ND. This insect is a pest of certain agricultural crops in the United States so would not be a suitable insect for rearing and release on leafy spurge. It is possible that other species of this genus would be more host specific to Euphorbia plants. The other insect found in great numbers was Cluptina

atriventris Horn, a flea beetle closely related to the genus Apthona which has been imported and released on leafy spurge in the U.S. and Canada. The larvae of this insect is believed to feed on the roots of Euphorbia plants although the larvae was never found in this study. The remainder of the insects collected were either nectar feeders, polyphagous, or incidental on leafy spurge.

WYOMING NEWS

More Help!

Camal Heneidi, a Ph.D. candidate in Weed Science will be conducting research on the affects of herbicides applied at various stages of growth on leafy spurge seed viability.

Funds for Spurge

Dr. Mark Ferrel reported that the University of Wyoming has received a \$50,000 grant from the Wyoming Department of Agriculture, effective April 1984, to continue research on leafy spurge. It is a cooperative agreement in which the University of Wyoming will be responsible for 1) continuation of the repetitive herbicide treatment program, 2) continuation of physical practices (mowing) prior to herbicide treatment, 3) researching the use of light rates of 2,4-D as a set-up prior to treatment with Tordon, 4) continuation of evaluation of forage production and crop tolerance to various herbicides, and 5) continued monitoring of environmental conditions and plant behavior.

* * * * *

For additional information or to be added to the mailing list, please contact:

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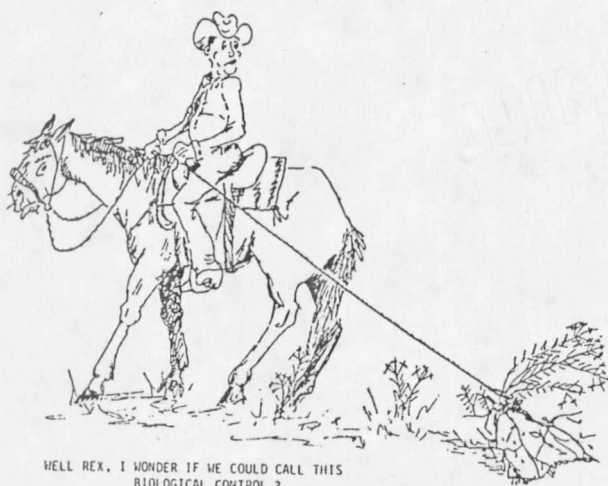
Leafy Spurge News

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
BOZEMAN, MONTANA 59717

VOLUME V

Dec 1984

ISSUE 4



MONTANA NEWS

Hawkmoth Spreads

Several releases of the spurge hawkmoth *Hyles euphorbiae* L., have occurred in Montana since 1964. Attempts to establish this biological control agent on leafy spurge have been regarded as only marginally successful.

Recent studies of this insect by Noah Poritz, graduate student, MSU, indicate that the spurge hawkmoth is well established near Bozeman, MT. Noah's studies on the population dynamics of the hawkmoth have shown that adult hawkmoths have dispersed miles from their initial release sites.

Noah is also studying rates of feeding and development of the hawkmoth at different temperatures in the laboratory and field. He is also examining mortality and survivorship factors as well as expanding studies on field population dynamics of the spurge hawkmoth for 1985.

Hawkmoth Releases

Seven new release sites were established on leafy spurge in Montana. Dr. Robert Nowierski, Steve Harvey, and Noah Poritz, MSU, and Norman Rees, USDA Range Insect Lab were responsible for the release of over 1000 hawkmoth larvae in Carter, Gallatin, Richland, Stillwater, Sweetgrass, and Teton counties in 1984. Initial observations indicate that the hawkmoth is well established. Follow-up evaluations will be conducted in 1985.

Oberea Releases

Mr. Norman Rees (USDA) reports that the root-boring beetle, *Oberea erythrocephala*, which was released in Gallatin, Richland, and Stillwater counties, has shown its ability to damage roots of leafy spurge. The agent is established in Gallatin and Stillwater counties. Populations will be monitored in 1985 to confirm establishment in Richland Co.

Controlling Leafy Spurge Buds

Scott Nissen, Ph.D. candidate at MSU, is conducting greenhouse and laboratory studies to determine factors responsible for bud control in leafy spurge. The studies have shown that during flowering and in late summer when day lengths shorten, leafy spurge root buds enter a state of dormancy which is not broken by simply removing the auxin supply. During these periods the initiation of active growth

requires a period of chilling temperatures. Laboratory studies indicate that a period as short as 8 days at 36°F is sufficient to break this type of dormancy.

ALBERTA NEWS

Starch Utilization

Scott Nissen reported that large starch reserves are stored in both the root system and latex of leafy spurge. The ability of leafy spurge to utilize shoot, root, and latex starch has been examined by growing plants in the dark. Preliminary results indicate that shoot and root starch levels decrease by 50% after 11 days without light, while latex starch remains relatively constant. It appears that latex starch is not a reserve of utilizable carbohydrate. At this time the purpose of this starch is unknown.

NORTH DAKOTA NEWS

Association Meets

Dr. Russ Lorenz and Dr. Rod Lym reported that the first annual meeting of the North Dakota Weed Control Association will be held on January 14, 1985, at the Kirkwood Motor Inn, Bismarck, ND. The weed control conference has been formed to unite weed control officers in the 52 counties of ND.

Leafy spurge control will be emphasized, but information will be presented on knapweed and other perennial weeds. Reports on sprayer calibration, regulations, and weed surveys will also be presented. Speakers on the program include researchers with USDA-ARS, Coop. Extension Service, Agric. Exp. Stn., and NDSU.

For more information, please contact Wayne Colberg, 600 W. Main & Riverside, West Fargo, ND 58078. His phone number is (701) 282-5487.

Euphorbia Species Wanted

Dr. Alec McClay reported that the Commonwealth Institute of Bio Control at Delemont, Switzerland, needs seed of a number of Euphorbia species for use in screening tests for potential biocontrol agents for leafy spurge. If any readers of the Leafy Spurge News have seed of these species available, or know where they can be obtained, please contact Andre Gassmann, CIBC European Station, I Shemin des Grillons, CH-2800 Delemont, Switzerland. Your help is greatly appreciated. The species needed are:

Euphorbia antisuphilitica

E. corollata

E. grandialata

E. maculata

E. meloformis

E. oblongata

E. serpyllifolia

E. trigona

E. wulfenii

WYOMING NEWS

Mowing Sets Up Herbicide Treatments

Dr. Mark Ferrell reported that plots were established near Hulett, WY to determine the effectiveness of mowing prior to treatment with herbicides on controlling leafy spurge shoot regrowth.

Leafy spurge was mowed on June 30, 1982. Herbicide treatments were applied on July 21, 1982. Leafy spurge shoot counts were taken in May, 1983 and 1984.

Results of the treatments showed that Tordon at 0.5 lb/A and 2,4-D LVE continued to provide good control of leafy spurge 2 years following application.

Additional studies using mowing prior to herbicide applications are planned for 1985.

Table 1. The effects of mowing as a set-up treatment prior to herbicide application.

Herbicide	Rate lb/A	% Control	
		1983	1984
Banvel 4L	1.0	32	36
Tordon 22 K	0.5	86	75
2,4-D LVE	1.0	91	85
Check	0.0	0	0

Alley Retires

Dr. Harold Alley, Extension Weed Scientist at the University of Wyoming, retired on November 30, 1984. His expertise and dedication to weed science will certainly be missed in Wyoming; however, Harold plans to serve as a consultant in the future.

Harold is currently living in Casa Grande, Arizona until April 1985. We certainly hope his golf game improves substantially.

We'll miss your words of wisdom,
Harold -- Good Luck!

* * * * *

For additional information or to be added to the mailing list, please contact:

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knapweed update

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
BOZEMAN, MONTANA 59717

Volume I

OCTOBER 1983

ISSUE 1

Greetings! This is the first issue of the knapweed update that will be published two to three times yearly by the Plant and Soil Science Department at Montana State University. The purpose of the newsletter is to help coordinate research efforts, share information, arouse interest, and increase awareness of spotted and diffuse knapweed. We appreciate any contributions or suggestions that you may have.



POOR OL' JED, KNAWEED GOT HIS RANCH!

In This Issue

The Knapweed Problem in North America

Montana Update:

Rate of Knapweed Spread
Knapweed Phytotoxins
Current Research

British Columbia News

Knapweed Infestations
Research Update
Economic Loss from Knapweed

The Knapweed Situation:

Idaho
Oregon
Washington

Spotted and Diffuse Knapweed in North America

Johnny Cash, the country western singer has a song where he states that the "water is 5 feet high and risin'." If he was asked how the knapweed was doing in North America, he would probably say "it's infested 8 million acres -- and infestin'."

Spotted and Diffuse knapweed was introduced to North America from the Eurasian steppe grasslands in the early 1900's and has spread rapidly over rangelands in British Columbia, Montana, Idaho, Oregon, and Washington. These knapweeds are causing substantial losses to the livestock industry, environmental deterioration and undetermined reduction in recreational value, aesthetics, quality of wildlife habitat and property values. Only in recent years have significant efforts been made to contain its spread.

The knapweeds are highly competitive plants which are capable of invading rangelands to the near exclusion of desirable forage. Reduction in forage of 90% or more is common on severely infested sites. These weeds are extremely aggressive, drought tolerant, and very prolific, with a high rate of seed viability. Since knapweed is not native to North America, there are no native enemies or parasites to keep it in check. These factors enable knapweed to form large, dense infestations and spread rapidly.

herbicides, a high level of public awareness and effective biological control.

Economic Impact

Roy Cranston estimates that the losses in stocking rate on B.C. rangelands due to knapweed are 32,000 Animal Unit Months (A.U.M.). This figure was obtained by using data in Table 1. With the value of an A.U.M. at \$10, this represents a loss of \$320,000 annually in forage production. However, by using a forage-to-beef conversion of 12:1, the loss in beef value at the farm gate is over \$1.5 million annually.

If knapweed spread over the projected 1.1 million ha. of rangeland, the potential loss in annual farm gate beef value would be nearly \$41 million based on 1982 prices.

Table 1: Loss in Animal Unit Months (A.U.M.) Due to Knapweed

Average Stocking Rate on Grass-land and Ponderosa Pine Sites in Good Condition (No Knapweed)	Average Stocking Rate on Knapweed Infested Range
Forage Production 560 kg/ha	112 kg/ha
A.U.M.* 1.0 ha/A.U.M.	5.0 ha/A.U.M.

* Based on 63% utilization of forage

Current Research

Research on the knapweed species currently underway in B.C. and which will be reported on in future issues include:

1. Use of Micro-Max Ultra-Low Volume spray nozzles
2. Biological control
3. Alternatives to picloram
4. Soil seedbank longevity
5. Knapweed phenology
6. LANDSTAT imagery to map knapweed infestation
7. Allelopathy

IDAHO



Weed Survey

Steve Dewey, Extension Weed Specialist, conducted a telephone-mail survey to determine locations and size of infestations of noxious weeds in Idaho. Russian knapweed has been reported in 25 counties. Diffuse knapweed was reported in 15 counties and spotted knapweed in 24 counties. Although total acres infested have not been quantified, estimates include 300,000 acres of spotted knapweed, 25,000 acres of diffuse knapweed and about 50,000 acres of Russian knapweed in southern Idaho.

OREGON



Knapweed Spreads

Robert Hawkes, Supervisor of the Weed Control Program, reported that the knapweeds are a serious problem in Oregon. Diffuse knapweed is the most prevalent, occupying about 5 million acres in the northeast quarter of the state. Spotted knapweed infests about 20,000 acres, but is spreading at a rapid rate in some areas.

A chemical control program is being used to eliminate new infestations while they are still small. This involves areas west of the Cascade Mountains and south central and southeastern Oregon. Biological control methods are being utilized in the northeastern portion of the state.

WASHINGTON



The Knapweed Situation

Ben Roche, Range Specialist at WSU reported that there are about 12 million acres of timbered and non-timbered rangeland in Washington. A 1982 survey showed that 39% of the non-timbered range was in poor condition and 30% was in fair condition. The range condition has been lowered by misuse, overuse, and the resulting increase in less desirable native species (big sage) or invasions of exotic grasses (cheatgrass and medusa head).

Now there is a new problem that makes everything we've experienced in range rehabilitation mild by comparison. This is the introduction and spread of diffuse and spotted knapweed and yellow star thistle. Recent surveys suggest a non-timbered acreage of 1,146,740 acres of diffuse and spotted knapweed and 179,317 acres of yellow star thistle.

Research on herbicides and herbicides in combination with N fertilizer is currently being conducted. A detailed report of this research will follow in future issues.

* * * * *

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MONTANA UPDATE:The Knapweed Take-over

Dr. John Lacey, range specialist at MSU, estimates that there are about 2 million acres of spotted and diffuse knapweed in Montana. However, he feels that the seriousness of the problem cannot be appreciated until the rate of knapweed spread is known. He proposes that the rate of spread can be estimated with the compounding formula that bankers use to "convert present values to a future sum:"

$$V_n = V_0 (1+i)^n$$

V_n = value after "n" years; V_0 = present value; n = number of years, and i = rate of spread.

The compounding formula is basic to calculating the value to which amounts of money deposited at interest today will grow to by some future date. Knapweed appears to increase the same way.

If we assume that there was only 1 acre of knapweed in Montana in 1920, and 2 million acres in 1980, we can calculate the rate of spread by using the compounding formula:

$$2,000,000 = 1 (1+i)^{60}$$

By solving for "i" it appears that knapweed has been spreading at an annual rate of 27%!

If we assume that this rate of spread continues it will take only about 14 years before 60 million acres of rangeland are infested with spotted knapweed in Montana.

This clearly indicates that land managers, economists, researchers, and legislators must place more emphasis on knapweed. Economic benefits of a control program should include the value of resource protection as well as forage increases.

Phytotoxins Studied

Dr. Rick Kelsey, Dept. of Chemistry at the University of Montana in Missoula, recently received a research award of \$105,000. The award will be used to conduct a study entitled "Spotted Knapweed Phytotoxins and Their Ecological Significance." The goal is to gather information

on the natural phytotoxins produced by spotted knapweed and evaluate their contribution to the ecological success of these plants. This will improve our understanding of knapweed biology and should help in the development of an economical control.

Since the study began in March, one compound has been isolated and identified. It is a major component of the green tissue and inhibits the germination of crested wheatgrass and lettuce seed in the lab. At lower concentrations lettuce seeds will germinate, but the root growth is severely retarded. The effects on bluebunch wheatgrass, Idaho fescue, rough fescue, and prairie junegrass is being tested with seeds collected this summer. Techniques are being developed to measure the concentration of this phytotoxin in the plant and surrounding soil.

Current Research

Research currently being conducted on spotted knapweed in Montana includes:

1. Biological control
2. Herbicide control
3. Predicting weed migrations
4. Seed longevity studies
5. Allelopathy studies

This research will be reported on in future issues.

BRITISH COLUMBIAKnapweed Spreads

Roy Cranston, weed specialist for B.C., estimates that over 40,000 ha. (100,000 ac.) of B.C. rangelands are currently infested with knapweed. There is a potential for spread to over 1 million ha. (2.5 million ac.) of open grassland and an undetermined amount of open forest range.

He feels that the ultimate solution to the knapweed problem in B.C. does not lie in massive application of herbicides. This is mainly because of the inaccessibility of many infestations, the high cost of herbicides and application, the prolific nature of knapweed, and the restrictive legislation to protect the environment.

The long-term solution to knapweed control in B.C. will be a combination of proper grazing management, judicious use of

knapweed update

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
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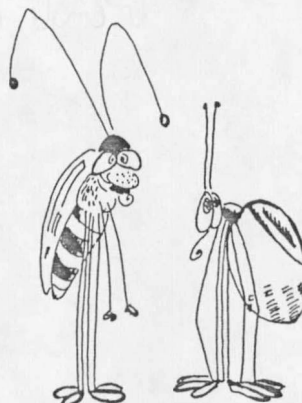
This issue of the Knapweed Update will feature the status of biological control of spotted and diffuse knapweed in the United States and Canada.

KNAPWEED SYMPOSIUM

The biggest knapweed event of the year is being held on April 3 and 4 at the Sheraton Hotel in Great Falls, Montana. The purpose of the symposium is to present new research data on the ecology and management of the knapweeds and devise strategies to implement new control technology.

The symposium is sponsored by Montana State Univ. Plant and Soil Science Dept., Montana Coop. Ext. Service, Western Montana Weed Council, Montana Knapweed Action Committee, and Lewis and Clark and Lincoln Co. Conservation Districts.

Anyone wishing to present a paper should submit the title to Dr. John Lacey, Ext. Range Specialist, 221 Linfield hall, Montana State Univ., Bozeman, MT 59717-0002 by January 25, 1984. Additional information is available from Dr. Peter K. Fay, Plant and Soil Science Dept., Montana State Univ., Bozeman, MT 59717-0002 (406)994-5061.



ONE THING'S FOR SURE MAVIS, THERE'S PLENTY TO EAT!

INTRODUCTION

Biological control is the use of natural enemies (insects, diseases, and other organisms) to control weed species. The objective of biological control is not eradication of weeds, but rather the reduction and stabilization of the weed population below economic thresh-holds.

Because the knapweeds were introduced to N. America, there are very few native insects or diseases that attack the plants. Thus research scientists have been introducing organisms for the biological control of these weeds.



MONTANA

Jim Story, Western Montana Agricultural Research Center at Corvallis, and Dr. Robert Nowierski, M.S.U., are working cooperatively on the biological control program for spotted and diffuse knapweed in Montana. During the past 10 years four species of insects have been released on these two knapweed species. The status of the insects follows:

Urophora affinis: This small fly attacks the flower buds of spotted and diffuse knapweed. The fly larvae cause the plant to form "galls" in the flower buds which reduce seed production. Releases of the fly were made at 15 sites during 1973-1977 in western Montana. The fly became established and has dispersed to a radius of at least 5 miles at all sites. A four year study at 5 sites showed that the percent knapweed seedheads infested with the fly and the average number of galls per seed head increased significantly. In 1981, the percent of fly infested seed heads ranged from 63-95%. Large populations of the fly now occur at release sites near Butte, Townsend, Livingston, Geyser, and Roundup.

Urophora quadrifasciata: This insect is another gall fly, closely related to U. affinis. This fly, introduced in British Columbia, Canada in 1972, is migrating into western Montana at a rapid rate. In contrast to U. affinis which has only one generation per year, U. quadrifasciata has 2 generations per year, forms thinner galls, and attacks more mature flower buds than U. affinis. Because the two flies attack the flower buds at different plant growth states, they complement each other in their attack of the seed head and spotted knapweed seed reductions of 95% have been reported in areas where both flies are well established.

Metzneria paucipunctella: The larvae of this small moth attacks the flower buds of spotted knapweed. Four releases of this moth were made in

Montana during 1980-1983. Data collected in 1982 showed 11.2% infested seed heads in a field cage compared to only 1.0% at a field-release area.

Studies are currently being conducted to determine the compatibility between this moth and the seed head fly.

Sphenoptera jugoslavica: This beetle mines the roots of diffuse knapweed. Small numbers of the beetle were released in 1983; status of the beetle has not yet been determined.

CURRENT STUDIES

Several studies relating to bio-control of spotted knapweed are currently underway:

1. Fly impact study: This study (initiated in 1983) will measure the total impact of the 2 seed head flies on the seed production, biomass, and number of flower heads/plant on spotted knapweed.

2. Fly-herbicide integration study: A study was initiated in 1983 to determine if U. affinis and the herbicide 2,4-D could be used in an integrated control program against spotted knapweed. The objective is to determine the optimum timing of 2,4-D applications to achieve the maximum control of spotted knapweed with a minimal effect on the fly population.

3. Spotted knapweed degree-day study: The objective of the study is to determine the relation of temperature to development of spotted knapweed. This information will be used to develop growth models of the plant and predict optimum times for biocontrol agent release.

NEW INSECTS!

Preparations are being made for the release of two root mining moths in Montana on spotted and diffuse knapweed in 1984 or 1985. The larvae feed in the roots of small rosettes which commonly results in the death of the plant.



OREGON

Bob Hawkes reported that in the northeastern portion of Oregon, chemical control of spotted and diffuse knapweed does not appear feasible, thus biological control agents are being used. Both species of seed head gall flies, Urophora affinis and U. quadrifasciata are widespread and redistributions are being made to new areas. The root boring beetle, Sphenoptera jugoslavica, is well established on diffuse knapweed at one site in Morrow county and will be redistributed in 1984. The moth Metzneria paucipunctella is established on spotted knapweed at one site in Deschutes county and plans are being made to relocate some of them in the near future. It is still too early to see much effect on the knapweed plants from these latter two insects.



WASHINGTON

Dr. G. L. Piper, W.S.U., reported that the knapweeds infest about 1.5 million acres in Washington, with diffuse knapweed being the predominant species.

In 1974, an active biological control program was initiated with the release of the seed head fly Urophora affinis. This fly attacks both spotted and diffuse knapweed infesting up to 90% of the heads produced by a plant. The fly is established in nine central and eastern Washington counties.

Another seed head gall-forming fly, U. quadrifasciata was first discovered in the state in 1979. The fly invaded Washington from British Columbia. This bioagent now occurs in all counties east of the Cascade Mts. This fly completes two generations a year and is a much better colonizer of spotted and diffuse knapweed infested sites than is U. affinis. Over 90% of the flower heads may be attacked and

up to 15 galls have been found in a single head.

The moth, Metzneria paucipunctella was released in 1981 at three sites in eastern Washington for the control of spotted knapweed. The moth established easily, but is increasing its numbers slowly at the release sites. Normally only one or two larvae develop per head. It is too early to assess the biocontrol potential of Metzneria.

The beetle, Sphenoptera jugoslavica, whose larvae feed in the roots of diffuse knapweed, was released in 1983 at a site in Okanogan County. Gall formation by the larvae structurally weaken the root and reduce plant vigor, particularly among plants occupying low rainfall areas.

New Insects

New biological control agents scheduled for release include the diffuse knapweed root-feeding moths Pelochrista medullana (1984) and Pterolonche inspersa (1985) and the spotted knapweed root-infesting moth Agapete zoegana (1985). Studies are also being carried out in Europe presently to find and evaluate additional enemies (insects, mites, pathogens) which may be suitable for introduction into the state in the future.



IDAHO

Dr. Joe McCaffrey, Univ. of Idaho, reported on biocontrol activities on the knapweeds in Idaho.

Activities during 1983:

1. Redistribution of the two species of gall-forming flies U. affinis and U. quadrifasciata to additional spotted knapweed sites.

2. Monitored establishment and population build-up of the moth Metzneria paucipunctella on spotted knapweed.

3. Developed preliminary phenology model describing first generation adult emergence of the two

gall-forming flies from spotted knapweed seed heads.

4. Undertook field and lab studies to evaluate the effects of picloram and 2,4-D on *Urophora* spp. on spotted knapweed.

5. Greg Wheeler, a grad student, continued biological, ecological and behavioral studies on two spiders, *Dictyna major* and *D. coloradensis*, that are potentially important mortality factors affecting the gall-forming flies on knapweeds. The thesis will be completed by June 1984.

New Work for 1984

1. Continue redistribution efforts of seed head flies.

2. Initiate biological studies on the moth *Metzneria* to determine its compatibility with *Urophora* spp.

3. Evaluate fly synchrony with spotted knapweed phenology.

4. Monitor field plots previously treated with Tordon and 2,4-D to evaluate long term effects relating to re-establishment of *Urophora* species.

5. Complete field survey of arthropods associated with spotted knapweed, continue with diffuse knapweed.

6. Elizabeth Vogt, a new student will initiate a study of the nutritional requirements of *Urophora* spp. adults.



CANADA

Drs. Peter Harris and J. H. Meyers reported on the release of four insects in Canada. The status on the release of these insects follows.

Urophora affinis: This seed head fly was released in 1970 and has established on both spotted and diffuse knapweed in British Columbia and Quebec. In Hastings County, Ontario, galls were found the year following release, but subsequent heavy grazing destroyed most of the knapweed heads.

Urophora quadrifasciata: Populations of this seed head fly increased rapidly

after release in 1972, but has since declined to low numbers at original release sites. *U. quadrifasciata* has spread more widely and rapidly than *U. affinis* and has been found on remote knapweed stands in B.C.

The immediate effect of both the seed head flies on the study site at Kamloops, B.C. has been a decline in seed production from about 25,000 to 1,500/m² and a reduction in the biomass of the weed, but the number of plants per unit area has remained the same.

Metzneria paucipunctella: Adult moths were released in 1973 and 1974 at Castlegar and Westwold, B.C. No moths have been recovered from Castlegar. However Westwold moth populations had spread to a radius of .5 km by 1981.

The effect of this moth on spotted knapweed was less than expected from European studies as a different species of knapweed appears to be involved in B.C. Also, the overwintering larvae at Westwold, B.C. have suffered a periodic large and unexplained winter mortality. The ability of both this moth and the fly *U. quadrifasciata* to survive in colder parts of the Canadian prairies is doubtful.

Sphenoptera jugoslavica: Releases of this beetle were made at Grandforks and White Lake, B.C. in 1976. No survivors were found at Grandforks, but the colony at White Lake increased to infest 25-50% of the rosettes within a 250 meter radius in 1981, and over 1/2 of the flowering plants had been attacked.

The effect of the beetle on diffuse knapweed was not studied in detail because of the small size of the populations. However, the beetle tends to reduce seed production and may prevent rosettes from bolting. There was also an indication that the beetle had a synergistic effect on seed reduction in plants stressed by drought or attacked by the seedhead gall flies.

Control Strategy

The seed reduction achieved by the biological control agents already

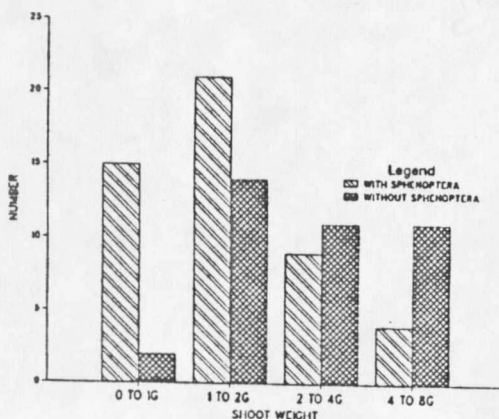
established in B.C. should have decreased the rate of knapweed invasion from headlands onto tame pasture as well as the spread to new regions within western Canada. However, to reduce knapweed with biological control agents to the point where the chemical control programs become unnecessary will require the establishment of more biocontrol agents on knapweed in Canada.

Current Research

Univ. of British Columbia:

Rob Powell, a graduate student at the Univ. of British Columbia, is currently working on the effect of the beetle, *Sphenoptera* on diffuse knapweed. Preliminary analysis of his data show that the beetle has a significant effect on both the size of the bolted plants and the proportion of good seedheads per plant.

FREQUENCY OF SHOOT WEIGHT CLASSES WITH AND WITHOUT SPHENOPTERA



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Macdonald Campus of McGill Univ.

Dr. A. K. Watson reported that current research involves the evaluation of rust fungi (*Puccinia* spp.) as biocontrol agents of diffuse, spotted and Russian knapweed and yellow starthistle.

Graduate Student Projects

- O. Anas. Studies on the mass culturing of *Paranquina picridis* (nematode) and its host/parasite relationship with Russian knapweed.
- M. Clement. Evaluation of *Puccinia centaureae* (a rust) for the biological control of spotted knapweed.
- C. Rafuse. Biosystematics of N. America spotted knapweed.
- C. Cranch. Threat of N. American safflower to possible introduction of knapweed rusts.

Spotted Knapweed in Eastern Canada

Dr. Watson reported that approximately 1700 ha (4165 ac.) are infested with spotted knapweed in eastern Canada with major infestations occurring in Grey, Hastings, Norhtumberland and Simcoe counties in Ornario and in Iberville and Deux Montagnes counties in Quebec. Spotted knapweed has been reported to occur in New Brunswick and in Nova Scotia, but is not a weed problem in these provinces.

Alberta

Shaffeck Ali reported that spotted and diffuse knapweed was discovered in Albert in 1974, and currently infests about 150 ha (375 ac.) in the southern part of the province. Environmental conditions are ideal for knapweed growth, and an estimated 1 million ha (2.5 m ac.) are susceptible to invasion. Thus, Alberta has initiated an active chemical program to eradicate the weed from the province. Additional information on this program will be reported on in the following issue.

knapweed update

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
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VOLUME II

May 1984

ISSUE 2



Knapweed Symposium

The knapweed symposium held April 3 and 4 in Great Falls, MT was a great success with over 100 people attending the program. Researchers, ranchers, and extension personnel representing 7 states and provinces presented current research programs and research needs for knapweed control.

The sessions included information on biological, cultural, and chemical control of spotted and diffuse knapweed and yellow star thistle. Ranchers and extension personnel stressed the current problems and research needs concerning spotted and diffuse knapweed. The proceedings from the sessions will be published this summer.

We appreciate the support and encouragement from all those who attended the symposium. A special thanks to John Lacey, Pete Fay, and Tim Chicoine for organizing the symposium. We also appreciate the support of the Knapweed Action Committee, Montana Weed Control Association, Lewis and Clark Conservation Dist. and Lincoln County Conservation Dist., Western Montana Weed council, and Dow Chemical Company.

MONTANA NEWS



Moving On

Tim Chicoine recently finished his MS degree at MSU and has taken a job with Dupont Chemical Co. Tim's thesis included spotted knapweed control with chemicals, seed longevity, and the potential migration of spotted knapweed in Montana. The results of his research will be published in the next several issues of this newsletter. We will miss Tim's contributions to our knapweed program in Montana, however several of his studies will be continued.

Long-term Control

Experiments were established at two locations in Montana in 1979 by Larry Baker. These experiments were used to determine the duration of control of spotted knapweed with $\frac{1}{4}$ lb/A of Tordon. Initial reinvasion of plots by spotted knapweed began in 1982, 3 years following herbicide applications. However, in 1983, control at the two locations remained at 98 and 88%. There was no increase in control when 2,4-D amine was added to Tordon.

Table 1: Spotted Knapweed control 50 months after herbicide application at Harlowton and Ovando, Montana.

Treatment	Rate lb/A	Date of Treatment	% Control	
			Harlowton	Ovando
2,4-D amine + Tordon	2 1/4	5-21-79	88.0	98.5
Tordon	1/4	5-21-79	86.0	100.0
2,4-D amine + Tordon	1 1/4	5-21-79	91.0	99.0
2,4-D amine + Tordon	2 1/4	6-13-79	88.0	98.0
Control	0		0.0	0.0

ALBERTA NEWS

Knapweed Eradication!

Schafeek Ali reported that diffuse and spotted knapweed were first discovered in Alberta in 1974. Since then an intensive eradication program has been in effect to locate and destroy these weeds.

There is approximately 150 ha (375 acres) currently infested in Alberta. These infestations are largely confined to transportation routes and adjacent rangeland in the southern part of the province. Climate and soil conditions are ideal for knapweed growth in this part of the province and an estimated one million hectares (2.5 million acres) are susceptible to invasion.

Both knapweeds are listed as restricted weeds in Alberta under the Provincial Weed Control Act. This means that it is mandatory for the landowner or occupant to destroy these weeds if found on his property. Also, it is mandatory for weed inspectors to issue weed notices to landowners to destroy these weeds.

Through the cooperative effort of all local municipalities and support from the Provincial Government, the eradication program is progressing very well. The infestation on 150 ha. has been kept in check and is being reduced. While new infestations have been found, many of the original infestations have been eradicated.

Tordon has provided the best control for as long as 3 years. However, in gravelly or lighter soils, control is reduced to 1 or 2 years.

Since the use of Tordon is restricted in Alberta, 2,4-D and Banvel are commonly substituted for it. However these herbicides have not been as effective.

NOTE Because of the success of this effort in Alberta, North Dakota is adopting an eradication program in the western part of the state where knapweed infestations are just being discovered.

BRITISH COLUMBIA NEWS

Program Prevents Knapweed Takeover

Roy Cranston reported that a protection program initiated in 1970 in the E. Kootenai Region of Canada has been effective in preventing knapweed takeover of grasslands in the Caribou-Chilcotin, Thompson-Nicola and E. Kootenai regions. The program has included four main components:

* Intensive Awareness Effort:

The awareness program has included newspaper advertisements, radio and television presentations, production of a 16-mm film, a knapweed brochure, bumper stickers, highway signs, knapweed signs on range access roads, knapweed alerts for hunters and fishermen, infested hay warning posters, distribution of botanical mounts, mall and fair displays, and seminars with range user groups.

* Equipment and Material Loan:

Equipment, including 100 gallon skid mount sprayers, backpack and micron Herbi sprayers, and a PTO-driven boom sprayer were made available to ranchers at no cost. Herbicidal samples for demonstrations were distributed with each sprayer.

* Professional Services:

Grants to support research on biocontrol, allelopathy, and remote sensing were available.

* Weed Control grants were made available to regional districts (\$5,000 plus 50% of additional expenditure to a maximum of \$35,000 annually). Grants for livestock associations were available. A maximum of \$15,000 per association - utilized mainly for herbicide purchase.

Rangeland Herbicide Sprayer

Larry Thomas and Roy Cranston developed a micro-max ultra-low volume sprayer to be used for control of knapweed on rangeland. The sprayer increases efficiency of other government agency knapweed control spray units by decreasing

the volume output of sprayers. This allows for more acres to be treated per day than with conventional equipment.

The sprayer consists of three Micro-Max Ultra-low spinning disc nozzles mounted on independent booms. Each boom is collared around a 3.5" x 13" pipe in which the booms can move vertically independent of each other. This system is mounted to the rear bumper of the vehicle. The system allows a four-wheel drive pickup with a spray tank to cover relatively rough, open range at 6 to 7 km/h, contouring to the terrain, and giving an effective spray swath of 5.4 meters (17 feet).

For additional information concerning this sprayer, please contact Roy Cranston, 162 Oriole Rd., Kamloops, BC Canada V2C 4N7.

IDAHO NEWS



Improvement of Spotted Knapweed Infested Pastures

Shely, Callihan, and Huston of University of Idaho reported that a study was initiated at Hayden Lake, Idaho to determine the long-term effect of Tordon and fertilizer alone or in combination for restoration of spotted knapweed infested rangeland. Tordon at .38 lb/A and nitrogen fertilizer at two rates, 62.5 lb/A and 125 lb/A, were used. Treatments were applied in May and October, 1982.

In 1983, both the Tordon + 62.5 lb/A nitrogen and Tordon + 125 lb/A nitrogen treatments increased grass yields over either treatment without Tordon or Tordon without fertilizer. There was no difference in the effect of fertilizer rate upon grass yields. The 62.5 lb/A nitrogen + Tordon treatment applied in the fall produced the greatest control of spotted knapweed and greatest grass yields.

CALIFORNIA AND OREGON



Court Ruling

A real blow to knapweed control was noted in a recent California court ruling in a case brought by SAVE OUR ECOSYSTEMS versus SECRETARY OF INTERIOR CLARK and SECRETARY OF AGRICULTURE BLOCK. In the decision the court held that the programmatic Environmental Impact Statements which cover all uses within the state were unacceptable. Instead the court asked that individual Environmental Impact Statements would have to be made for any actions on federal land involving the use of 2,4-D, Silvex, Simazine, Atrazine, Diruon, Tordon, Dalapon, Banvel, Krenite, Roundup, and 2-3-4-T. The decision asked that a worst case analysis be prepared for each herbicide and each area to be sprayed. While this decision may be read to only apply to California and Oregon, it was thought that undoubtedly no federal official will attempt to use any of the described herbicides on any federal lands until the decision is clarified.

For additional information or to be added to the mailing list, please contact:

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knapweed update

PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
BOZEMAN, MONTANA 59717

VOLUME II

OCTOBER, 1984

ISSUE III

* SUMMERTIME IN MONTANA!



ALBERTA, CANADA



Eradication Program Pays

Shafeek Ali, vegetation management specialist, Edmonton, reported that 1984 was another successful year in the Knapweed Eradication Program. All known infestations were inspected and treated as required. Several sites appear to be eradicated as no plants have been found for 2 or 3 years. Such sites will be monitored to ensure they remain knapweed-free.

The public awareness campaign is continuing and is paying off. More landowners, technical specialists, and field staff are searching for knapweed and all sightings are reported and catalogued in a computerized program. The success of the awareness campaign is obvious because there are fewer total acres, however, more known infestations have been recorded.

Both British Columbia and Montana have cooperated very well in maintaining a knapweed-free buffer zone close to Alberta's borders. Their efforts are greatly appreciated.

BRITISH COLUMBIA, CANADA



Fall Applied Herbicides

Roy Cranston, weed specialist, Kamloops, reported on the effect of four fall applied herbicides on diffuse knapweed control. Tordon, Glean, Dowco 290 (Lontrel), and Garlon were applied on November 15, 1982 near Kamloops, B.C. The treatments were rated for percent control of diffuse knapweed on March 18, 1983, August 19, 1983, and September 10, 1984 (Table 1). Fall applied Tordon and Dowco 290 provided excellent control of seedling and bolted diffuse knapweed in the year following treatment. Initial early spring setback of knapweed by Glean and Garlon was not evident in late summer. Twenty-two months following application, Tordon was still providing excellent control. No bolted plants were evident in Dowco 290 plots after 22 months, however, numerous seedlings and rosettes were appearing. No grass injury was noted with any of the herbicides used.

Table 1: Effect of four fall applied herbicides on diffuse knapweed control.

Treatment	Rate a.i./ha. (lb./ac)	Percent Control		
		3/18/83	8/19/83	9/10/84
Tordon 22K	0.56 kg (0.5)	55.5	100.0	95.5
Tordon 22K	1.12 kg (1.0)	100.0	100.0	100.0
Glean	35 gr (0.03)	22.0	0.0	0.0
Glean	50 gr (0.04)	33.3	0.0	0.0
Dowco 290	200 gr (0.2)	96.6	100.0	59.0
Dowco 290	400 gr (0.4)	100.0	100.0	66.6
Garlon	400 gr (0.4)	41.0	0.0	0.0
Garlon	800 gr (0.7)	33.0	0.0	0.0
check	-	0.0	0.0	0.0

Knapweed Affects Soil Microbe Activity

Allister Muir and Walter Majak, Kamloops Research Station, conducted studies in 1983 to determine the relationship between the presence of knapweed, soil microbial activity, and extractable soil phenols. Soil respiration was used to measure the level of soil microbial activity. The results of their research suggested that knapweed was not secreting large quantities of phenols into the root zone of the plants. However, they did find reduced respiration levels from soil under knapweed infestations. This suggests that knapweed does alter the soil microbial activity and change the active decomposition of soil organic matter. This may affect the growth of other plants or enhance the growth of knapweed. (Information presented at the Knapweed Symposium, April, 1984).

IDAHO



Insect for Diffuse Knapweed

Joe McCaffrey, Moscow, ID, reported that the beetle, *Sphenoptera jugoslavica*, was released in Idaho in 1981 on diffuse knapweed. A second release was made in 1984 in south-central Idaho. Both release sites will be evaluated in 1985 to determine the success of the insect for controlling diffuse knapweed. Work is also continuing on the development of a phenology model for the seed head flies *U. affinis* and *U. quadrifasciata*.

MONTANA



New Bio Control Agents

Jim Story, Corvallis, MT, reported that the first release in the United States of two root-mining moths

(*Agapeta zoegana* and *Pelochrista medullana*) that attack spotted knapweed, was made in western Montana in 1984. The moth larvae attack and damage the roots of small spotted knapweed rosettes. Studies will be conducted in 1985 to determine level of overwintering success. Additional releases of the two moths are planned for 1985. The two moths were collected by the Commonwealth Institute of Biological Control (CIBC) of Delemont, Switzerland, as part of a contract arrangement between the CIBC and Montana State University.

A 3-year screening project of two to four additional promising natural enemies of spotted knapweed was started by the CIBC in 1984. Funding for the project is comprised of monies received in a grant through the Montana Dept. of Natural Res. and Conservation, matching funds by the province of British Columbia, and USDA-CSRS special grant funds. Emphasis will be on two promising root-mining weevils.

Gall Flies Establish

A survey of the distribution of the two fly species *U. affinis* and *U. quadrifasciata*, was completed in May 1984. The survey showed *U. quadrifasciata*, the fly which migrated from Canada into Montana, to be established throughout the knapweed infested areas of western Montana. As expected, the highest numbers of *U. quadrifasciata* were found in northwest Montana, close to the flies' origin in British Columbia. *U. quadrifasciata* was found to already be more widely dispersed than *U. affinis*, the fly which was deliberately introduced into Montana during 1973-1977. Large populations of *U. affinis* were found, but only within a 3 to 5 mile radius of the original site. (Note: The four seed head gall fly collection/-workshops have resulted in the redistribution of an estimated 5 million flies at over 900 knapweed sites in Montana).

Tordon Rate Study

Experiments were established at two locations in Montana in 1982 to determine the effect of low rates of Tordon and Tordon/2,4-D combinations on control of spotted knapweed. Tordon at .125 (1/8) lb a.i./ac. continued to provide 100% control of mature spotted knapweed plants 24 months following herbicide application. Combinations of Tordon and 2,4-D increased spotted knapweed control over Tordon at rates less than 1/8 lb/A alone. Grass production was 247 to 770% greater on Tordon or Tordon/2,4-D treated plots than on untreated plots (Table 1).

Table 1: Effect of various rates of Tordon and Tordon/2,4-D combinations on spotted knapweed control 24 months after application.

Treatment	Rate (lb./ac)	Percent Control on 7/84			
		Harlowtown		Gvando	
		2,4-D 0 lb/ac	2,4-D 2 lb/ac	2,4-D 0 lb/ac	2,4-D 2 lb/ac
Tordon 22K	0.25	100	100	100	100
Tordon 22K	0.22	100	100	100	100
Tordon 22K	0.20	100	100	100	100
Tordon 22K	0.1875	100	100	100	100
Tordon 22K	0.125	100	100	100	100
Tordon 22K	0.0975	96	98	98	100
Tordon 22K	0.0625	95	97	77	97
Tordon 22K	0.0	0	86	0	0

Cash for Knapweed?

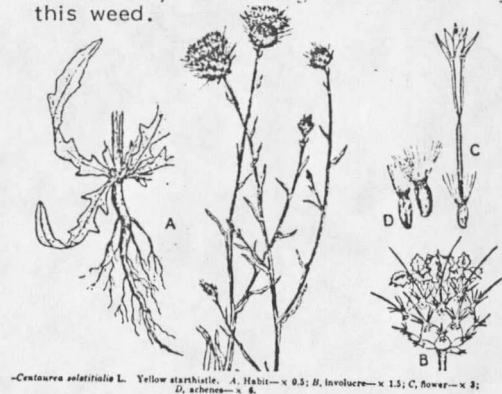
Chuck Egan and Wayne Pearson (Stillwater Co. Extension Agent and Weed Supervisor, respectively) have found a successful way to stop the spread of spotted knapweed. This past summer they offered a \$5.00 bounty for each new patch of spotted knapweed discovered, and an additional \$55.00 if the patch was completely controlled. Anyone less than 18 years old could participate in the bounty program. According to Chuck, the program cost only \$1,100 to implement, and has saved the county \$4,000 to \$5,000. "We've had more public education with this program than with any other weed program we've tried so far," said Chuck. "It really gets people involved and concerned about controlling knapweed."

Congratulations to Chuck and Wayne for their hard work and dedication to our weed control effort. Anyone interested in implementing a "bounty" program in their county should contact Chuck Egan, Stillwater County Agent, P.O. Box 807, Columbus, MT 59019.

Yellow Starthistle Reported

Yellow starthistle (*Centaurea solstitialis*), a close relative of spotted knapweed, was reported at two locations in Gallatin County this summer. The weed currently infests about 3 million acres of rangeland in California, Idaho, Oregon, and Washington. A 1981 field survey in Idaho showed that yellow starthistle infested 185,000 acres and was invading new areas at the rate of about 5,000 acres per year.

Yellow starthistle has the potential to become a serious problem in Montana. Landowners, county agents, and weed supervisors must be alert for this weed so we can keep it out of our state. A yellow starthistle bounty program may be the key to finding and eradicating this weed.



For more information or to be added to the mailing list please contact:

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* Cartoon courtesy of Bigfork Eagle

APPENDIX B

TABLE 34. LIST OF
HERBICIDE DEMONSTRATION PLOTS

Experiment No: 83001001

Title: Leafy Spurge Demonstration Plot

Location: Gallatin County (Northeast of city dump in Bozeman.)

Date: 5/29/83--Retreated with aerial application of dicamba on 6/83.

Trt. No.	*Herbicide	Rate kg/ha
1	Picloram	0.56
2	Picloram	1.12
3	Picloram	2.24
4	Dicamba	2.24
5	2,4-D	2.24
6	Control	0.00

*No retreatments applied in 1984.

Experiment No: 83002002

Title: Leafy Spurge Demonstration Plot

Location: Petroleum County (Don Kimmel Ranch, one mile northwest of headquarters on state land section.)

Date: 6/3/83

*6/19/84

Trt. No.	Herbicide	Rate kg/ha
*1	Picloram	0.56
*2	Picloram	1.12
3	Picloram	2.24
*4	Dicamba	2.24
*5	2,4-D	2.24
6	Control	0.00

*Retreatment applied to half of plot in 1984.

Experiment No: 83003003

Title: Knapweed Demonstration Plot

Location: Fergus County (On railroad bed northwest of Cargill Plant by Mile Marker 2.)

Date: 6/3/83

Trt. No.	*Herbicide	Rate kg/ha
1	2,4-D + Picloram	2.24 0.14
2	Picloram	0.14
3	Picloram	0.28
4	Dicamba	1.12
5	2,4-D	2.24
6	Control	0.00

*No retreatments in 1984 because of poor location.

Experiment No: 83004005 and 83004006

Note: Experiment No. 83004005 is enclosed within a fenced area. Herbicide treatments are the same for both experiments.

Title: Spotted Knapweed Demonstration Plot

Location: Silverbow County (Feely Exit, south of Butte.)

Date: 6/6/83

Trt. No.	*Herbicide	Rate kg/ha
1	2,4-D + Picloram	2.24 0.14
2	Picloram	0.14
3	Picloram	0.28
4	Dicamba	1.12
5	2,4-D	2.24
6	Control	0.00

*No Retreatments in 1984.

Experiment No: 83004007

Title: Leafy Spurge Demonstration Plot

Location: Powell County (Eeilanberg Road--take racetrack exit, first road to right, then west past old school house.)

Date: 6/17/83

*9/14/84

Trt. No.	Trt. Date	Herbicide	Rate kg/ha
*1	6/7/83	Picloram	0.56
*2	6/7/83	Picloram	1.12
3	6/7/83	Picloram	2.24
*4	6/7/83	Dicamba	2.24
5	6/7/83	2,4-D	2.24
6	6/7/83	Control	0.00
7	7/27/83	Picloram	1.12
8	9/15/83	Picloram	1.12

*Retreatment applied to half of plot in 1984.

Experiment No: 83005008

Title: Spotted Knapweed Demonstration Plot

Location: Musselshell County (Bruno Rodeghiero Ranch, Roundup.)

Date: 6/9/83

*6/6/84

Trt. No.	Herbicide	Rate kg/ha
1	2,4-D + Picloram	2.24 0.14
2	Picloram	0.14
3	Picloram	0.28
*4	Dicamba	1.12
*5	2,4-D	2.24
6	Control	0.00

*Retreatment applied to half of plot in 1984.

Experiment No: 83006009

Title: Russian Knapweed Demonstration Plot

Location: Rosebud County (Bill Tadsen Ranch; six miles west of Forsyth.)

Date: 6/10/83

Trt. No.	*Herbicide	Rate kg/ha
1	Picloram	0.56
2	Picloram	1.12
3	Picloram	2.24
4	Dicamba	2.24
5	2,4-D	2.24
6	Control	0.00

*No retreatment applied in 1984.

Experiment No: 83007010

Title: Leafy Spurge Demonstration Plot

Location: Custer County (Phillip Flemming Ranch.)

Date: 6/10/83

6/12/84

Trt. No.	Herbicide	Rate kg/ha
*1	Picloram	0.56
*2	Picloram	1.12
3	Picloram	2.24
*4	2,4-D + Picloram	2.24 0.56
5	Dicamba	2.24
6	2,4-D	2.24
7	Control	0.00

*Retreatment applied to half of plot in 1984.

Experiment No: 83008011

Title: Leafy Spurge Demonstration Plot

Location: Fallon County (Two miles northwest of Glen Rugg Ranch Hdq. on west side of road.)

Date: 6/11/83

*6/13/84

Trt. No.	Herbicide	Rate kg/ha
*1	Picloram	0.56
*2	Picloram	1.12
3	Picloram	2.24
*4	2,4-D + Picloram	2.24 0.56
*5	Dicamba	2.24
*6	2,4-D	2.24
7	Control	0.00

*Retreatment applied to half of plot in 1984.

Experiment No: 83009012

Title: Leafy Spurge Demonstration Plot

Location: Dawson County (Engle Ranch, south of Glendive.)

Date: 6/12/83

*6/13/84 Picloram Retreatments (0.56 kg/ha) applied to 1/2 plot

Trt. No.	Herbicide	Rate kg/ha
*1	Picloram	0.56
*2	Picloram	1.12
3	Picloram	2.24
*4	2,4-D + Picloram	2.24 0.56
*5	Dicamba	2.24
*6	2,4-D	2.24
7	Control	0.00

Experiment No: 83010013

Title: Leafy Spurge Demonstration Plot

Location: Richland County (Five miles northwest on Charlie Creek Road--Don Palmer Ranch.)

Date: 6/13/83 *6/14/84

Trt. No.	Herbicide	Rate kg/ha
*1	Picloram	0.56
*2	Picloram	1.12
3	Picloram	1.67
4	Picloram	2.24
*5	Dicamba	2.24
*6	2,4-D	2.24
7	Control	0.00

*Retreatment applied to half of plot in 1984.

Experiment No: 83011014

Title: Leafy Spurge Demonstration Plot

Location: Valley County (Funk Ranch--thirteen miles north of Hindsdale.)

Date: 6/18/83

*6/15/84

Trt. No.	Herbicide	Rate kg/ha
*1	Picloram	0.56
*2	Picloram	1.12
3	Picloram	2.24
*4	Dicamba	2.24
*5	2,4-D	2.24
6	Control	0.00

*Retreatment applied to half of plot in 1984.

Picloram retreatments were applied at a rate of 0.56 kg/ha.

Experiment No: 83012015

Title: Leafy Spurge Demonstration Plot

Location: Toole County (Tomsheck Ranch--Eleven miles East of Kevin.)

Date: 6/16/83

Trt. No.	*Herbicide	Rate kg/ha
1	Picloram	0.28
2	Picloram	0.56
3	2,4-D	2.24
	Picloram	0.56
4	Picloram	1.12
5	Picloram	2.24
6	Dicamba	2.24
7	2,4-D	2.24
8	Control	0.00

*No retreatments made in 1984.

Experiment No: 83012016

Title: Russian Knapweed Demonstration Plot

Location: Toole County (East of golf course; Marias River.)

Date: 6/16/83

Trt. No.	*Herbicide	Rate kg/ha
1	Picloram	0.56
2	Picloram	1.12
3	Picloram	2.24
4	Dicamba	2.24
5	2,4-D	2.24
6	Control	0.00

*No retreatments made in 1984.

Experiment No: 83016017

Title: Spotted Knapweed Demonstration Plot

Location: Meagher County (Bob Hanson Ranch)

Date: 6/15/83

Trt. No.	*Herbicide	Rate kg/ha
1	2,4-D + Picloram	2.24 0.14
2	Picloram	0.14
3	Picloram	0.28
*4	Dicamba	1.12
*5	2,4-D	2.24
6	Control	0.00

*Retreatment applied on half of plot in 1984.

Experiment No: 83013018

Title: Spotted Knapweed Demonstration Plot

Location: Flathead County (1,000' south of Spring Creek Road--Mile Marker 101--Lakeside.)

Date: 6/17/83

*9/24/84

Trt. No.	Herbicide	Rate kg/ha
1	2,4-D + Picloram	2.24 0.14
2	Picloram	0.14
3	Picloram	0.28
*4	Dicamba	1.12
*5	2,4-D	2.24
6	Control	0.00

*Retreatment applied on half of plot in 1984.

Experiment No: 83014019
 Title: Leafy Spurge Demonstration Plot
 Location: Cascade County (Great Falls.)
 Date: 9/15/83

Trt. No.	*Herbicide	Rate kg/ha
1	Picloram	0.56
2	Picloram	1.12
3	Picloram	2.24
4	Dicamba	2.24
5	2,4-D	2.24
6	Control	0.00

*No retreatments made in 1984.

Experiment No: 83015020
 Title: Spotted Knapweed Demonstration Plot
 Location: Sanders County (North of Plains.)
 Date: 6/83
 Notes: Plots destroyed in 4/84.

Trt. No.	Herbicide	Rate kg/ha
1	2,4-D + Picloram	2.24 0.14
2	Picloram	0.14
3	Picloram	0.28
4	Dicamba	1.12
5	2,4-D	2.24
6	Control	0.00

Experiment No: 84008001

Title: Leafy Spurge Demonstration Plot

Location: Sweetgrass County (Tom Brownly Ranch)

Date: 6/6/84

Trt. No.	Herbicide	Rate kg/ha
1	Picloram	1.68
2	Picloram	1.12
3	Picloram	0.56
4	Dicamba	3.36
5	2,4-D	2.24
6	Control	0.00

Experiment No: 8470002

Title: Spotted Knapweed Demonstration Plot

Location: Gallatin County (Flying D Ranch--Spanish Fork exit.)

Date: 6/18/84

Trt. No.	Herbicide	Rate kg/ha
1	2,4-D + Picloram	2.24 0.14
2	Picloram	0.14
3	Picloram	0.28
4	Dicamba	1.12
5	2,4-D	2.24
6	Control	0.00

Experiment No: 84006003

Title: Herbicide Treatment on Sheep Grazed Spurge

Location: Fergus County (On hilltop, about one mile south of Peterson Ranch Hdq.)

Replication: Three

Date: 6/7/84

Trt. No.	Herbicide	Rate kg/ha
1	Dowco 290	1.12
2	2,4-D + Picloram	1.12 0.56
3	Picloram	1.12
4	Picloram	1.68
5	Dicamba	2.24
6	2,4-D	2.24
7	Control	0.00

APPENDIX C

SURVEY QUESTIONNAIRE

CAN WEED CONTROL
PRACTICES BE
IMPROVED IN MONTANA ?



Montana State University
Plant and Soil Science Department
Bozeman, Montana

In cooperation with

Cooperative Extension Service
Bozeman, Montana



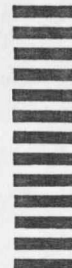
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Montana State University
Department of Plant & Soil Science
Bozeman, MT 59717



Dear Landowner:

Weeds are costing Montanans about \$100 million dollars annually in lost production. Although new advances have been made in weed control, several weeds continue to spread so rapidly that they are threatening the farm and ranch operations in the state.

We would like to develop a statewide weed control program in Montana. However, it is important that we have accurate information on the weed control practices that you are currently using. Only then will we be able to design our programs to best fit your needs. Therefore, I would appreciate your assistance in completing this questionnaire on weed control practices.

Results from this survey will be used to establish weed programs and direct extension efforts in Montana. Your answers will also tell us where additional weed research is needed.

We are only sampling four counties in the state, thus your response is critical to the survey. You can be assured of complete confidentiality, in no way will your response be linked to your name.

Please return your questionnaire as soon as possible. Just drop it in the mail after you have answered the questions, no stamp or envelope is required.

If you have any questions concerning the questionnaire, please contact me, my number is 994-5078.

Thank you for your courtesy and help.

Sincerely,

Celestine Lacey

Celestine Lacey
Graduate Research Assist.

WEED SURVEY

1. What type of operation do you have?
(check one or more)

farm (most income from sale of grain
or agronomic crop) _____
ranch (most income from sale of
livestock) _____
1 to 25 acres _____
other (specify) _____

2. Do you or your spouse have income other than from
the sale of farm or ranch products?

yes _____
no _____

3. Do you lease or own your land or both?

lease land _____
own land _____
both _____

4. Please check the degree to which each of the
following weeds are a problem on land you manage.

	a problem	no problem	don't know
spotted knapweed	_____	_____	_____
leafy spurge	_____	_____	_____
Russian knapweed	_____	_____	_____
dalmatian toadflax	_____	_____	_____
Canada thistle	_____	_____	_____
others (specify)	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

5. Please check the degree to which you feel leafy
spurge and spotted knapweed are a problem in Montana.

	serious problem	slight problem	don't know
leafy spurge	_____	_____	_____
spotted knapweed	_____	_____	_____

6. Do you have spotted or diffuse knapweed on any land
that you manage?

yes _____ (continue to 6a)
no _____ (skip to number 7, page 3)

If you answered no to number 6 above, please go to
number 7 page 3!

Page 2

- 6a. How many acres of spotted or diffuse knapweed do you have? (check one)

under 1 acre _____
 1 to 5 acres _____
 5 to 30 acres _____
 30 to 60 acres _____
 60 to 100 acres _____
 more than 100 acres _____

- 6b. How many acres of spotted or diffuse knapweed have you treated in the past 3 years?

0 acres _____
 1-5 acres _____
 5-10 acres _____
 10-20 acres _____
 20-50 acres _____
 more than 50 acres _____

- 6c. What method of treatment did you use? (check one or more answers)

Biological (insects) _____
 Herbicides _____

Which herbicide(s) do you use?

Tordon _____
 Banvel _____
 2,4-D _____
 other (specify) _____

Mechanical (plow, disk, etc.) _____

No treatment method used _____

Other treatment methods used (specify) _____

- 6d. Is your knapweed control program cost effective? (check one)

yes _____ (skip to number 7)
 no _____ (continue below)

(If no) please check why your program is not cost effective.

Herbicides too expensive _____
 Application cost too high _____
 Value of land too low _____
 other (specify) _____

Page 3

7. Do you have leafy spurge on any Land you manage?

yes _____ (continue to 7a)
 no _____ (skip to number 8 page 4)

If you answered no to number 7 please skip to number 3 page 4!

- 7a. How many acres of leafy spurge do you have?

under 1 acre _____
 1-5 acres _____
 5-30 acres _____
 30-60 acres _____
 60-100 acres _____
 more than 100 acres _____

- 7b. How many acres of leafy spurge have you treated in the past 3 years? (check one)

0 acres _____
 1-5 acres _____
 5-10 acres _____
 10-20 acres _____
 20-50 acres _____
 more than 50 acres _____

- 7c. What treatment method do you use? (check one or more)

Mechanical (plow, disk, etc.) _____
 Biological (insects) _____
 Herbicides _____

Which herbicide(s) do you use?

Tordon _____
 Banvel _____
 2,4-D _____
 Other (specify) _____

No treatment methods used _____

Other treatment methods used (specify) _____

- 7d. Is your spurge control program cost effective?

yes _____ (skip to number 8)
 no _____ (continue below)

(If no) please check why your program is not cost effective.

Herbicides too expensive _____
 Application costs too high _____
 Value of land too low _____
 others (specify) _____

Page 4

8. Please indicate which reasons you feel are most important for landowners not treating leafy spurge and spotted knapweed. Rate the below responses from 1 (most important) to 4 (least important).

Fear of herbicides _____
 Lack of information on weed control _____
 Lack of application equipment _____
 Value of land too low to justify treatment _____
 Others (specify) _____

9. Which of the following sources has provided you with the most information in the past 2 years? Please rate responses from 1 (most important) to 7 (least important)

popular magazine _____
 newsletter _____
 radio or television _____
 neighbor _____
 Montana State University _____
 Cooperative Extension Service _____
 Agri-business (chemical company) _____
 Others (specify) _____

10. What should the Cooperative Extension Service do to help landowners with weed control? (list in order of importance)

11. What kind of weed research would you like to see conducted at Montana State University? (list in order of importance)

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12. Would you like to receive a summary of the results of this survey?

yes _____

no _____

13. Would you like additional information on certain problem weeds?

yes _____ (Specify which weeds) _____

no _____

14. Please print your name and address below if you answered "yes" to either questions 12 or 13.

THANK YOU FOR YOUR COOPERATION! Please drop this questionnaire in the mail. No envelope or stamp is necessary.

APPENDIX D

RESEARCH TABLES AND FIGURES

Table 35. A List of All Species Observed on Site One (Ovando) and Site Two (Harlowtown).

Location	Common Name	Latin Binomial ¹	Author ¹
Ovando	Perennial Grasses		
	Western wheatgrass	<i>Agropyron smithii</i>	Rydb.
	Smooth brome grass	<i>Bromus inermis</i>	Leys.
	Timothy	<i>Phleum pratense</i>	L.
	Kentucky bluegrass	<i>Poa pratensis</i>	L.
	Perennial Forbs		
	Western yarrow	<i>Achillea millefolium</i>	L.
	Arrowleaf balsamroot	<i>Balsamorhiza sagittata</i>	(Pursh)Nutt
	Spotted knapweed	<i>Centaurea maculosa</i>	Lam.
	Silky lupine	<i>Lupinus sericeus</i>	Pursh
	Annual Forbs		
	Clasping pepperweed	<i>Lepidium perfoliatum</i>	L.
	Stoneseed	<i>Lithospermum</i> sp.	
	Owlclover	<i>Orthocarpus</i> sp.	
Harlowton	Perennial Grasses		
	Western wheatgrass	<i>Agropyron smithii</i>	Rydb.
	Blue grama	<i>Bouteloua gracilis</i>	(HBK)Lag.
	Smooth brome grass	<i>Bromus inermis</i>	L.
	Prairie junegrass	<i>Koeleria cristata</i>	Pers.
	Timothy	<i>Phleum pratense</i>	L.
	Canada bluegrass	<i>Poa compressa</i>	L.
	Kentucky bluegrass	<i>Poa pratensis</i>	L.
	Annual Grasses		
	Downy cheatgrass	<i>Bromus tectorum</i>	L.
	Perennial Forbs		
	Louisiana sagewort	<i>Artemisia ludoviciana</i>	Nutt.
	Spotted Knapweed.	<i>Centaurea maculosa</i>	L.
	Cinquefoil	<i>Potentilla</i> sp.	
	Slenderflr. Scurf-pea	<i>Psoralea tenuiflora</i>	Pursh
	Golden pea	<i>Thermopsis rhombifolia</i>	Nutt.
	Annual Forbs		
	Stoneseed	<i>Lithospermum</i> sp.	
	Clasping pepperweed	<i>Lepidium perfoliatum</i>	L.
	Shrubs		
	Arkansas rose	<i>Rosa arkansana</i>	Porter
	Western snowberry	<i>Symphoricarpos occidentalis</i>	Hook.

¹ Latin binomials and authors are listed according to Hitchcock and Cronquist (1973).

Table 36. Mean monthly precipitation data for Harlowton and Ovando, Montana from June 1982 to October 1984.¹

Date	Location	Monthly Precipitation (cm)												Annual
		Jan	Feb	Mar	Apr	May	Jn	Jl	Aug	Sept	Oct	Nov	Dec	X
1982	Harlowton						6.3	5.0	2.1	6.6	2.9	0.7	1.3	49.3
	Ovando						6.6	2.0	0.8	3.2	1.2	1.7	4.6	41.1
1983	Harlowton	0.9	0.2	1.2	1.9	3.0	8.8	4.2	4.4	5.2	3.9	1.8	2.0	36.6
	Ovando	3.2	3.5	1.1	1.1	4.4	4.3	5.9	2.6	3.5	1.8	1.9	3.8	38.8
1984	Harlowton	0.3	0.5	1.0	3.5	4.2	4.2	0.7	6.0	3.4	0.7			-
	Ovando	1.8	0.8	2.0	4.5	4.3	7.2	0.6	5.6	1.6	3.2			-

¹Harlowton is located approximately 15 miles north of study site 2 and Ovando is located approximately 16 miles southeast of study site 1.

Table 37. Mean monthly temperatures for Harlowton and Ovando, Montana from June 1982 to October 1984.¹

Date	Location	Mean Monthly Temperature (C)												Annual
		Jan	Feb	Mar	Apr	May	Jn	Jl	Aug	Sept	Oct	Nov	Dec	X
1982	Harlowton						14.7	18.2	19.2	12.3	7.6	-0.5	-2.7	5.8
	Ovando						14.3	15.7	16.6	11.2	5.4	-3.8	-8.2	2.5
1983	Harlowton	0.8	1.4	2.7	4.8	10.0	14.9	19.1	21.0	12.0	8.6	1.2	-12.4	7.0
	Ovando	-4.1	-1.6	2.4	2.4	9.2	13.8	16.0	17.1	8.1	3.5	-1.2	-15.7	3.8
1984	Harlowton	-0.4	1.5	1.8	5.6	11.0	45.0	20.2	20.7	10.6	5.1			-
	Ovando	-5.1	-2.0	1.4	3.5	7.5	11.7	15.3	16.3	7.1	1.9			-

¹Harlowton is located approximately 15 miles north of study site 1 and Ovando is located approximately 16 miles southeast of study site 2.

Table 38. Representative Soil Profile for Site 1 (Ovando, MT).

-
- A11 -- 0 to 10 cm, dark grayish brown (10YR 3/3) sandy loam (58% sand, 31% silt, 14% clay), very dark brown (10YR 2/2) moist; weak, fine granular structure; 5% gravel; many fine and moderate coarse roots.
- A12 -- 10 to 25 cm, dark grayish brown (10YR 3/3) very gravelly sandy loam (60% sand, 27% silt, 13% clay), very dark brown (10YR 2/2) moist; weak, fine granular structure; 35% gravel; many fine and moderate coarse roots.
- B -- 25 to 56 cm, brown (7.5 YR 4/4) very gravelly sandy loam (67% sand, 21% silt, 11% clay), dark brown (7.5YR 4/4) moist; moderate, medium, subangular blocky structure; 50% gravel, 20% cobble; many fine roots.
- C -- 56 to 100 cm, brown (7.5YR 4/4) extremely gravelly sandy loam (76% sand, 11% silt, 13% clay), dark brown (7.5 YR 4/4) moist; massive; 65% gravel, 35% cobble; many fine roots.
-

Table 39. Representative Soil Profile for Site 2 (Harlowton).

-
- A -- 0 to 7.5 cm, brown (10YR 4/3) gravelly loam (42% sand, 29% silt, 26% clay) dark brown (10YR 3/3) moist; weak fine granular structure; 40% gravel; many fine and few coarse roots.
- C1 -- 7.5 to 25 cm, brown (10YR 5/3) very gravelly sandy loam (81% sand, 7% silt, 11% clay) dark brown (10YR 3/3) moist; massive; 65% gravel, 2% cobble; many fine roots.
- C2 -- 25-55 cm, brown (10YR 5/3) very gravelly sandy loam (80% sand, 9% silt, 11% clay) brown (10YR 4/3) moist; massive; 68% gravel, 5% cobble; many fine roots.
- C3 -- 55 to 100 cm, brown (10YR 5/3) very gravelly sandy loam (86% sand, 5% silt, 9% clay), brown (10YR 4/3) moist; massive; 78% gravel, 15% cobble; many fine roots.
-

Table 40. Diversity of Other Forb Species 24 Months Following Application of Picloram at Site One (Ovando).¹

Latin Binomial Species	Picloram Rate (kg/ha)							
	0.00	0.07	0.11	0.14	0.20	0.21	0.25	0.28
<i>Achellia lanulosa</i> ²			X					
<i>Lepidium perfoliatum</i>				X				
<i>Lithospermum</i> sp.		X	X					
<i>Potentilla</i> sp.			X					
<i>Orthocarpus</i> sp.	X	X	X	X	X	X	X	X

¹ Picloram was applied on June 16 and 17, 1982.

² The letter X in each row denotes the presence of the forb in the picloram treatment.

Table 41. Diversity of Other Forb Species 24 Months Following Applications of Picloram at Site Two (Harlowton).¹

Latin Binomial Species	Piclorm Rates							
	0.00	0.07	0.11	0.14	0.21	0.22	0.25	0.28
<i>Artemisia ludoviciana</i> ²		X			X			X
<i>Lepidium perfoliatum</i>	X			X				X
<i>Lithospermum</i> sp.			X	X				
<i>Potentilla</i> sp.		X				X		
<i>Psoralea tenuiflora</i>		X						
<i>Thermopsis rhombifolia</i>	X	X	X	X	X	X	X	X

¹ Picloram was applied on June 16 and 17, 1982.

² The letter X in each row denotes the presence of the forb within the picloram treatment.

Table 42. Mean monthly precipitation data for Bozeman and Townsend, Montana from June 1982 to October 1984.¹

Monthly Precipitation (cm)														Annual
Date	Location	Jan	Feb	Mar	Apr	May	Jn	Jl	Aug	Sept	Oct	Nov	Dec	X
1982	Bozeman						9.0	3.8	2.0	6.8	3.1	0.8	2.4	47.7
	Townsend						3.9	2.6	4.3	3.6	1.5	0.4	1.2	25.9
1983	Bozeman	0.3	0.9	2.2	2.9	4.7	8.4	6.6	5.3	6.8	5.2	5.3	2.5	51.0
	Townsend	0.2	0.1	1.2	0.8	1.2	7.6	11.9	3.7	3.0	2.0	0.4	0.6	32.8
1984	Bozeman	0.8	1.6	3.8	4.1	4.2	6.8	2.6	4.3	4.9	3.5			-
	Townsend	0.2	0.3	1.1	1.8	2.9	7.5	2.0	5.7	1.4	1.8			-

¹Townsend climatic data was used for the burial site at the Dale Folkvord Farm since it is more representative of the study site than climatic data from Three Forks.

Table 43. Mean monthly temperatures for Bozeman and Townsend, Montana from June 1982 to October 1984.¹

Mean Monthly Temperature (C)														Annual
Date	Location	Jan	Feb	Mar	Apr	May	Jn	Jl	Aug	Sept	Oct	Nov	Dec	X
1982	Bozeman						13.7	17.6	18.7	11.7	6.6	-2.8	-5.3	5.1
	Townsend						14.8	18.4	19.1	12.1	7.1	-0.1	-4.4	5.9
1983	Bozeman	-0.2	0.6	3.1	3.7	9.1	13.9	17.7	19.5	11.8	7.6	0.1	-13.2	6.2
	Townsend	-0.1	0.1	3.9	5.0	10.6	15.3	18.3	20.2	11.9	8.0	2.4	-12.7	7.1
1984	Bozeman	-3.0	-1.1	1.9	5.0	10.6	13.1	18.4	18.9	10.8	4.6			-
	Townsend	-2.6	0.3	3.0	6.4	11.8	14.2	19.2	19.6	10.7	4.9			-

¹Townsend climatic data was used for the burial site at the Dale Folkvord Farm since it is more representative of the study site than climatic data from Three Forks.

Table 44. Changes in the Soil Reserve of Spotted Knapweed Seeds After Seed Production was Stopped on 6-20-82 With Various Cultural Practices at Harlowton.

Treatment	Viable Spotted Knapweed Seeds per 0.5 m ² Months After Seed Production was Stopped				
	0	10	15	22	28
Harrow ¹	420a	140b	107b	54b	76b
Roll	670a	195b	238b	141b	118b
Burn	594a	203b	201b	22b	97b
Mow	648a	301ab	246b	173b	86b
Spray	248a	92b	115b	140b	108b
Control	523a	564a	1214a	520a	813a
CV%	30	16	16	22	9

¹ Means in the same column followed by the same letter are not significantly different at the 5 percent level using the LSD test.

Table 45. Changes in the Soil Reserve of Spotted Knapweed Seeds After Seed Production was Stopped on 6-20-82 With Various Cultural Practices at Ovando.

Treatment	Viable Spotted Knapweed Seeds per 0.5 m ² Months After Seed Production was Stopped				
	0	10	15	22	28
Harrow ¹	549a	41b	86b	107b	32b
Roll	463a	53b	64b	86b	43b
Burn	439a	96b	109b	43b	32b
Mow	447a	22b	164b	86b	21b
Spray	502a	96b	53b	21b	42b
Control	603a	607a	635a	639a	488a
CV%	16	14	14	12	5

¹ Means in the same column followed by the same letter are not significantly different at the 5 percent level using the LSD test.

Table 46. The Concentration of ^{14}C 2,4-D (expressed as Total DPM's) That Was Recovered in the Leaf Wash and Different Parts of Spotted Knapweed Plants from Harlowton (H) and Ovando (O), Montana, 1, 4, 8 and 12 Days Following Application.

Assayed Portion	Total DPM's ²							
	Days After application							
	1		4		8		12	
Leaf Wash ¹	H 918700a	O 931700a	H 950400a	O 940400a	H 931900a	O 918600a	H 851600a	O 889800a
treated leaf	59870a	58750a	38310a	54480a	45520a	56640a	38460a	43430a
leaves with treated leaf	9619a	3531a	10990a	12550a	9292a	7550a	9678a	16263a
other leaves	3001a	2113a	4824a	5664a	6245a	3036a	6667a	2374a
crown	3648a	5416a	12550a	10990a	13650a	11750a	25030a	5347a
upper root	3307a	3234a	6532a	9447a	12700a	16040a	17090a	8958a
lower root	512a	432a	1367a	2337a	3638a	4447a	5913a	4330a
Total	998657	1005176	1024973	1035822	1022945	1018063	954442	970502

¹Means in rows for each date followed by the same letter are not significantly different at the 5 percent level using the LSD test.

²A total of 1,067,000 DPM's were applied to each plant.

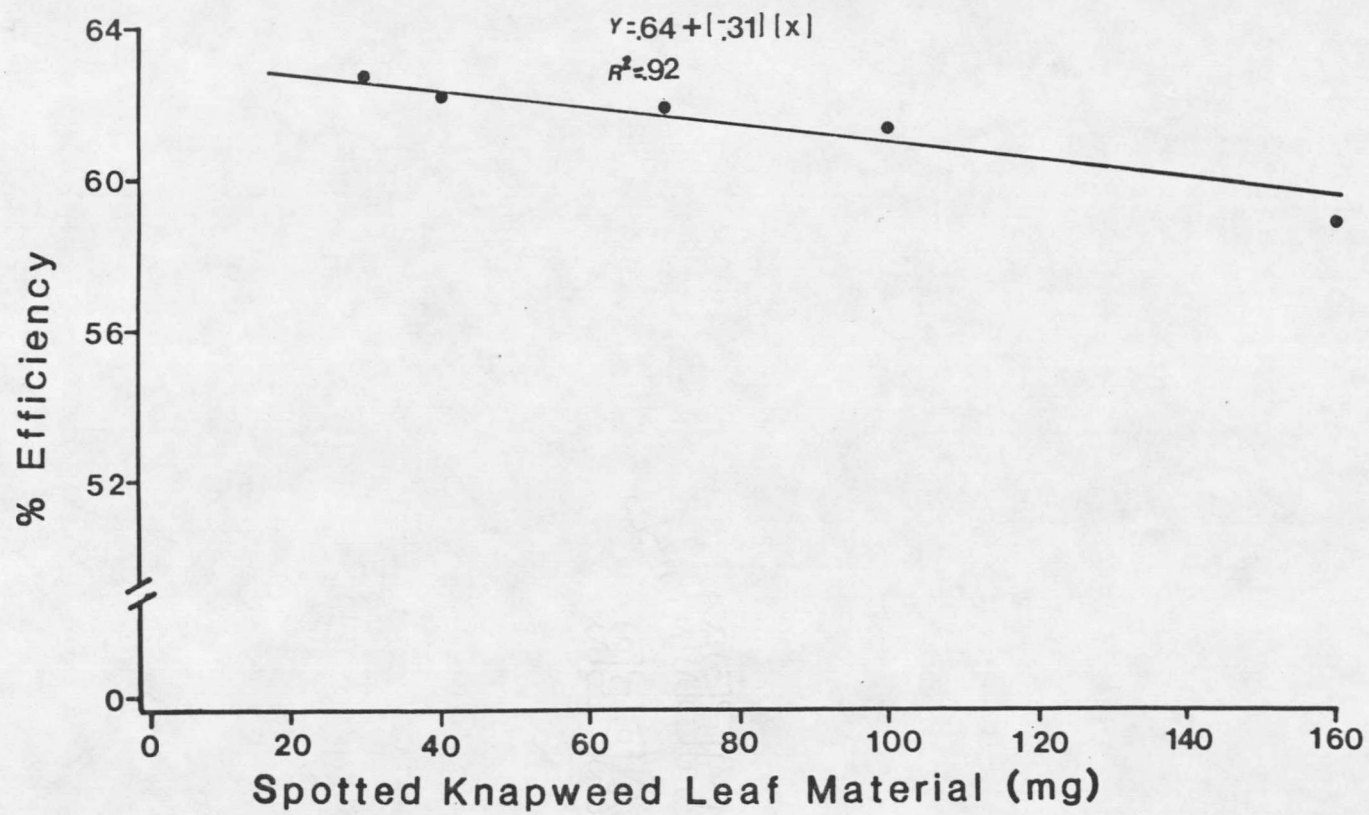


Figure 19. Oxidizer Efficiency Curves for Spotted Knapweed Leaf Material.

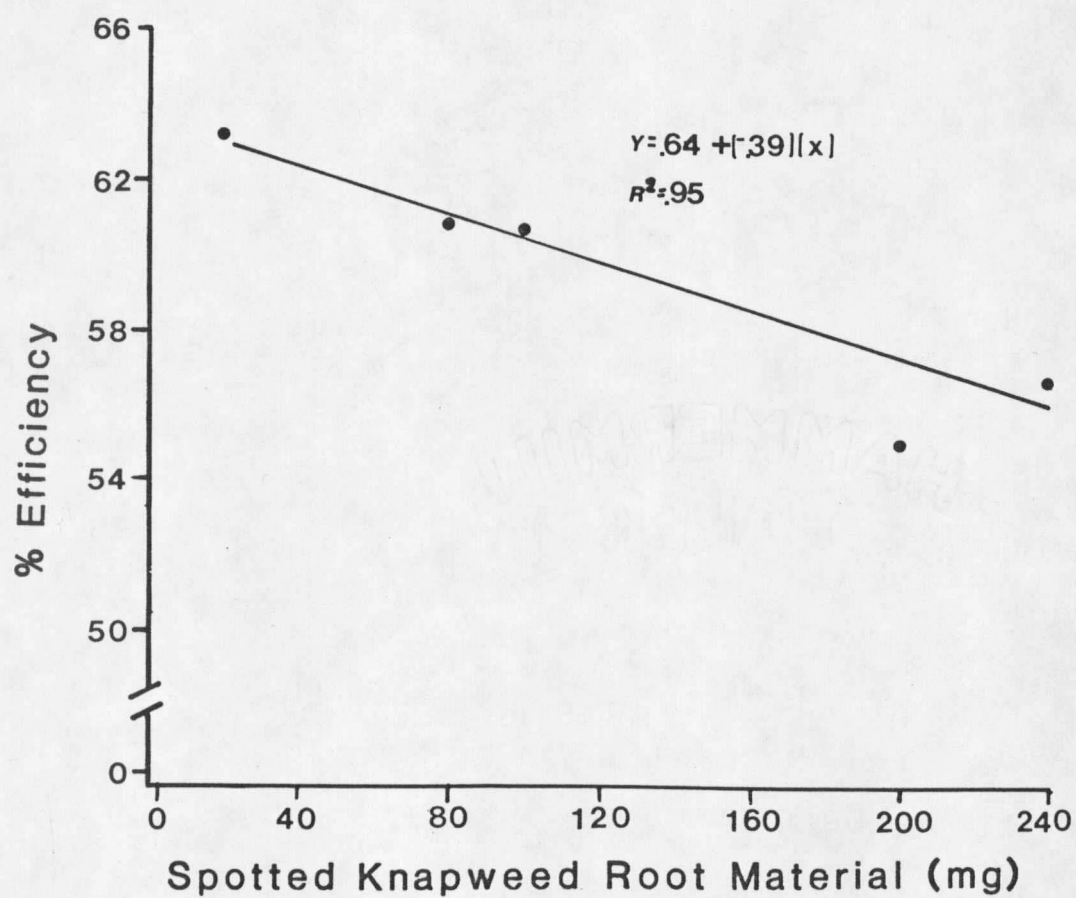


Figure 20. Oxidizer Efficiency Curves for Spotted Knapweed Root Material.

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