



An education program, hydrocarbon extractions and allelopathy studies on leafy spurge (*Euphorbia esula* L.)

by Claire Louise Barreto

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.) is an introduced perennial weed infesting one half million acres in Montana. Once established, leafy spurge is difficult to eradicate due to its deep extensive root system. Three approaches to the leafy spurge problem were utilized.

A statewide education program utilizing articles, newsletters and field tours was initiated in an effort to make more people aware of the leafy spurge problem. A ten part series of articles covering the history, biology, control and research of leafy spurge was sent to Montana newspapers. Twenty newspapers printed some or all of the articles. The articles resulted in requests from producers for additional information and copies of the complete series.

A quarterly leafy spurge newsletter was initiated in 1980. The newsletter included research results and updates from five universities and the Biological Control Laboratory in California. The newsletter was mailed to county agents, weed district supervisors, county commissioners, legislators, research personnel, chemical company representatives, farmers and ranchers. The mailing list for the newsletter numbered over 850 in October, 1981.

Eighteen field tours were conducted in 1980 and 1981. The tour sites utilized demonstration plots showing chemical control of leafy spurge using picloram (4-amino-3,5, 6-trichloropicolinic acid), dicamba (3,6-dichloro-o-anisic acid) and 2,4-D [(2,4-dichloro-phenoxy) acetic acid]. Displays and discussions covering statewide infestations, leafy spurge biology, biological control and new chemical application methods were included in the field tour. Two hundred and forty people attended the 1980 tours and over 300 attended the 1981 tours.

Leafy spurge was examined as a possible source of hydrocarbons. Twelve strains of leafy spurge were harvested three times or as many times as regrowth allowed during the 1980 growing season. A benzene:hexane mixture was used to extract hydrocarbons. No statistical differences were observed among strains for June, August and October harvests. Four ecotypes contained high amounts of hydrocarbon when harvested in July. Several ecotypes contained more than two percent hydrocarbons on a plant dry weight basis. Fertilizer did not improve hydrocarbon content.

Native and introduced grass species were grown in soil taken from two leafy spurge infestations to determine whether leafy spurge root exudates have allelopathic properties. There was no difference in the rate of emergence of the grass species in the infested and check soils. No differences were observed in the growth rate of the species grown in each soil. Four species showed weight differences between the Missoula infested and check soil one month after planting, however, there were no weight differences two months after planting. Plant dry weight of *Alopecurus arundinaceus* was lower in Missoula infested soil than in check soil two months after planting. Plant dry weight of *Bromus inermis* was lower when grown in Vaughn infested soil one month after planting.

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CLAIRE LOUISE BARRETO

A thesis submitted in partial fulfillment
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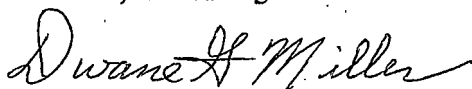
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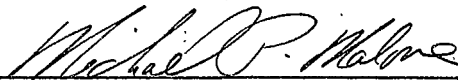
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ABSTRACT

Leafy spurge (*Euphorbia esula* L.) is an introduced perennial weed infesting one half million acres in Montana. Once established, leafy spurge is difficult to eradicate due to its deep extensive root system. Three approaches to the leafy spurge problem were utilized.

A statewide education program utilizing articles, newsletters and field tours was initiated in an effort to make more people aware of the leafy spurge problem. A ten part series of articles covering the history, biology, control and research of leafy spurge was sent to Montana newspapers. Twenty newspapers printed some or all of the articles. The articles resulted in requests from producers for additional information and copies of the complete series.

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INTRODUCTION

Leafy spurge (*Euphorbia esula* L.) is a noxious perennial weed which probably originated in the Caucasus region of Russia (Croizat, 1945). It was first collected in the United States in Massachusetts in 1827 (Britton, 1921). It was found as far west as Michigan in 1881 (Dunn, 1979). A distribution map produced by Hanson and Rudd (1933) showed limited infestations of spurge as far south as Colorado, and the heaviest infestations in North Dakota, eastern South Dakota and Minnesota. An updated infestation map (Dunn, 1975) showed leafy spurge infestations were centered in Montana, North Dakota, South Dakota, and Wyoming. The weed had not spread southward since the Hanson and Rudd (1933) survey. Noble et al. (1979) reported that more than 2.3 million acres in the United States are currently infested with leafy spurge. By 1970 leafy spurge was present in every province in Canada except Newfoundland (Harris and Alex, 1971).

The spread of leafy spurge is attributed to its efficient reproduction by seed and vegetative buds (Bakke, 1936). Vegetative root buds are found as deep as ten feet below the soil surface and shoots are capable of emerging from as deep as three feet (Selleck et al., 1962). Buds from root tissue ten feet deep can produce shoots when brought to the soil surface (Raju et al., 1964). Bakke (1936) and Selleck et al. (1962) attribute the persistence of leafy spurge to its deep, extensive root system which accumulates a large carbohydrate reserve.

Reproduction by seed is an efficient process since a leafy spurge plant can produce several hundred seed per year (Muenscher, 1930). Seeds are normally produced in a three-lobed capsule. At maturity the seeds dehisce and can be projected as far as fifteen feet (Bakke, 1936).

Leafy spurge seeds are spread by hay, machinery and waterways. Animals aid seed dispersal (Selleck, 1962).

The extensive root system and vegetative buds make it difficult to eradicate leafy spurge by chemical, cultural or mechanical means (Dunn, 1979; McIntyre, 1972). Several chemicals are available to control topgrowth but none eradicate the plant. Biological control has been attempted with two insects, the spurge hawkmoth, *Hyles euphorbiae*, and a root mining moth, *Chamaesphecia tenthrediniformis*. Neither insect was successful. A root boring beetle, *Oberea erythrocephala*, is being evaluated in the field for its potential as a biological control agent on leafy spurge.

The following thesis examines three aspects of leafy spurge:

(1) In an effort to create an awareness of the leafy spurge problem and the possibilities for control, an education program was started in the state of Montana. The education program was carried out over a two year period and constitutes the major emphasis of the thesis work.

(2) The latex of certain members of the Euphorbiaceae family has been studied as a source of hydrocarbons to replace some petroleum products (Calvin, 1979b; Coffey and Halloran, 1979). Distinct ecotypes of leafy spurge exist (Barreto et al., 1980) so it is possible that high latex-bearing strains of spurge exist. Since leafy spurge is a perennial with excellent regrowth capacity, it might be possible to obtain several hydrocarbon harvests per season.

(3) There is evidence to suggest that some *Euphorbia* species exude toxic substances into soil that inhibit growth of nitrifying bacteria (Rice, 1974). Studies have shown that leafy spurge extracts will inhibit sensitive indicator plants (Steenhagen and Zimdahl, 1979;

LeTourneau et al., 1956). Leafy spurge is often found in areas which were formerly productive grassland. The third portion of the thesis was an investigation of the allelopathic potential of leafy spurge against native and introduced grass species.

PART I

A LEAFY SPURGE AWARENESS PROGRAM

CHAPTER ONE

LITERATURE REVIEW: AGRICULTURAL COMMUNICATION

Communication is the process of imparting or exchanging information (Bradfield, 1966). Kelsey (1963) further defined communication as "the process of transferring an idea, skill or aptitude from one person to another accurately and satisfactorily. Satisfaction is achieved when the communicator gets the attention, interest, decision and actions of the audience."

Mass communications are used in agriculture to aid in bridging the gap between farmers and research which enhances agricultural development (Myren, 1964; Bradfield, 1966). Mass communication techniques multiply contacts with farmers, help change habits of farmers, and transmit a *mood* of change (Myren, 1964). [The emphasis is the author's.]

Bradfield (1966) cautions that the communicator should know beforehand what type of change is desired in order to present the material correctly. How much the audience learns is affected by the confidence they have in the communicator and the communicator's attitude. The information transferred should be interesting to the people participating, understood by the audience and useful to those learning (Morgan, 1976; Mager, 1968).

Communication Studies

National and international organizations have recognized that communication is a necessary part of agriculture, and that methods of communication can be improved. In 1953 the Kellogg Foundation funded the National Project in Agricultural Communications "to study, stimulate and apply communication research and knowledge to the field of agricultural communications" (Michigan State University). The first interamerican research

symposium on the role of communications in agricultural development was held in Mexico City in 1962 (Myren, 1964). The symposium participants identified key research areas which identified guidelines for action programs.

Agricultural producers need an increasing amount of knowledge as agriculture technology becomes more advanced (Jensen et al., 1964). Training and education programs are necessary to keep producers current on new products and techniques (Bender et al., 1972). The Cooperative Extension Service has been an integral part of the search for new and innovative methods to reach the public with educational material since 1914 (Trent and Kinlaw, 1979). A major thrust of the Extension Service has involved adult education programs which offer a dissemination technique for presenting the newest farming practices and information. Adult education is uniquely beneficial since it can respond to the demands made by people involved with changing technologies (Jensen et al., 1964). The goals for an instructional program for adults need to be clearly defined at the onset so that there is a basis for selecting materials, content or instructional methods (Mager, 1962).

Communication Methods

Agricultural communication is accomplished through a five step diffusion process. Awareness of an idea initiates the process. Interest, evaluation, trial and adoption of the new idea complete the process. People are influenced to begin the process and make changes in proportion to the number of different teaching methods with which they come into contact. Contacts can be made via radio, newspaper, bulletins, meetings or demonstrations (Kelsey, 1963; Bender et al., 1972).

Operators of large commercial family farms have identified agricultural media including farm publications, newspapers, radio and television as important sources of infor-

mation (Brown and Collins, 1978). The audience and the response desired will determine the method of communication used (Bradfield, 1966).

Audio-Visual Communication

Radio first came to be of general interest in the 1920s. Programs were initially very general since one station covered a statewide area. Today, the radio approach can be more local since most towns have a radio station (Kelsey, 1963). Radio is an inexpensive means to reach a large number of people that would not be contacted otherwise (Dale, 1954; Kelsey, 1963).

Television altered the use of radio as a means of communication in agriculture (Kelsey, 1963). Radio is currently used as method of stimulating the listener to think and then follow through. Radio supports other methods of communication and has the advantage of being easily changed as conditions change (Bradfield, 1966).

Television is a tool of agricultural communication in the home and classroom. North Carolina agricultural educators first used television in 1966 to present 30 minute lessons to adult education classes (Boone, 1968). Teachers were available to prepare the class for the lesson, localize the information and help with individual questions. A similar program was used in Virginia with ten weekly lessons on farm management (Jewell and Oliver, 1968).

Agricultural extension agents in Ohio used a TV program "The Crop Game" for four years and gained a wide audience for teaching new farming practices (Koetz and Cole, 1978). The program covered areas relating to tillage, weed control, marketing, fertility and crop management. One-half of the estimated 10,000 viewers indicated changes in farming practices as a result of the program.

Written Communication

Whether the communication is through journal articles, bulletins, circulars or mimeographs, it must be clear and precise so the reader knows exactly what the writer is saying (Fuccillo, 1980). The communicator must understand the audience; readers may be intelligent but not be technically informed.

Written information comes in a variety of forms. Circulars, newspapers, flyers and bulletins can all work in separate ways to create interest, publicize events and dispense information (Bradfield, 1966; Myren, 1964). Magazines have an advantage in that they will often be saved for future reference (Myren, 1964). Newsletters rank high on the most-preferred list of written communications when they are well-written and pertinent to the problems of the receiver (Kelsey, 1963; Reisbeck, 1980; Brown and Collins, 1978).

Agricultural communication reaches out to other means of written information. The Public Health Service, Soil Conservation Society of America and the Environmental Protection Agency have successfully used comic books to portray poison control, pesticide safety and environmental improvement. The United States Department of Agriculture and the Wisconsin Extension Service have used cartoon series to teach soil fertility and food prevention (Trent and Kinlaw, 1979).

Many authors stress that the communicator should understand the audience (Fuccillo, 1980; Kelsey, 1963; Bradfield, 1966; Morgan et al., 1976). Awa (1974) demonstrated that in using mass media to help the poor, the message sent was understood best by the sender and not by the poor. Joseph Pulitzer aptly stated the facts when he said, "Put it before them briefly so they will read it, clearly so they will understand it, forcibly so they will

appreciate it, picturesquely so they will remember it and above all, accurately so they will be guided by its light" (Kelsey, 1963).

Group Meetings

Field demonstration or result demonstration sites for new agricultural practices and products can be effective communication tools (Cunningham and Simeral, 1977). The site should be in an area where the practices demonstrated offer a practical solution to a common problem (Kelsey, 1963). In some areas the farmers participate in observing and recording data and the programs continue year after year (Witt, 1968). Part of the success of farm tours or demonstration sites depends on planning ahead, a good location, a respected cooperator and media coverage before the tour or field day (Cunningham and Simeral, 1977; Bradfield, 1966).

Group meetings can be in the form of conferences, workshops, seminars, lectures, formal classes or open discussion. The amount of information transferred will depend on the communicator, the type of information and the audience (Morgan, 1976; Kelsey, 1963).

Communication transfer, written or oral, can be reinforced and clarified by visual aids (Bradfield, 1966). These may include drawings or photographs with written material or real objects and models at meetings or demonstrations.

One of the newest agricultural communication tools is the computer (Harrison, 1974). Currently, Montana, North and South Dakota, Wyoming, Nebraska and Minnesota are making computer programs available through county agents to help farmers make com-

plex management decisions (Kresge, 1981). Clarity, reliability and accessibility are important to the program users (Harrison, 1974).

Communication Survey

Brown and Collins (1978) surveyed farmers in the U.S. to determine the educational needs of large scale family farms and current sources of information. Suggestions from the survey ranged from returning to the old techniques of personal visits from county agents to experimenting with the latest electronic and computer devices.

The survey indicated that the source for agricultural information depended on the type of information being sought. Radio was the most popular source for market information, farm magazines provided new product information and universities and extension services were listed as the most important source for information on product technology.

Brown and Collins (1978) pointed out that agribusinessmen felt that the Extension Service and agribusiness firms should combine efforts to reach a larger audience with greater efficiency.

In closing, the survey indicated that innovative programs need to be developed that will meet the needs of young farmers.

CHAPTER TWO

LEAFY SPURGE ARTICLES

Abstract

A ten part series of newspaper articles covering the history, biology, control and research of leafy spurge was written and sent to Montana daily and weekly newspapers in 1980. The series was printed either partially or in their entirety in 20 newspapers. After the articles began, requests from producers were received for additional leafy spurge information, missed articles and copies of the complete series. In 1981, the articles were sent out again to newspapers that agreed to reprint them and were made available to other states and agencies for their use.

Introduction

Newspapers have a wide audience and few households go without at least one. When attempting to reach a large population, information can be easily disseminated by the use of newspapers. In an agricultural state like Montana, sections of newspapers are written specifically for farmers and ranchers. Problems pertinent to a local area can be addressed.

Materials and Methods

A ten part series of articles on leafy spurge was written in early 1980. The series included the history of leafy spurge, seed production, flowering, roots, biological, chemical and cultural control, economic impact of the weed, leafy spurge research and taxonomy of the plant.

An appropriate logo (Figure 1) was selected for accompanying the articles to aid in their identification and continuity. The logo was drawn and lettered by the Montana State

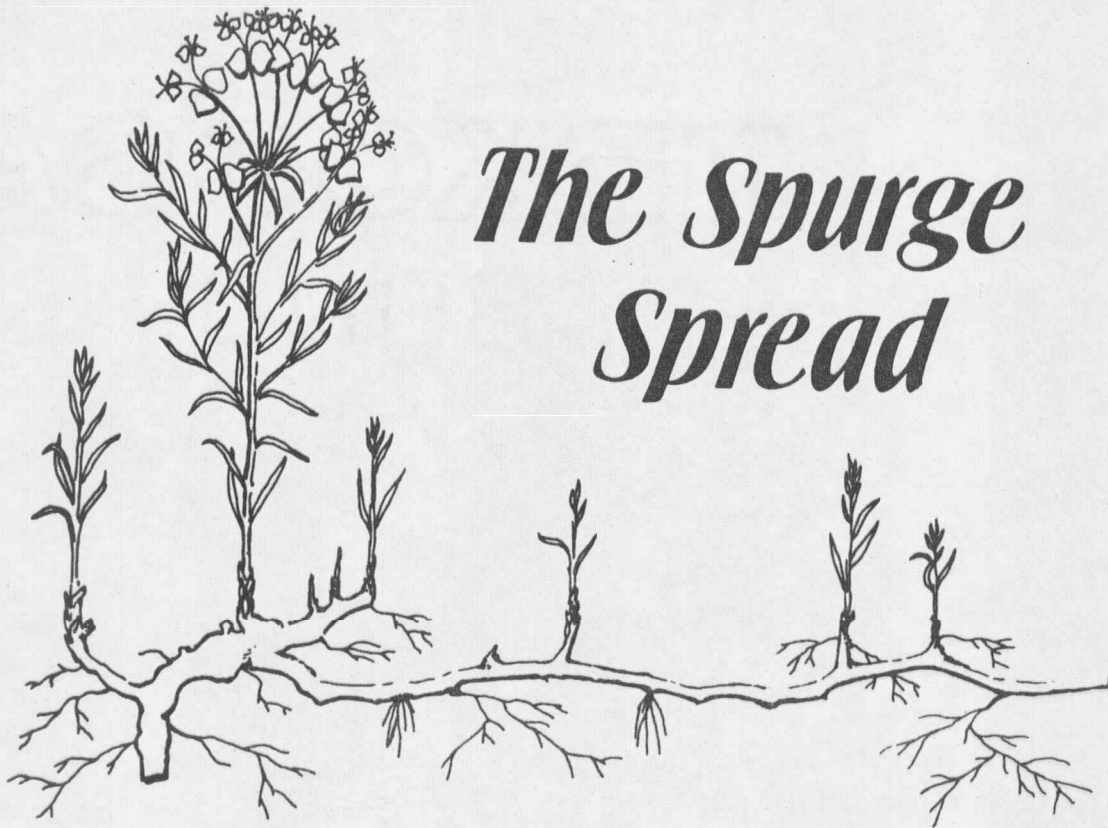


Figure 1. Logo for leafy spurge newspaper articles.

University Art Services. Photographic plates of the logo were made in sufficient quantity to send one to each newspaper in Montana.

Preceding each article was a brief description of the leafy spurge problem and the number of Montana acres involved. Concluding each article was a listing of the writer's name and address for those people interested in obtaining additional leafy spurge information or for those interested in being placed on the leafy spurge newsletter mailing list.

The articles were sent out on a bi-weekly basis to 82 daily and weekly papers in Montana. The initial article was accompanied by an introductory letter informing the newspaper editor of the leafy spurge problem in the state and requesting his assistance by printing the articles. All articles were sent to the newspaper through the Montana Agricultural Experiment Station News and Publication Office.

One year after the original articles were printed, the complete series was rewritten and sent to Montana papers that agreed to print them. The articles were also made available to other states and agencies by use of an announcement to that effect in the April 1981 issue of the Leafy Spurge Newsletter.

Results and Discussion

The logo was widely used by the newspapers printing the articles.¹

Twenty-one of the 82 newspapers printed the series either partially or in its entirety (Table 1). Of those newspapers carrying the series, the large majority were in areas of the state where leafy spurge is a problem.

Various responses were received from readers of the articles. Several requests were made for additional information on control of leafy spurge or for the complete series. The articles contributed approximately 30 names to the leafy spurge newsletter mailing list.

¹ Appendix A.

Table 1. Newspapers printing some or all of the leafy spurge articles

Newspaper	Town
<i>Miles City Star</i>	Miles City, MT
<i>Winnett Times</i>	Winnett, MT
<i>Judith Basin Press</i>	Stanford, MT
<i>Ravalli Republic</i>	Hamilton, MT
<i>The Madisonian</i>	Virginia City, MT
<i>Silver Star Post</i>	Deer Lodge, MT
<i>Glacier Reporter</i>	Browning, MT
<i>River Press</i>	Fort Benton, MT
<i>Laurel Outlook</i>	Laurel, MT
<i>Tribune Examiner</i>	Dillon, MT
<i>Times Clarion</i>	Harlowton, MT
<i>Meagher County News</i>	White Sulphur Springs, MT
<i>Phillips County News</i>	Malta, MT
<i>Glasgow Courier</i>	Glasgow, MT
<i>Big Timber Pioneer</i>	Big Timber, MT
<i>Montana Farmer Stockman</i>	Statewide
<i>Fairfield Times</i>	Fairfield, MT
<i>Roundup Record Tribune</i>	Roundup, MT
<i>Ranger Review</i>	Glendive, MT
<i>Forsyth Independent</i>	Forsyth, MT
<i>Prairie Star</i>	Statewide

One editor whose publication did not print the series stated that the articles needed to be written in more specific local terms. Other editors selected certain articles they felt were more important or that fit into the layout of their newspaper.

Several county agents and weed district supervisors requested an article series. They felt their county newspapers would be more likely to print an article if it was presented to them from someone within the county.

The newspaper articles provided the background on leafy spurge and were the first step in the awareness program.

CHAPTER THREE

LEAFY SPURGE NEWSLETTER

Abstract

A leafy spurge newsletter was initiated on a quarterly basis in April, 1980. The newsletter included leafy spurge research results and updates from five universities, progress reports on biological control of leafy spurge and summaries of leafy spurge conferences. Legislative action concerning leafy spurge was included in the newsletter. The newsletter was mailed to county agents, weed district supervisors, county commissioners, legislators, research personnel, chemical company representatives, farmers and ranchers. The mailing list for the newsletter numbered over 850 in October, 1981.

Introduction

Agricultural newsletters are a convenient means for communication between university agronomists and producers. The reader is given a brief summary of new findings, remedies for problems, and upcoming events. A number of specific problems such as crop varieties, weed control or harvesting can be addressed at a given season of the year.

Newsletters are usually printed several times a year so information can be updated as needed. The information can reach a large number of people in a short period of time.

Newsletters are not meant to replace research reports or farm magazines but rather to present a summary of available information.

Materials and Methods

The first issue of the leafy spurge newsletter was printed in April 1980. A letterhead was designed by Montana State University Art Services (Figure 2). The picture from the

letterhead was used as part of the return address on the backside of the second page of the newsletter (Figure 3).

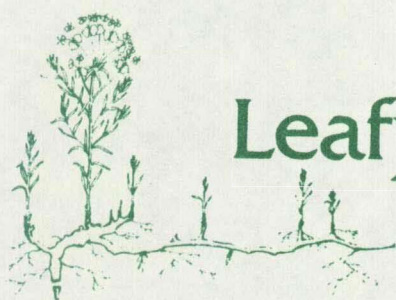
Information contacts were developed at each of four universities other than Montana State University. Research personnel working with leafy spurge at North Dakota State University, South Dakota State University, University of Nebraska and University of Wyoming were contacted for details regarding current research programs on leafy spurge research results. Personnel from the United States Department of Agriculture Biological Control Laboratory in Albany, California, were contacted for updates on new insect releases for biological control of leafy spurge. United States Forest Service personnel in Montana and South Dakota were contacted for leafy spurge information.

All university, state and federal agency contacts were notified one month prior to the printing deadline to submit information or research results for the newsletter. Contacts who had not submitted articles by the deadline were telephoned in order to solicit late submissions.

News items received were rewritten in one or two paragraphs. The items were compiled by state and put together in newsletter form. The newsletter was typed on plain white paper and was reprinted on letterhead sheets by multilith process.

The leafy spurge newsletter mailing list was initially developed from a list of persons attending two leafy spurge symposia held in 1979. County agents, weed district supervisors, county commissioners and legislators were added to the mailing list. Names of persons attending the 1980 and 1981 leafy spurge tours were placed on the newsletter mailing list. The entire mailing list was placed on computer cards for printing address labels.

All newsletters with the except of those mailed overseas were mailed bulk postage.



Leafy Spurge News

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

Figure 2. Letterhead for leafy spurge newsletter.

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

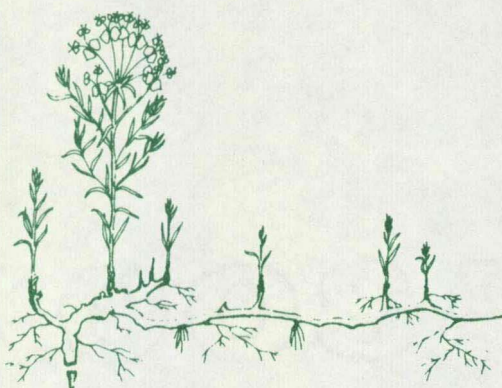


Figure 3. Return address for leafy spurge newsletter.

The leafy spurge newsletter was printed on a quarterly basis beginning in April, 1980.

Results and Discussion

The newsletter² was received favorably. This was indicated not only by comments from persons receiving the newsletter but also by continual additions to the mailing list. The April, 1980 issue was mailed to 240 people in five states. The October 1981 issue was mailed to 850 people in 14 states and four foreign countries.

The newsletter reported new leafy spurge research projects ranging from sheep feeding trials at Montana State University to herbicide root kills at University of Wyoming. Weed legislation involving leafy spurge in Montana and North Dakota resulted in articles in the newsletter.

The newsletter serves a purpose in providing an update on research to scientists at other universities. Farmers, ranchers, county agents, legislators and weed district personnel in the state of Montana are becoming informed about leafy spurge research being conducted at Montana State University and are aware that research is an on-going process.

The farmer/rancher population reached by the newsletter is limited to Montana. Researchers at the contributing universities were made aware that they were welcome to submit names for the mailing list. Very few names were received. In May 1982 the newsletter will be headquartered at one of the other cooperating universities. It is hoped that this move will help add more names of the ranchers in that state to the mailing list.

² Appendix B.

CHAPTER FOUR

LEAFY SPURGE FIELD TOURS

Abstract

Leafy spurge field tours were held at eight locations in 1980 and ten locations in 1981. The majority of the tour sites had demonstration plots showing chemical control of leafy spurge using picloram (4-amino-3,5,6-trichloropicolinic acid), dicamba (3,6-dichloro-o-anisic acid) and 2,4-D[(2,4-dichloro-phenoxy) acetic acid]. Displays and discussions covering the statewide infestations, leafy spurge biology, biological control and new chemical application methods were included in the field tour. Two hundred and forty people attended the 1980 tours and over 300 attended the 1981 tours.

Introduction

Field tours in agricultural communities offer an on-the-site link between research and the producer. The topic of the field tour is based on the needs and interests of those in the area (Kelsey, 1963).

Producers attend tours to gain knowledge about their problem. It is the responsibility of tour personnel to satisfy that need and learn from the producer's experiences.

The tours must be carefully planned. The objective of the tour must be evaluated and sufficient pre-planning conducted to meet the objective (Morgan, 1976). Cooperating farmers and county agents must be contacted well in advance to set up the location and plot sites. Immediately prior to the tour, publicity announcements need to be made, using as many different news media as possible (Cunningham and Simeral, 1977; Bradfield, 1966).

Field tours offer an opportunity for farmers and ranchers to come together and discuss common problems. The tour becomes a social gathering for producers in an area. Refreshments may be beneficial in these situations to allow an informal intermingling of producers and university personnel (Morgan, 1976).

Materials and Methods

Field tours. In October, 1979, demonstration plots showing chemical control of leafy spurge were put out in Judith Basin, Cascade and Missoula counties in Montana for field tours in June, 1980. In September, 1980, plots were put out in Park, Phillips, Powder River, Fergus and Deer Lodge counties for use as tour sites in June, 1981. Site selection was based on county agent or county weed district supervisor recommendations. Only picloram and dicamba were applied in 1979. In 1980, picloram, dicamba and 2,4-D were applied (Table 2). Tour sites where the writer did not apply treatments were in areas treated by Extension or Weed District personnel (Table 3).

Displays were constructed to show statewide leafy spurge infestations, the biology of the leafy spurge plant, biological control and demonstration models of the rope wick and roller applicators. The displays were constructed in a manner so they could be easily set up and taken down in the field.

Bumper stickers were designed and printed by Colorworld of Montana, Bozeman, Montana (Figure 4). These were disseminated at the tours as an awareness tool.

Publicity for the tours was coordinated by Greg Northcutt, editor for the Montana Agricultural Experiment Station. Radio announcements were taped and sent to the radio

Table 2. Chemicals applied for leafy spurge control at eight demonstration locations

County	Herbicide	Formulation	Rates of application kg/ha
Judith Basin	picloram	5G	2.24
	dicamba	5G	8.96
Cascade	picloram	2E	.56, 1.12, 2.24, 3.36
	dicamba	4E	4.48, 6.72, 8.96
Missoula	picloram	2E	.56, 1.12, 2.24, 3.36
	dicamba	4E	4.48, 6.72, 8.96
Park	picloram	2E	.56, 1.12, 2.24
	picloram	2G	1.12, 2.24
	dicamba	4E	4.48, 6.72
	dicamba	5G	4.48, 6.72
	2,4-D	4E	2.24
Powder River	picloram	2E	1.12, 2.24
	picloram	2G	1.12, 2.24
	dicamba	4E	4.48, 6.72
	dicamba	5G	4.48, 6.72
	2,4-D	4E	2.24
Fergus	picloram	2E	1.12, 2.24
	picloram	2G	1.12, 2.24
	dicamba	4E	4.48, 6.72
	dicamba	5G	4.48, 6.72
	2,4-D	4E	2.24
Phillips	picloram	2E	1.12, 2.24
	picloram	2G	1.12, 2.24
	dicamba	4E	4.48, 6.72
	dicamba	5G	4.48, 6.72
	2,4-D	4E	2.24
Deer Lodge	picloram	2E	.56, 1.12, 2.24
	picloram	2G	1.12, 2.24
	dicamba	4E	4.48, 6.72
	dicamba	5G	4.48, 6.72
	2,4-D	4E	2.24

Table 3. Herbicides were applied at 10 tour locations by Cooperative Extension or weed district personnel

County	Herbicide Demonstration Location	Applicator
Carter	Fix Farm Ekalaka, MT	M. Jackson MSU Ext. Weed Spec.
Fallon	Rugg Ranch Plevna, MT	M. Jackson Ext. Weed Spec.
Yellowstone	Morledge Ranch Billings, MT	M. Jackson Ext. Weed Spec.
Blaine	Bob Sharples Chinook, MT	Blaine Co. Weed District
Hill	Robert Davey Havre, MT	Gregg Carlson Hill Co. Ext. Agent
Lake	Several	Ranch owners
Silver Bow	Several	Silver Bow Co. Weed District
Sheridan	Don Hedges Plentywood, MT	Sheridan Co. Weed District
Roosevelt	Berry Bros. Bainville, MT	Roger Ashley Roosevelt Co. Ext. Agent
Stillwater	Several	Stillwater Co. Weed District

station nearest the tour site several weeks before the tour. Newspaper releases regarding the tours were sent to the county agents for distribution.

Hot dogs, beer and pop were available at each tour to provide refreshments and act as an icebreaker.

Funding for the travel expenses and refreshments was obtained from Dow Chemical Company in 1980 and Dow and Velsicol Chemical companies in 1981.



Figure 4. Bumper sticker utilized in leafy spurge field tours.
(Reduced from original 7.6 cm by 38.1 cm.)

Table 4. Attendance at 1980 and 1981 leafy spurge field tours

Year	County	Number of persons in attendance
1980	Carter	6
	Fallon	6
	Yellowstone	15
	Judith Basin	50
	Hill	70
	Cascade	33
	Blaine	20
	Missoula	40
1981	Lake	25
	Park	25
	Silver Bow	30
	Hill	70
	Phillips	27
	Sheridan	20
	Roosevelt	53
	Stillwater	18
	Powder River	14
	Judith Basin	400
	total	922

In addition to the funding, Dow and Velsicol Chemical companies donated herbicides which were given away as door prizes at the tours.

Slide-tape sets. As a follow-up for the field tours, leafy spurge slide-tape sets were made available at a minimum price to county agents and vocational agriculture instructors. A narrative on the biology and control of leafy spurge was recorded on cassette tape and reproduced in quantity by the Modern Languages Department, Montana State University. The tape accompanied twenty-one slides showing leafy spurge plant stages, root systems

and various means of controlling the weed. A Riker mount containing a leafy spurge plant and seeds was also made available at minimum cost.

Results and Discussion

Field tours. The 1980 tours were completed in June, 1980. The 1981 tours were held in June, 1981. There were additional requests for tours in 1981 from county agents and county weed district personnel. Fergus and Deer Lodge county tours were cancelled because of poor weather conditions. The author set up and manned a leafy spurge booth at the Deer Lodge county fair in place of a field tour.

The tours were enthusiastically received by the county agents and producers. Attendance exceeded original expectations (Table 4). Tours were held in both 1980 and 1981 in Judith Basin and Hill counties due to county agent requests. The 1981 Judith Basin leafy spurge tour was part of a statewide Weed Fair.

Picloram applied at a rate of 1.12 kg/ha or 2.24 kg/ha provided the best control of leafy spurge one year after application with the least amount of grass injury (Table 5). Because of the cost of the 2.24 kg/ha treatment³, many ranchers decreased the rate of picloram applied to .56 kg/ha, added 2,4-D and treated every year. When examining the control by the various chemicals, it was stressed that the roots were not killed and retreatments would be necessary.

The producers were a valuable source of information. They suggested numerous practices which were working for them. Several ranchers at the tour in Stillwater County had obtained excellent topgrowth control of leafy spurge by grazing sheep. The pastures

³ Chemical cost of 2.24 kg/ha of picloram is currently \$90.00.

Table 5. Percent topgrowth control of *Euphorbia esula* in six tour locations. 0 = no control; 100 = complete control

Chemical	Rate kg/ha	Formulation	County					
			1980			1981		
			Cascade	Judith Basin	Missoula	Park	Powder River	Phillips
picloram	.56	2EC	60*		62	75		
picloram	1.12	2EC	90		91	95	95	100
picloram	2.24	2EC	100*	100*	97	98	99	100
picloram	3.36	2EC	100*		99			
picloram	.56	2G			10			
picloram	1.12	2G			45	85	85	95
picloram	2.24	2G			85	93	90	95
picloram	3.36	2G			95			
dicamba	4.48	4EC	70*		75	85	20	90
dicamba	6.72	4EC	80*		80	94	70	85
dicamba	8.96	4EC	90*	100*	88			
dicamba	4.48	5G			10	98	60	50
dicamba	6.72	5G			50	98	70	60
dicamba	8.96	5G			70			
2,4-D	2.24	4EC				20	0	0

*Grass injury greater than 50%.

were in good condition, however, the ranchers noted that spurge would return if sheep grazing was terminated.

A common statement made by ranchers was that they would not object to the price of picloram if one application would control the weed. Since retreatments are necessary for leafy spurge control, most ranchers feel they cannot afford to use picloram on grazing land because of its low rate of annual return.

Many ranchers commented that a use should be found for the weed since it grows so well in Montana. Ranchers whose land adjoined state land said it would take cooperative

efforts from the ranchers, the state and railroads before the problem could be brought under control.

Some older ranchers stated that leafy spurge was first introduced to their area by threshers and hay from infested areas.

The leafy spurge tours were helpful in that some people who did not recognize the plant before the tour left with an awareness of the weed and the problems it can cause once it becomes established. Frequently, ranchers who would not identify leafy spurge before the tour took plants home so they could alert their neighbors to the identity and threat of leafy spurge.

The tours demonstrated side-by-side comparisons of chemical control, gave a review of leafy spurge research and offered encouragement that universities are studying the weed and control methods.

Slide-tape sets. Twenty-two leafy spurge slide tape sets and 28 Riker mounts of the weed were sent to county agents and vocational agricultural instructors. Although materials were ordered by some county agents who had hosted leafy spurge tours in 1980 or 1981, many were requested by county agents or instructors in whose county a tour was not held.

The slides, tapes and plant mounts allowed the information to reach a large number of people around the state with a minimum amount of time, travel and money. The educational materials provided a continuity of the awareness program even when Montana State University personnel were not available to present a program.

CHAPTER FIVE

SUMMARY

Leafy spurge infests over one half million acres in Montana and continues to spread. The weed is most easily controlled when infestations are small. An education program was initiated in Montana in 1980 to aid in identification of and knowledge about the weed.

Newspaper articles, leafy spurge newsletters, summer tours and slide sets were utilized to provide needed information on a troublesome weed problem. The education program created a greater awareness of leafy spurge and the possibilities for control. The articles, tours and slide sets reached a large number of people and delivered basic information about the weed and the leafy spurge newsletter is continuing to update that information. Legislative action on leafy spurge has occurred as a result of the increased awareness of the problem.

The education and awareness program is not completed. Many people still need to become informed about the weed. The ideas and background material have been disseminated and local county agents and weed district personnel can continue the program. Areas utilized as demonstration plots can be retreated and used again or county personnel can set up their own treated areas. Local weed authorities can draw on information provided in the education program to improve or add to their existing weed programs.

PART II

HYDROCARBON EXTRACTIONS

CHAPTER SIX

LITERATURE REVIEW: PLANT PRODUCTION OF HYDROCARBONS

Historical Research

The extraction of natural rubber from the rubber tree (*Hevea brasiliensis*) is a familiar form of hydrocarbon extraction. During the nineteenth century rubber was tapped from scattered trees in the Amazon jungle. From 1910 until 1940 most natural rubber came from rubber plantations in Malaysia (Calvin, 1977).

The blockades against Germany during World War I stimulated unsuccessful attempts to synthesize rubber (Polhamus, 1967). United States, British and German scientists successfully developed an economical synthetic rubber from petroleum during World War II (Calvin, 1977). By the end of World War II natural rubber could no longer compete economically with synthetic rubber.

As a result of the German rubber shortage during World War I, Thomas Edison examined thousands of plants that could be grown in the United States as a domestic source of rubber (Polhamus, 1967). Edison reported that plants in the genus *Euphorbia* contained high amounts of latex.

Buehrer and Benson (1945) reported the results of numerous studies that examined rubber content of native American plants. They restricted their investigation to plants indigenous to the southwestern United States. Minshall (1957) used a similar procedure to study the rubber content of plants found in Canada.

Current Research

The oil shortages of the past decade prompted scientists to examine plants not only for natural rubber content but also for other petroleum-like products (Calvin, 1974, 1976,

1977, 1979a, 1979b; Coffey and Halloran, 1979; Gartside, 1977; Nielsen et al., 1977; Sachs et al., 1981). Nishimura et al. (1977) point out that carbohydrates from sugar cane are converted to alcohols and then to olefins. Olefins are routinely produced at present by cracking crude petroleum products. Approximately ten percent of fossil hydrocarbons are cracked down to ethylene and used for the production of synthetic fibers and plastics. Calvin (1979b) feels that short-chained plant hydrocarbons could be used instead of fossil fuel for fiber and plastic production.

Several authors (Buchanan et al., 1978a, 1978b; Buchanan, 1978; Calvin, 1977; Gartside, 1975) suggest that agricultural production of hydrocarbons may be compatible with a need for increased food and fiber production if the entire plant could be harvested for hydrocarbons, fiber, protein and carbohydrates.

Potential Sources of Plant Material

Over 2,000 plant species produce hydrocarbons (Calvin, 1976). Plants in the Euphorbiaceae and Asclepiadaceae families contain hydrocarbons similar to those found in crude oil (Coffey and Halloran, 1979; Buchanan et al., 1978a). It is presently economically feasible to extract plant-derived hydrocarbons if they constitute two percent or more of the plant's dry weight (Buchanan et al., 1978a; Polhamus, 1967; Buehrer and Benson, 1945; Minshall, 1957). Coffey and Halloran (1979) stated that *Euphorbia tirucalli*, *E. lactea* and *E. lathyris* may have potential for hydrocarbon production.

Several species of *Euphorbia* were planted for hydrocarbon production in southern California (Calvin, 1979b). A Japanese firm planted *E. tirucalli* and estimated that five to ten barrels of oil¹ could be produced per acre per year. Calvin (1979b) estimated that *E.*

¹ Oil refers to fats, fatty acids, resins, terpenes and hydrocarbons.

lathyris could produce eight to twelve percent of the plant dry weight in oil which would yield ten to twenty barrels of oil per acre per year.

Selection and genetic improvement may improve the yield of hydrocarbons (Buchanan et al., 1978a; Calvin, 1979b; Coffey and Halloran, 1979). Strains of *Parthenium argentatum* contain different amounts of latex hydrocarbons (Coffey and Halloran, 1979). Economic pressures can influence agronomy and plant breeding. Rubber yields increased from an average of 224 kg/ha in 1945 to over 2240 kg/ha by 1965 (Calvin, 1977). The chemical composition of plant hydrocarbons could also be manipulated. Coffey and Halloran (1979) found distinct qualitative differences in hydrocarbons among *Euphorbia* species.

Agronomic and edaphic factors influence hydrocarbon content. Hydrocarbon levels of *Parthenium argentatum* were regulated by annual rainfall, growth temperature and time of harvest (Coffey and Halloran, 1979). Alternatively, Buehrer and Benson (1945) feel that climate and soil conditions are of lesser importance in determining rubber content than plant genus and age of the plant at the time of analysis.

Buchanan et al. (1978b) evaluated 100 plant species from 13 families and 60 genera for hydrocarbons, fiber, protein and carbohydrates. Several species in the family Labiatae contained more than one percent rubber. Several Compositae, *Cacalia atriplicifolia*, *Solidago graminifolia* and *S. rigida* contain significant amounts of crude rubber. These findings were supported by Edison (Polhamus, 1967). *Euphorbia dentata* and *E. heterophylla* contain high oil percentage.

Buchanan et al. (1978) found oils and hydrocarbons distributed throughout the plant. Variations in whole plant oils may be due to growing conditions, soil fertility, disease and insect infestations.

Euphorbia lathyris is a potential source of hydrocarbons (Coffey and Halloran, 1979; Calvin, 1979b). Sachs et al. (1981) studied irrigation and fertilization effects on hydrocarbon yield. Although their irrigated plots produced more dry matter than non-irrigated plots, the percentage of rosin was greater in non-irrigated plants because of a greater proportion of leaf to stem dry weight. Little or no response was noted to additional nitrogen.

In this same study, problems were encountered with seedling emergence and crop establishment, pathogens, and plant drying. Early expectations were that *Euphorbia lathyris* could be established and grown without irrigation. This is unlikely. According to Sachs et al. (1981), the economic potential of *E. lathyris* for hydrocarbon production is low. Genetic improvement may be difficult since no differences were observed in hydrocarbon content among the germplasm tested.

Extraction Procedures

The determination of hydrocarbon content in most plants is usually carried out by an acetone extraction to remove resins, fat, saponifiable oils, sugars, coloring matter and essential oils. This is followed by a benzene extraction that removes the hydrocarbon substance (Buehrer and Benson, 1945; Buchanan, 1978a; Buchanan, 1978; Minshall, 1957; Polhamus, 1967).

A survey of the methods used for hydrocarbon extraction found that sample size varied from two grams (Buehrer and Benson, 1945) to greater than 500 grams (Buchanan

et al., 1978). Plant samples were air dried and coarsely ground before storing. Samples were finely ground prior to the extraction (Buchanan et al., 1978).

Buehrer and Benson (1945) recommend air drying plant material out of direct sunlight since ultraviolet light tends to destroy the rubber substance. Drying the plant material in a vacuum oven also resulted in partial decomposition of the rubber substance.

Extraction periods range from six (Minshall, 1957) to 24 hours using a Soxhlet apparatus (Buchanan et al., 1978a). The extraction time, sample size and particle size of the materials may affect the final results of an extraction (Buehrer and Benson, 1945).

CHAPTER SEVEN

HYDROCARBON CONTENT OF LEAFY SPURGE

Abstract

Twelve strains of leafy spurge were harvested three times or as many times as regrowth allowed during the 1980 growing season. The topgrowth was dried, ground and extracted with acetone and benzene:hexane to determine hydrocarbon content. The extracted hydrocarbons were expressed as a percent of plant dry weight.

No statistical differences were observed among strains for June, August and October harvests. Four ecotypes contained higher amounts of hydrocarbon than the rest when harvested in July. Several ecotypes contained more than two percent hydrocarbons on a plant dry weight basis. Additional research is needed to completely assess the potential of leafy spurge as a source of hydrocarbons.

Introduction

Hydrocarbons and seed oils have the potential to supply chemicals similar to those presently derived from crude petroleum oil. Green plants utilize solar energy to produce a wide variety of products that are competitive with synthetic petrochemicals. Collectively referred to as hydrocarbons, they include isoprene polymers, waxes and terpenoids.

Leafy spurge (*Euphorbia esula*) is a well-established perennial plant in the north-central United States and Canada. Since no diseases or insects attack leafy spurge this would not pose a threat to production in North America. The plant does not need to be established each year, has excellent regrowth potential after cutting, and contains hydrocarbons. The following study was conducted to measure the hydrocarbon content of

several ecotypes of leafy spurge and to measure the potential of the plant for hydrocarbon production.

Materials and Methods

An existing collection of *Euphorbia esula* from twelve locations was used as the source of plant material in this study. Ecotypes were identified according to collection location: Lethbridge, Saskatchewan, Colorado, Wyoming, Idaho, South Dakota, North Dakota I, North Dakota II, Missoula MT, Moccasin MT, Bozeman MT and Antelope MT. Plants were established in 17.8 cm diameter by 90 cm long metal cans which were placed in concrete pipe sunk into the ground on 1.2 m centers. The plants were established in 1962 at the Agricultural Experiment Station, Bozeman. The plants were placed on a randomized complete block design. There were three replications.

Harvest dates. Plants were harvested June 18, July 15 or August 1, 1980, at three stages of plant growth: bloom, seed set and post seed dispersal, respectively. Regrowth was harvested six weeks after the initial harvest. Plants were air dried and ground with a Wiley mill to pass through a 20-mesh screen. The samples were finely ground and oven dried at 30°C immediately before extraction.

A 85 ml Soxhlet apparatus equipped with 90 by 33 mm Schleicher and Schuell extraction thimbles was used in the extraction process. Each sample was weighed, extracted for 24 hours with acetone, dried, reweighed and extracted for 24 hours with a 2:3 (V:V) benzene:hexane mixture. Samples were dried and weighed after the benzene:hexane extraction. The difference in weight before and after the benzene extraction was taken to be the weight of the hydrocarbons.

Effect of fertilizer. The effect of nitrogen fertilizer on hydrocarbon content was measured on three ecotypes. Ammonium nitrate fertilizer (67 kg/ha) was surface applied July 5, 1980. Plants were harvested July 15 or August and October (two harvests) and analyzed for hydrocarbons as described above.

Results and Discussion

All ecotypes were not represented in the first harvest because of drying problems encountered with harvested material. The ecotypes did not produce regrowth at the same rate and all ecotypes were not harvested at all cuttings.

Harvest dates. The June and August harvests showed no statistical differences in hydrocarbon content among ecotypes (Tables 6 and 8).

The July harvest of Wyoming, Missoula and Bozeman ecotypes contained higher levels of hydrocarbons (Table 7). Each ecotype had one replication with an exceptionally high hydrocarbon content which may account for the difference. Ecotypes from Lethbridge, Saskatchewan and North Dakota I produced statistically less hydrocarbon than ecotypes from Missoula, Wyoming or Bozeman.

Only ecotypes from Lethbridge and Wyoming had sufficient regrowth to harvest in October (Table 9). Those plants had been previously harvested in July. Hydrocarbon content of those ecotypes was statistically different but neither reached the two percent level (Table 9).

Four ecotypes produced greater amounts of hydrocarbon with a first cutting in July than with a first cutting in June. Only the Saskatchewan ecotype produced a higher percentage of hydrocarbon in June (Table 10).

Table 6. Percent hydrocarbon in *Euphorbia esula* ecotypes harvested June 18, 1980.

Ecotype	% hydrocarbon
Saskatchewan	1.97
Colorado	.12
Idaho	.14
South Dakota	.47
Antelope	.17
LSD (.05)	2.02

Table 7. Percent hydrocarbon in *Euphorbia esula* ecotypes harvested July 15, 1980.

Ecotype	% hydrocarbon
Lethbridge	.40
Saskatchewan	.60
Colorado	1.12
Wyoming	2.27
Idaho	1.56
South Dakota	.73
North Dakota I	.38
North Dakota II	.88
Missoula	2.18
Moccasin	.73
Bozeman	1.96
Antelope	1.24
LSD (.05)	1.58

Table 8. Percent hydrocarbon in *Euphorbia esula* ecotypes harvested August 1, 1980.

Ecotype	% hydrocarbon
Lethbridge	1.22
Wyoming	.42
North Dakota I	.24
North Dakota II	.60
Moccasin	1.36
LSD (.05)	1.20

Table 9. Percent hydrocarbon in *Euphorbia esula* ecotypes harvested in October, 1980.

Ecotype	% hydrocarbon
Lethbridge	1.10
Wyoming	.15
LSD (.05)	.75

Table 10. Percent hydrocarbon in *Euphorbia esula* ecotypes harvested in June and July, 1980, for the first time.

Ecotype	Month of harvest	% hydrocarbon
Saskatchewan	June	1.97
Saskatchewan	July	.40
Colorado	June	.12
Colorado	July	1.12
Idaho	June	.14
Idaho	July	1.56
South Dakota	June	.47
South Dakota	July	.73
Antelope	June	.17
Antelope	July	1.24
LSD (.05)		1.71

Effects of fertilizer. No statistical differences were measured between hydrocarbon content of fertilized and unfertilized ecotypes (Table 11).

Several problems are inherent in this study. The plants had been in the cans for 18 years. *Euphorbia esula* roots are extensive in a field situation; the confined roots of the experimental plants may have hindered the regrowth abilities of these plants. Some plants demonstrated vigorous regrowth while others produced only one or two shoots after cutting.

Euphorbia esula seed capsules can project seed as far as four meters. Since the cans were placed on 1.2 m centers, seed from one ecotype could have easily contaminated an

Table 11. Percent hydrocarbons in fertilized and non-fertilized ecotypes of *Euphorbia esula* harvested in August, 1980.

Ecotype	Fertilizer added	% hydrocarbons
Lethbridge	no	2.65
Lethbridge	yes	1.33
Wyoming	no	3.21
Wyoming	yes	.42
Moccasin	no	.89
Moccasin	yes	1.36
LSD (.05)		2.85

adjoining can. Contamination may explain the variation between replications.

The sample size used in the extraction can markedly change the outcome. Some ecotypes produced less than two grams of dried plant material. Small samples did not grind well and had larger particles than ten gram samples. Samples with large particles consistently gave higher hydrocarbon percentages. Buehrer and Benson (1945) note that if the acetone extraction is incomplete, results from the benzene extraction will be high. Resins and benzene-soluble compounds normally extracted by acetone remain in the sample and are extracted by the benzene, giving excessive estimates for hydrocarbon content. This is evident in the Saskatchewan ecotype at the June harvest, the Missoula ecotype at the July harvest and the unfertilized Lethbridge ecotype at the August harvest where the dried samples in one replication were 1.7 g, 1.2 g and 0.26 g, respectively.

Results from extraction of plant material from the unfertilized ecotype from Wyoming indicate it contained 3.21 percent hydrocarbons, considerably higher than the .41 percent plant dry weight reported by Minshall (1957) for leafy spurge. This number should be accepted cautiously because of a large variation between replications.

Ecotypes of leafy spurge cannot be recommended as a potential source of hydrocarbons. Results obtained in this study were unreliable due to the inconsistency of the replications and the uncertain identification of plant material.

CHAPTER EIGHT

SUMMARY

Euphorbia species may have potential as sources of hydrocarbons which could replace crude petroleum products in the production of synthetic fibers and plastics. Some of the *Euphorbia* species being studied are annuals and problems have been encountered in establishing the plants. *Euphorbia esula* is a perennial and is already established on millions of acres in northcentral United States and Canada. In this study, twelve ecotypes of *E. esula* were harvested and hydrocarbons were extracted in an effort to find ecotypes which contained at least two percent of the plant dry weight as hydrocarbons. None of the twelve ecotypes contained high levels of hydrocarbon.

Several ecotypes appeared to have at least two percent hydrocarbons but the data were not sufficiently consistent to recommend *Euphorbia esula* as a possible hydrocarbon source. Additional data needs to be collected from properly identified ecotypes.

Euphorbia esula was originally examined partially because of its regrowth abilities. Extensive regrowth was not observed in this study possibly because of physical root inhibition. Studies are needed of *E. esula* regrowth in a field situation where root growth is not inhibited.

The use of a limited amount of fertilizer did not appear to change the hydrocarbon content of the plant. Heavier applications of fertilizer and irrigation may improve the hydrocarbon content of *Euphorbia esula*.

Before *Euphorbia esula* becomes a potential source of hydrocarbons, increased hydrocarbon yields must be realized. Agronomic research in the areas of plant breeding and fertility may aid in increasing the hydrocarbon content.

PART III

ALLELOPATHIC ACTIVITY OF *Euphorbia esula* L.

CHAPTER NINE

LITERATURE REVIEW: ALLELOPATHY

Introduction

Allelopathy is defined by Muller (1969) to be "the release by one plant of a chemical compound into the environment which inhibits the growth of another plant." Rice (1974) further defines allelopathy to be "any direct or indirect harmful effects by one plant, including microorganisms, on another through the production of chemical compounds released into the environment." Allelopathy and competition are two forms of interference which is defined to be all forms of reactions by one plant that are deleterious to another (Muller, 1969). Whittaker (1970) states that allelopathy is "not a peculiarity of a few plants but rather a widespread and normal, though inconspicuous, phenomenon of natural communities."

In order to establish that allelopathy exists, two conditions are important (Muller, 1971). It must first be determined that the plant contains an inhibitory compound, and that there is a mechanism by which the phytotoxin can be released from the plant, transported in the environment and accumulated in the area of the inhibited plant. Second, the relative weight of all pertinent physical factors must be determined in order to rule out competition.

Muller (1971) cites Plenck for the first suggestion of chemical interactions between plants in 1795. Börner (1960) credits DeCandolle (1832) with the original theory of plants releasing toxic substances.

"Soil sickness" was sometimes used to describe soil when it was no longer productive (Woods, 1960). Woods (1960) states Pantanelli (1926) attributed soil sickness to be

the result of root excretions preventing the development of soil microorganisms. Schreiner and Sullivan (1909) demonstrated unfavorable soil conditions may be caused by organic substances arising through crop growth.

A publication by Molisch (1937) initiated a series of studies concerning plant interactions (Börner, 1960). Since that time, allelopathy has been shown to alter the structure, function and diversity of plant communities (Muller, 1969; Whittaker, 1970; del Moral and Cates, 1971). Phenomena previously considered to be due to competition for light, moisture or nutrients may have to be reconsidered with a recognition of possible allelopathic effects (Muller, 1971).

Occurrence of Allelopathy

Allelopathic effects are widespread in both agricultural and wild species (Whittaker and Feeney, 1971). Crop plants from the genera *Avena*, *Triticum*, *Secale*, *Hordeum*, *Bromus* and *Brassica* are known to release toxic substances from roots (Putnam and Duke, 1974).

By using a split root technique Buchholtz (1971) found that *Agropyron repens* influenced the accumulation and utilization of mineral nutrients by corn (*Zea mays*) by impairing the adsorptive capacity of corn roots. Gabor and Veatch (1981) isolated a phytotoxin from *A. repens* rhizomes that inhibited seedling growth of corn. Ahlgren and Aamodt (1939) determined that adjoining roots may have an effect on the development and activity of other roots.

In natural communities allelopathy may regulate the density and distribution of plant species (Putnam and Duke, 1974), the vegetation pattern or plant succession (Whittaker and Feeney, 1971; Einhellig and Rasmussen, 1973; Rice, 1974).

Rice (1971) studied the four stages in old field succession and the plant interactions that determine why each stage replaced the other. He found that several first stage plants produced inhibitory compounds which rapidly eliminated the major portion of first stage plants but did not inhibit stage two plants. He also determined that pioneer species which require very little nitrogen produce inhibitors of the nitrogen-fixing and nitrifying bacteria and thereby slow the rate of succession.

Whittaker (1971) feels that invading plant species can influence the rate of plant succession by the use of allelochemicals. Bonner (1950) noted that *Encelia farinosa* and *Artemisia absinthium* showed true inhibition under field conditions. This may indicate that association or non-association of different species may be the result of specific compounds being released.

Newman and Rovira (1975) obtained strong correlations when they compared the field vegetation patterns with laboratory results. They concluded that auto-inhibitory exudates are a key process in the control of species diversity in grassland.

Mechanisms of Allelopathy

Germination inhibitors are found in nearly all plant parts (Evanari, 1949). Release routes for allelochemicals include rainwash and fog drop from leaf surfaces, volatilization from leaves, excretion or exudation from roots and decay of above and/or below-ground plant parts (Whittaker and Feeney, 1971).

Allelopathic chemicals have been collected after washing leaves of *Artemisia absinthium* (Bode, 1939 from Bonner, 1950; Bennett and Bonner, 1953). Other allelopathic compounds were found in litter of the same plant. Bell and Muller (1973) leached water soluble toxins from dead stalks and leaves of *Brassica nigra*.

Toxic substances are produced by excretions from roots or underground stems (Bonner, 1946; Bonner, 1950; Putnam and Duke, 1974) or from decaying plant residues (Bode, 1939 from Bonner, 1950; Benedict, 1941).

Einhellig and Rasmussen (1973) postulated that many allelochemicals are water soluble which would facilitate their release into the environment from fresh leaves. Woods (1960) cautions against the use of aqueous plant extracts because many of the toxins in such a solution would not be present under normal growing conditions.

Allelopathic effects have been observed from fresh and dead tissue. Dilutions of aqueous extracts from the fresh leaf tissue of *Rumex crispus* inhibited *Amaranthus retroflexus*, grain sorghum (*Sorghum vulgare*) and field corn (Einhellig and Rasmussen, 1973). Undiluted root extracts of three perennials, *Cynodon dactylon*, *Cyperus rotundus* and *Sorghum halepense* reduced root length in barley (*Hordeum vulgare*), *Brassica nigra* and wheat (*Triticum aestivum*) (Friedman and Horowitz, 1970).

Friedman and Horowitz (1970) stated that perennial plants may be toxic during decay because they may cause temporary inhibition of growth in nearby plants. They found that leaves or rhizomes of *Sorghum halepense* decaying in soil inhibited germination and seedling development of weed species planted in the soil. Volatile and water soluble toxins from *Eucalyptus camaldulensis* litter were found to inhibit growth in the lab and greenhouse. This was thought to be the reason for a lack of annual herbs around the plot when litter accumulated in the field (del Moral and Muller, 1970).

Other perennials have displayed allelopathic effects. Hanawalt (1971) found inverse correlations between the amount of plant litter and weed seedling number in an area dominated by *Arctostaphylos glauca* and *A. glandulosa* var. *zacaensis*. Environmental factors

were ruled out as a cause for differential growth. Fresh leaf litter was more toxic than partially decayed litter. Toxins were no longer present nine weeks after soil was taken from the field to the greenhouse.

Rice (1974) noted that deCandolle (1832) first observed that thistles injure oats in the field. DeCandolle also saw flax injured by euphorbe (*Euphorbia* spp.) and *Scabosia* spp. Rye plants (*Lolium* spp.) injured wheat. Reports of allelopathy in these plants have been supported by later work. Stachon and Zimdahl (1980) found that the addition of Canada thistle (*Cirsium arvense*) litter, ground roots and ground foliage to the soil reduced growth of *Amaranthus retroflexus* and *Setaria viridis*. Rice (1974) stated that allelochemicals from *E. supina* may inhibit growth of pioneer weeds and speed their elimination from the first stage of plant succession in abandoned fields. *Euphorbia corollata* also inhibits first stage succession plants.

Frank and Dechoetz (1980) found that phytotoxins from dwarf spikerush (*Eleocharis coloradoensis*) reduced growth of American pondweed (*Potamogeton nodosus*) and sago pondweed (*P. pectinatus*).

Annual plants have been shown to have allelopathic effects. Decomposing plants of timothy (*Phleum pratense*), corn (*Zea mays*), rye (*Secale cereale*) and tobacco (*Nicotiana tabacum*) produced substances that inhibited respiration, germination and growth of tobacco seedlings (Patrick and Koch, 1958).

Allelopathic Compounds

Rovira (1971) identified a wide range of compounds that were exuded from intact roots including sugars, amino acids, peptides, enzymes, organic acids, nucleotides, and

fungus stimulants. Root exudation is affected by plant species, plant age, temperature, light, plant nutrients and soil moisture.

Rovira (1965) as cited by Foy (1971) lists four references which present major evidence for root exudation of organic molecules:

1. Knudson (1920) provided conclusive evidence that peas and maize release specific organic substances from roots.

2. Lyon and Wilson (1921) measured organic nitrogen released from major roots under sterile conditions.

3. Cranner (1922) detected phosphatides from roots of both seedlings and mature plants.

4. O'Brien and Prentice (1930) demonstrated biological specificity of plant exudates.

Numerous toxic substances have been found in intact plants. Hydrolyzable tannins were isolated from extracts of *Euphorbia supina* after it was found to affect nitrifying bacteria (Rice, 1969). Cineole and camphor were found in toxic amounts in the air above *Salvia leucophylla* and *Artemisia californica*. The characteristic bare zones around these shrubs was shown to be a result of these terpenes which are bound by the soil (Muller, 1971). Muller (1971) demonstrated that volatile terpenes from *Salvia mellifera* and *Lepechinia calycina* inhibited growth of numerous other plant species.

Many substances are released from the roots into the soil, often as a result of death and decay (Whittaker, 1970). Chemicals responsible for allelopathic effects are often secondary plant substances such as phenols, terpenes, and alkaloids.

Jugalone (5-hydroxy-1,4-naphthoquinone) occurs as hydroxy jugalone in all plant parts of black walnut (*Juglans nigra*). After release from the leaves and dead tissue it is

converted to its toxic form (Davis, 1928; Whittaker, 1970). The inhibition of germination and growth as a result of allelochemical release by *Encelia farinosa* is partially attributed to 3-acetyl-6-methoxy benzaldehyde (Gray and Bonner, 1948). Went (1970) found trans-cinnamic acid to be the main inhibitor utilized by guayule (*Parthenium argentatum*). *Euphorbia corollata* was shown to produce gallic and tannic acids (Rice, 1974).

Börner (1971) found phlorizene in high concentrations in established apple (*Malus* spp.) plantings, however, the concentration was not high enough to cause toxic reactions.

Patterson (1981) examined ten compounds in the laboratory and found that t-cinnamic, caffeic, p-coumaric, ferulic, gallic, vanillic and 5-sulfosalicylic acids reduced plant growth. Uncertainty exists as to whether the concentration of these allelopathic compounds in the field ever reached the levels used in laboratory work. Long-term effects in the field may differ radically from short-term laboratory effects.

Plants have devised protective systems to avoid internal autotoxicity. Protective mechanisms include the synthesis and accumulation of inactive polymers such as tannins, the secretion of inactive compounds which become toxic after release such as juglone, cellular segregation such as the storage of calcium oxalate crystals, separation in the cell by compartmentalization of the inactive toxin and the activating enzyme (Whittaker, 1971). Seeds of *Eucalyptus camaldulensis* are not sensitive to the toxins produced by the parent plant (del Moral and Muller, 1970).

Factors Affecting Allelopathy

Toxins can be leached in the soil. Rice (1969) cites Blum and Rice (1969) as having discovered that tannic acid from the leaves of *Rhus copallina* leached 75 cm into the soil profile. Small amounts of tannic acid reduced nodulation of bean (*Phaseolus vulgaris*)

plants. Bonner (1950) found that *Encelia farinosa* leaves may retain their toxic properties for a year or more after falling and the toxin may be leached into the soil.

Soil texture affects toxin concentration. Del Moral and Muller (1970) found that toxins from *Eucalyptus camaldealensis* affected the surrounding grassland only after being adsorbed by the soil colloids since the toxins failed to inhibit other plant species grown in sand. Allelopathic compounds can interact with soil and be selectively adsorbed (del Moral and Muller, 1970).

Autotoxicity exists between guayule roots if plant roots become pot-bound (Bonner, 1950). Benedict (1941) demonstrated dead brome grass (*Bromus* spp.) roots inhibited growth of brome grass plants. Putnam and Duke (1974) discovered that cucumber (*Cucumis sativus*) accessions and cultivars differ greatly in their ability to control weed growth.

Bonner (1971) suggests the definition of allelopathy be expanded to include the influence of the products of soil microorganisms since they can convert inactive compounds secreted from plant residues into phytotoxic substances.

Börner (1971) studied the effects of root secretions of weeds among cultivated plants in water culture.

Stachon and Zimdahl (1980) found that ethanolic extracts of Canada thistle (*Cirsium arvense*) produced toxic effects on test species but dried plant residues had no effect. Some studies show microbes are responsible for an increase or decrease in allelopathic effects (Bonner, 1950). Patrick and Koch (1958) determined that initial microbial breakdown of plant tissue produced a toxin and later aided in decomposition of the plant tissue.

Allelopathic Activity of *Euphorbia esula*

Allelopathic extracts of *Euphorbia esula* have been demonstrated. LeTourneau and Heggeness (1957) used an aqueous extract of *E. esula* foliage to inhibit root growth of *Triticum aestivum*. The same extract caused shortening and discoloration of 'Alaska' pea (*Pisum sativum*) roots. On a dry weight basis, fresh extracts were found to be more inhibitory than extracts of dried ground material. *Euphorbia esula* leaf extracts were more inhibitory than stem extracts (LeTourneau et al., 1956; Selleck, 1972). Extracts from young spurge plants were more inhibitory than extracts from older plants (LeTourneau et al., 1956).

Selleck (1972) found that leaf and stem extracts from leafy spurge inhibited germination of wheat, *Bromus inermis*, *Brassica kaber* and *Agropyron cristatum*. Root extracts depressed germination and coleoptile elongation of all the species listed above except wheat. Extracts of soil in close association with leafy spurge roots inhibited radicle elongation of wheat and *Bromus inermis*.

Steenhagen and Zimdahl (1979) demonstrated that dried, ground leafy spurge added to the soil would inhibit growth of tomato (*Lycopersicon esculentum*) and crabgrass (*Digitaria sanguinalis*). Their results suggest that toxin levels in soil may be too low to inhibit growth of competing species when the leafy spurge litter is removed.

Newman and Rovira (1975) stated that toxic compounds are found in many plants but cautioned that laboratory results are not always relevant to the field situation.

Indicator species are sometimes chosen for convenience rather than ecological significance. Del Moral and Cates (1971) agree that subsequent work with potential allelo-

pathic species should utilize native species which are routinely influenced by the suspected allelochemic plant.

CHAPTER TEN

ALLELOPATHIC SOIL RESIDUES OF LEAFY SPURGE

Abstract

Soil was collected from two leafy spurge infested areas near Missoula and Vaughn, Montana. Soil from a nearby non-infested area served as the control. Twelve grass species were grown in the soils in the greenhouse to determine if plant growth was influenced by allelopathic compounds.

There was no difference in the rate of emergence of the grass species in the infested and check soils. In addition, there was no difference in growth rate of the species grown in each soil.

Four species showed weight differences when grown in the infested and check soil from Missoula one month after planting; however, there were no weight differences two months after planting. Plant dry weight of *Alopecurus arundinaceus* was lower in Missoula infested soil than in check soil two months after planting. Plant dry weight of *Bromus inermis* was lower when grown in Vaughn infested soil one month after planting.

Introduction

Allelopathy may regulate the distribution of plant species or plant succession (Einhellig and Rasmussen, 1973; Putnam and Duke, 1974; Rice, 1974). The following research was conducted to determine if leafy spurge utilizes allelopathy as a major strategic device since there is evidence to suggest that related species (*Euphorbia supina* and *E. corollata*) inhibit pioneer weeds in the first stage of plant succession in abandoned fields (Rice, 1974).

In addition, suspected allelochemicals from leafy spurge inhibited root growth of wheat, *Bromus inermis*, *Brassica kaber* and *Agropyron cristatum* (LeTourneau and Heggeness, 1957; Selleck, 1972). Steenhagen and Zimdahl (1979) inhibited growth of tomato and *Digitaria sanguinalis* by addition of leafy spurge residues to soil.

Several authors (del Moral and Cates 1971; Newman and Rovira, 1965) have emphasized the following points: (1) plants may contain toxic substances, however, these substances are not always utilized in the field situation, and (2) studies related to allelopathy need to utilize native species which are found in association with the suspected allelopathic plant.

The following study used twelve native and introduced grass species commonly found in areas infested with leafy spurge.

Materials and Methods

Soil was excavated under dense stands of leafy spurge in October, 1979, at Missoula and Vaughn, Montana. An equal quantity of soil was collected from an uninfested area within 30 m of the infested soil at each location. Soil was sieved to remove debris and plant material and stored in plastic bags at -4°C to await greenhouse testing. Soil pH, organic matter, phosphorus, potassium, salt hazard and texture were determined (Table 12).

Seed of 12 grass species was obtained from the Bridger Plant Center, Bridger, Montana (Table 13).

Plant height comparisons. Soil from infested and uninfested sites in Missoula as well as greenhouse potting soil (peat:sand:Huffine silt loam, 1:1:3 v/v/v) was placed in 3.8 cm diameter by 21 cm long containers. Four seeds of *Agropyron spicatum*, *A. trachy-*

Table 12. Soil properties of greenhouse, Missoula infested and Missoula check soils.

Soil	pH	Organic matter %	P ppm	K ppm	Salt hazard	Soil texture
Greenhouse	7.6	5.6	392	724	1.0	loam
Missoula infested	7.1	5.8	95	785	0.4	loam
Missoula check	7.1	5.0	104	587	0.7	loam

Table 13. Twelve grass species grown in infested and uninfested soils from Missoula and Vaughn, Montana.

Genus and species	Common name
Native species	
<i>Agropyron smithii</i>	western wheatgrass
<i>A. trachycaulum</i>	slender wheatgrass
<i>A. spicatum</i>	bluebunch wheatgrass
<i>A. dasystachum</i>	thickspike wheatgrass
<i>Calamovilfa longifolia</i>	prairie sandreed
<i>Stipa viridula</i>	green needlegrass
<i>Elymus cinereus</i>	basin wildrye
Introduced species	
<i>Agropyron cristatum</i>	Fairway crested wheatgrass
<i>Elymus junceus</i>	Russian wildrye
<i>Elymus angustus</i>	'Altai' wildrye
<i>Alopecurus arundinaceus</i>	creeping foxtail
<i>Bromus inermis</i>	smooth brome

caulum, *A. smithii*, *Elymus junceus*, *E. angustus*, *E. cinereus*, *Alopecurus arundinaceus* or *Bromus inermis* were planted in each container. After planting the soil surface in each container was covered with 0.5 cm sand to reduce evaporation. There were three replications per treatment.

The containers were placed in a germination chamber set at an alternating 15-25°C temperature. After 10 days they were placed in a growth chamber set to operate at a constant 22°C with 12 hours of light (22 Klux) per 24 hour period. Each container received 10 ml water every other day. Plant height was measured every other day for one month.

Plant weight comparisons. Soil from infested and uninfested sites from Missoula and Vaughn was placed in 13.5 cm by 21.5 cm by 9.0 cm deep flats. Twenty seeds of a species were planted 0.7 cm deep in rows 13 cm long. There were 4 species planted in each flat. There were three replications per treatment. The flats were maintained in the greenhouse without supplemental light with a temperature range of 18 to 25°C. Flats were watered as needed.

The number of emerged seedlings was counted daily and the speed of emergence was calculated. One month after planting half of the plants in each flat were cut at the soil surface, oven dried for three days at 38°C and weighed. Two months after planting the remaining plants were cut, dried and weighed.

Results and Discussion

Plant height comparison. There were plant height differences for four plant species in two soils on one or more days. *Agropyron smithii* and *Elymus cinereus* produced more growth in greenhouse soil than in the check or infested soils from Missoula (Figures 5 and

6). The greenhouse soil was slightly different in some soil properties which may explain differences in plant growth. *Agropyron trachycaulum* showed differences in growth on three dates among the soils tested (Figure 7). *Elymus junceus* was taller when grown in infested soil on three days (Figure 8). There were no differences in the growth curves of the other species tested.¹

Two differences were noted in growth between soils using regression analysis (Table 14). Two species had significant differences between slopes of the regression lines. The regression line of *Agropyron spicatum* in the check soil had less of a slope than the infested or greenhouse soils (Figure 9). The regression line of *Elymus junceus* in greenhouse soil had a steeper slope than either of the other two soils (Figure 10). All other species showed similar regression lines for the three soils.²

Similar slopes of the regression lines indicate no differences in rate of growth among the three soils. Dry weight accumulation for each species was the same in all soils. This would imply that no growth inhibitors were present in the infested soil to slow the growth rate.

The mean plant height of *Elymus cinereus* and *Elymus angustus* was lower when grown in uninfested soil compared to the infested or greenhouse soils (Table 15).

Plant weight comparison. Speed of emergence was determined by the following equation: (Wiesner, 1981).

$$\frac{\text{no. of plants emerged}}{\text{day 1}} + \frac{\text{no. of plants emerged}}{\text{day 2}} + \dots + \frac{\text{no. of plants emerged}}{\text{day 5}} = \text{speed of emergence}$$

¹ Appendix C.

² Appendix D.

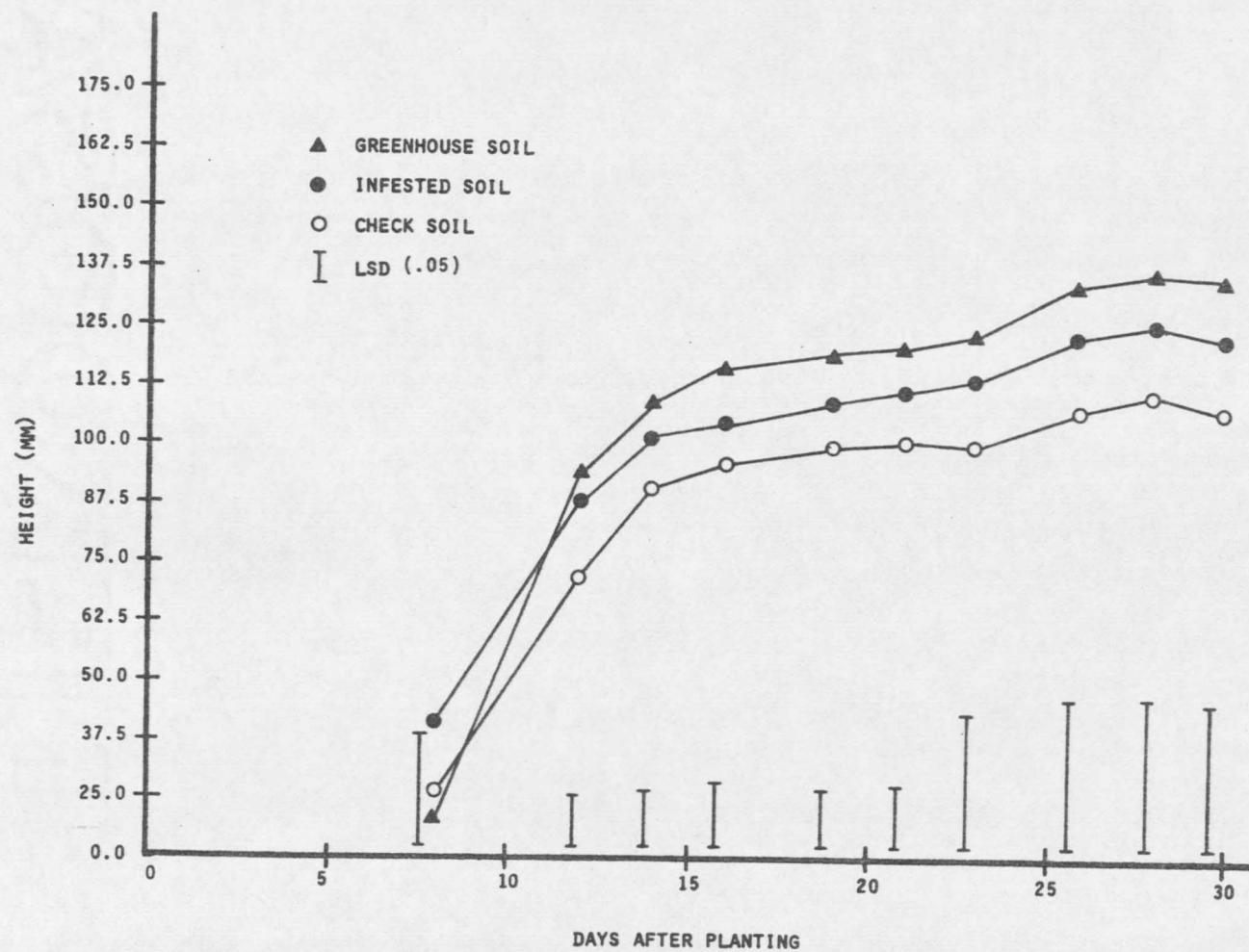


Figure 5. Growth curve of *Agropyron smithii* in three soils.

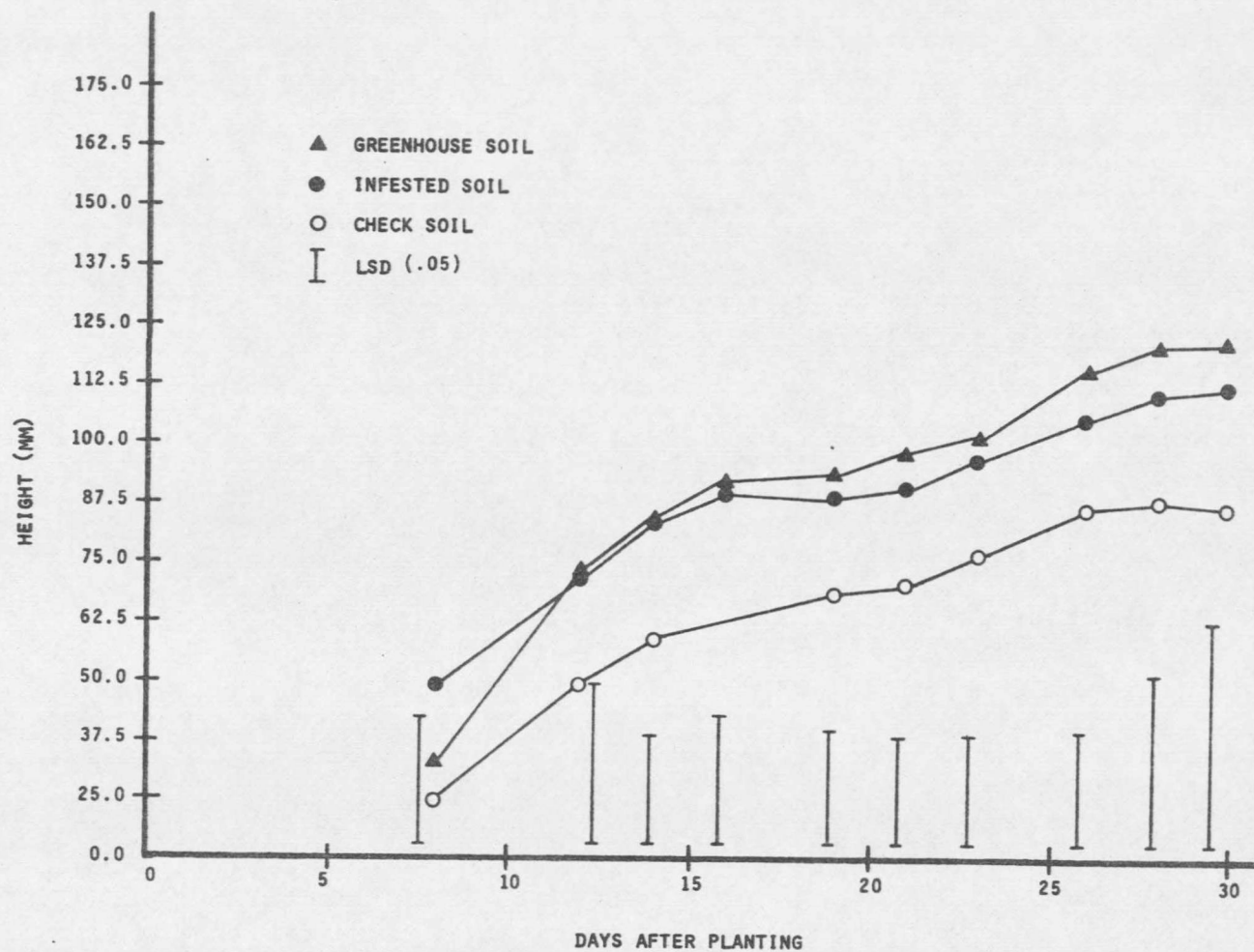


Figure 6. Growth curve of *Elymus cinereus* in three soils.

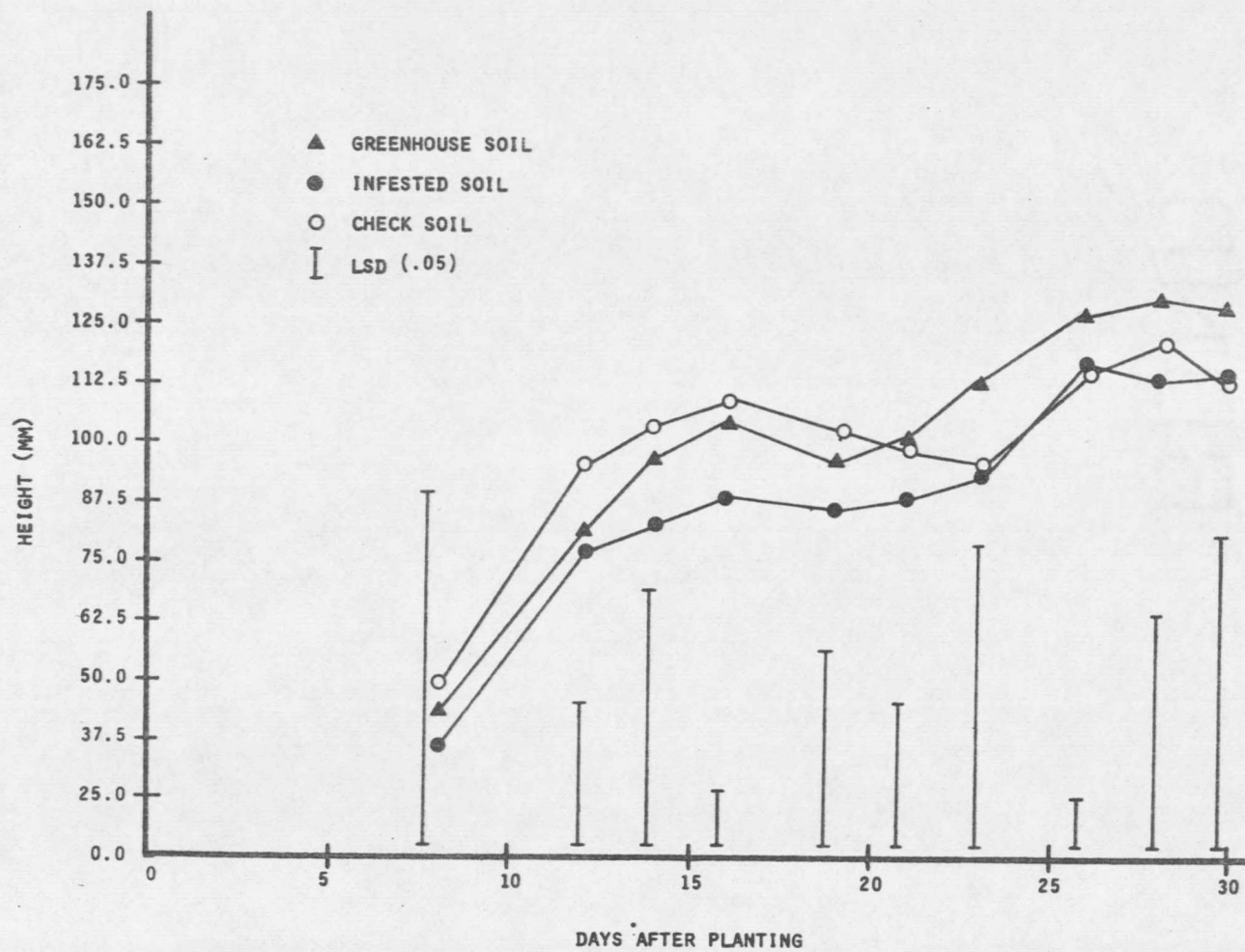


Figure 7. Growth curve of *Agropyron trachycaulum* in three soils.

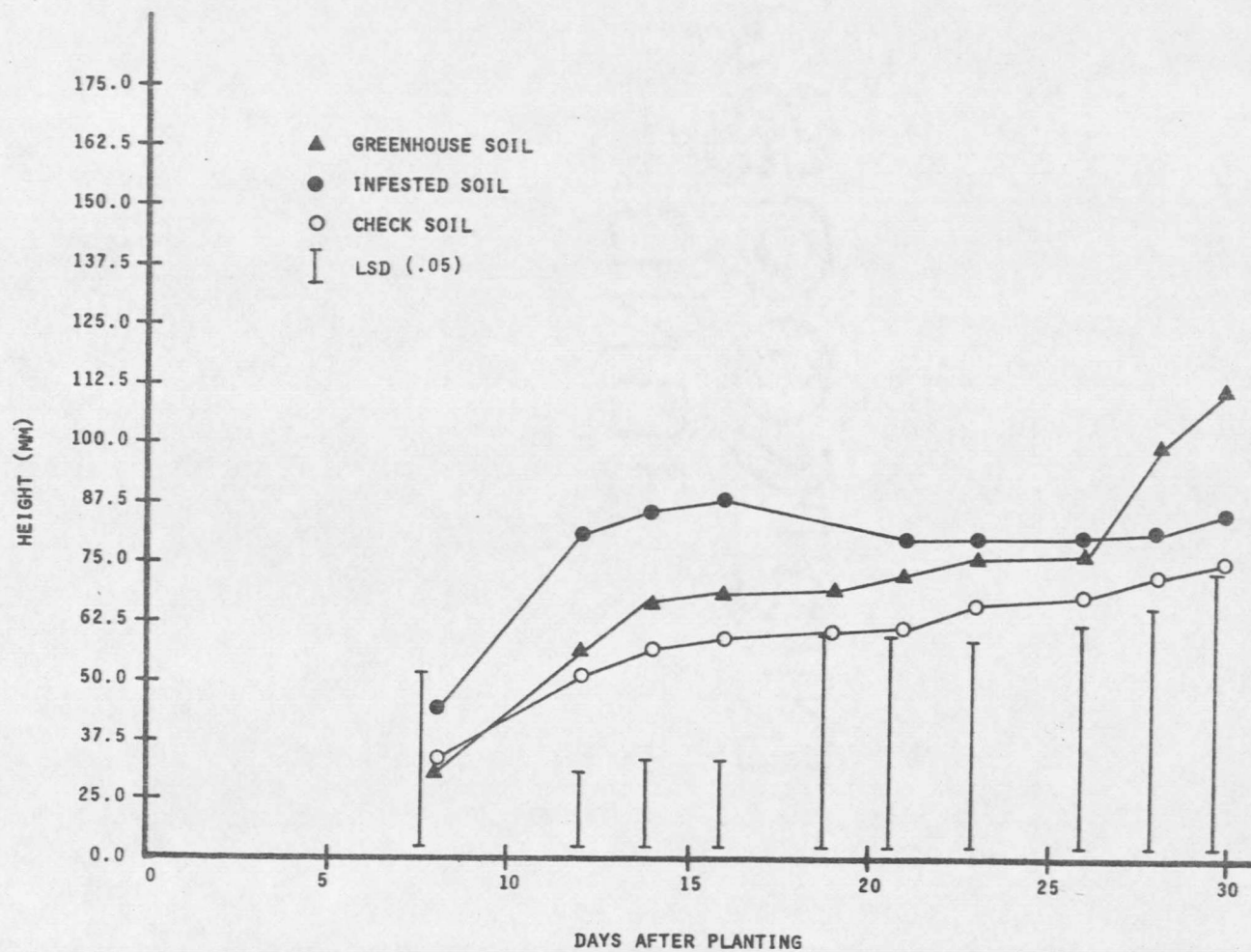


Figure 8. Growth curve of *Elymus junceus* in three soils.

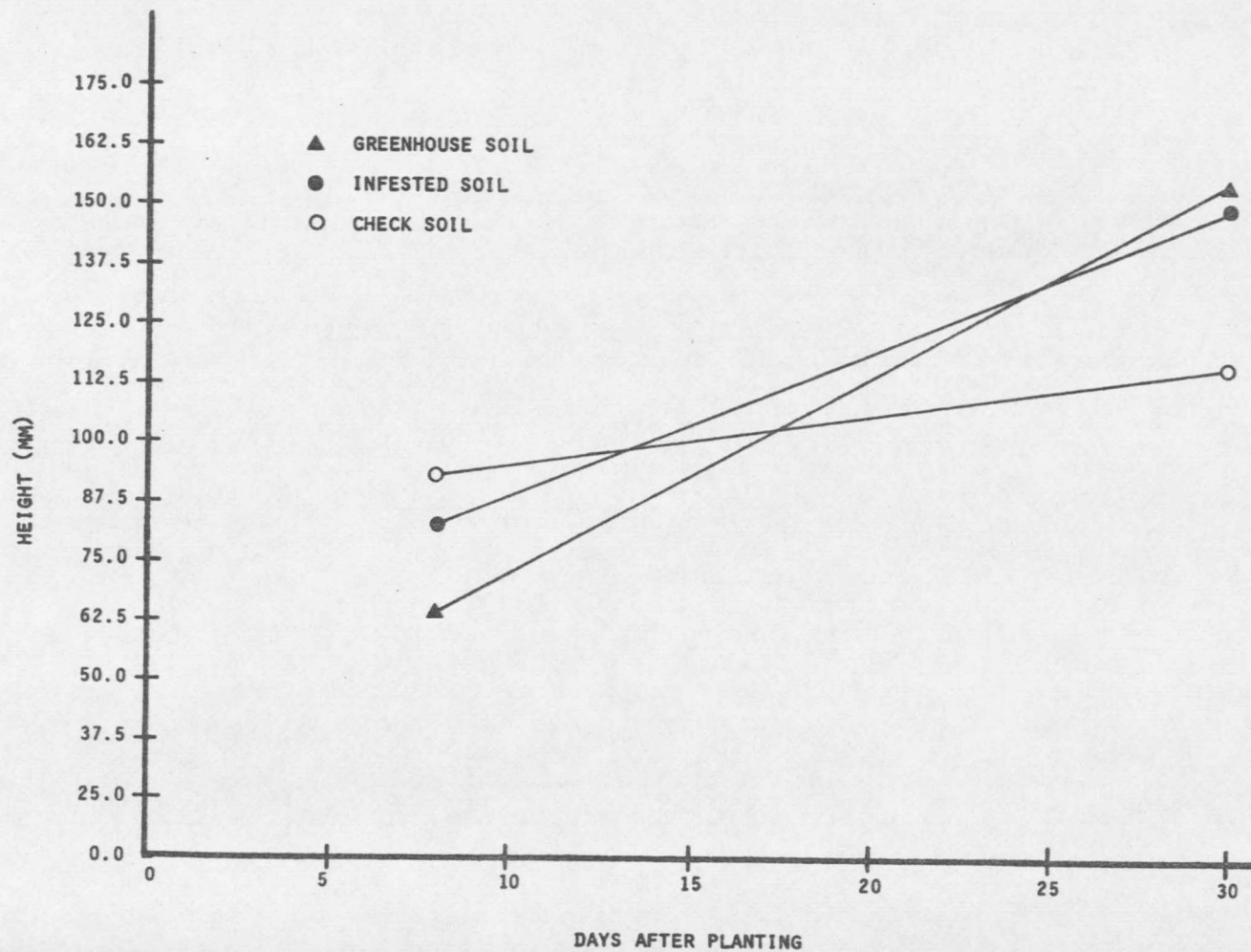


Figure 9. Regression lines for growth of *Agropyron spicatum* in three soils.

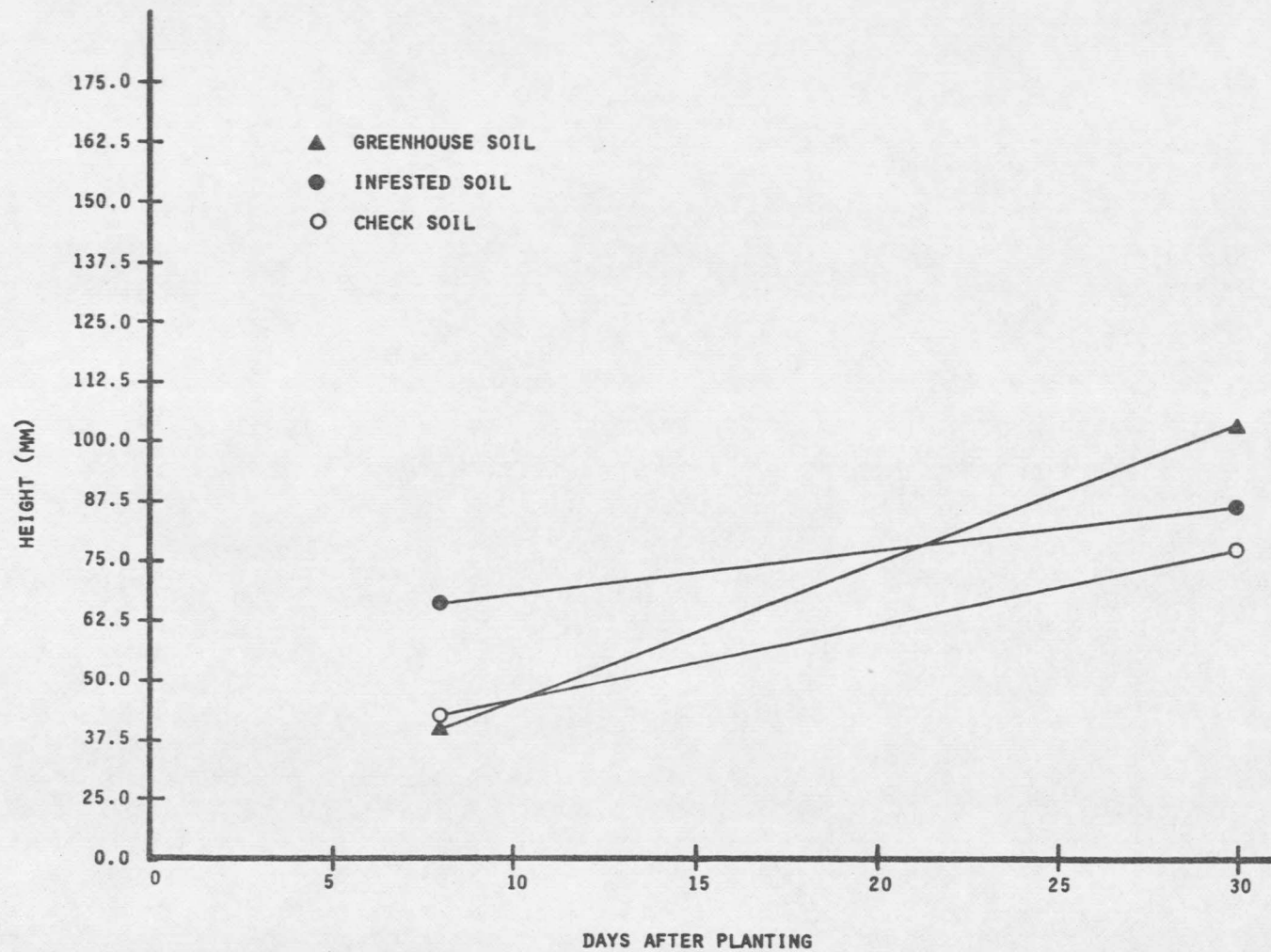


Figure 10. Regression lines for growth of *Elymus junceus* in three soils.

Table 14. Test for equality of slopes of three soil regression lines for each grass species.

Species	Test result p-value
<i>Agropyron spicatum</i>	.008 **
<i>A. trachycaulum</i>	.181 NS
<i>A. smithii</i>	.887 NS
<i>Elymus junceus</i>	.011 *
<i>E. cinereus</i>	.258 NS
<i>E. angustus</i>	.923 NS
<i>Bromus inermis</i>	.083 NS
<i>Alopecurus arundinaceus</i>	.096 NS

* = .05 significance

** = .01 significance

NS = not significant

Table 15. Mean height for each grass species after one month of growth in the Missoula check, Missoula infested and greenhouse soils.

Soil	Mean height (mm) ^a							
	Grass species ^b							
	Agsm	Alar	Agtr	Elju	Agsp	Brin	Elci	Elan
Greenhouse	92.7a	38.1a	89.8a	60.9a	98.9a	60.1a	82.3a	134.8a
Check	78.4a	29.3a	87.8a	48.3a	92.5a	80.8a	50.6b	78.7b
Infested	92.3a	32.3a	76.7a	64.5a	104.9a	66.2a	81.6a	92.9a,b

^a Means within each column followed by the same letter are not statistically different at the 5% level as determined by LSD test.^b Agsm = *Agropyron spicatum*Alar = *Alopecurus arundinaceus*Agtr = *Agropyron trachycaulum*Elju = *Elymus junceus*Agsp = *Agropyron spicatum*Brin = *Bromus inermis*Elci = *Elymus cinereus*Elan = *Elymus angustus*

No grass species showed differences in the speed of emergence between the Missoula check and infested soils (Table 16).

Table 16. Speed of emergence index number of twelve grass species grown in Missoula check and infested soils.

Soil	Grass species ^a											
	Calo	Agsm	Agcr	Stvi	Elci	Elan	Alar	Agda	Agsp	Brin	Elju	Agtr
Check	.91	5.35	4.88	1.79	4.75	7.69	7.57	8.92	8.94	10.30	4.57	7.52
Infested	2.37	5.84	2.20	1.82	6.61	5.83	6.30	8.62	8.01	9.69	5.57	6.99
LSD (.05)	1.77	3.00	3.12	1.16	4.27	4.81	3.36	4.39	1.81	2.31	8.62	5.15

^aCalo = *Calomovilfa longifolia*

Agsm = *Agropyron smithii*

Agcr = *Agropyron cristatum*

Stvi = *Stipa viridula*

Elci = *Elymus cinereus*

Elan = *Elymus angustus*

Alar = *Alopecurus arundinaceus*

Agda = *Agropyron dasystachum*

Agsp = *Agropyron spicatum*

Brin = *Bromus inermis*

Elju = *Elymus junceus*

Agtr = *Agropyron trachycaulum*

There were plant weight differences one month after planting for four species planted in soil from Missoula (Table 17). *Calomovilfa longifolia*, *Agropyron spicatum*, *Elymus junceus* and *A. trachycaulum* produced more plant tissue when grown in uninfested soils. Two months after planting there was no longer a weight difference among the four species in the two soils. *Alopecurus arundinaceus* had a lower plant weight in infested soil two months after planting.

Only *Bromus inermis* produced less growth in the infested soil from Vaughn one month after planting (Table 18). No significant differences in plant weight were detected at the time of the second cutting.

The plant weight of *Alopecurus arundinaceus* was three-fold higher two months after planting when grown in uninfested soil from Vaughn. Although not statistically dif-

Table 17. Weight of grass species grown in Missoula check and infested soil one and two months after planting.

Soil	Grass species ^a											
	Calo	Agsm	Agcr	Stvi	Elci	Elan	Alar	Agda	Agsp	Brin	Elju	Agtr
-----mg/plt-----												
One Month												
Check	18.0	31.3	39.3	12.0	22.7	31.7	6.0	28.0	28.7	26.7	16.0	44.0
Infested	5.7	21.7	27.7	7.3	16.0	26.7	3.3	24.0	23.0	18.7	11.7	18.0
LSD 5%	7.69	13.45	13.45	5.08	21.06	16.06	2.91	22.89	.73	9.99	1.92	15.46
Two Months												
Check	25.7	117.0	204.3	48.0	75.0	88.3	31.0	128.7	121.7	142.7	45.7	213.7
Infested	26.7	95.0	230.0	55.7	61.0	78.0	9.7	99.7	108.7	105.3	32.3	111.0
LSD 5%	89.26	50.73	164.69	50.69	124.81	81.35	18.97	223.59	99.65	186.60	16.54	114.23

^aCalo = *Calamovilfa longifolia*

Agsm = *Agropyron smithii*

Agcr = *Agropyron cristatum*

Stvi = *Stipa viridula*

Elci = *Elymus cinereus*

Elan = *Elymus angustus*

Alar = *Alopecurus arundinaceus*

Agda = *Agropyron dasystachum*

Agsp = *Agropyron spicatum*

Brin = *Bromus inermis*

Elju = *Elymus junceus*

Agtr = *Agropyron trachycaulum*

Table 18. Weight of grass species grown in Vaughn check and infested soil one and two months after planting.

Soil	Grass species ^a											
	Calo	Agsm	Agcr	Stvi	Elci	Elan	Alar	Agda	Agsp	Brin	Elju	Agtr
	-----mg/plt-----											
One Month												
Check	3.7	35.3	23.7	11.7	21.0	20.7	1.7	28.3	29.0	14.0	6.3	24.0
Infested	8.0	21.0	13.7	7.3	11.3	13.3	4.0	24.7	16.3	11.3	8.7	20.0
LSD 5%	11.20	61.68	30.22	13.68	22.27	25.38	3.79	13.68	13.68	1.43	5.17	9.94
Two Months												
Check	34.3	113.3	127.0	39.3	70.3	54.7	73.3	99.3	82.0	72.3	24.3	117.0
Infested	35.3	99.0	36.3	38.0	46.0	60.3	24.3	53.7	63.0	145.	18.7	104.0
LSD 5%	24.47	98.64	147.51	77.23	28.25	11.20	169.97	62.08	94.96	269.7	10.34	131.95

^a Calo = *Calamovilfa longifolia*

Agsm = *Agropyron smithii*

Agcr = *Agropyron cristatum*

Stvi = *Stipa viridula*

Elci = *Elymus cinereus*

Elan = *Elymus angustus*

Alar = *Alopecurus arundinaceus*

Agda = *Agropyron dasystachum*

Agsp = *Agropyron spicatum*

Brin = *Bromus inermis*

Elju = *Elymus junceus*

Agtr = *Agropyron trachycaulum*

ferent, this trend does correlate with the differences observed when the same plant was grown in soil from Missoula.

Confirmation trials were established with three of the four grasses which showed weight differences one month after planting when grown in soil from Missoula (Table 19). There were no differences in plant weights at either time of cutting in the confirmation trial.

Table 19. Weight of three grass species grown for a second time in Missoula soil one month and two months after planting.

Soil	Grass species ^a		
	Agsp	Agtr	Elju
	-----mg/plt-----		
One Month			
Check	35.0	38.0	13.0
Infested	30.0	34.0	13.5
LSD (.05)	162.2	101.7	57.2
Two Months			
Check	69.3	56.3	59.0
Infested	72.7	78.5	43.5
LSD (.05)	15.6	33.7	22.8

^a Agsp = *Agropyron spicatum*, Agtr = *Agropyron trachycaulum*, Elju = *Elymus junceus*.

The weight differences in *Alopecurus arundinaceus* between the infested and uninfested soils from Missoula were not evident until the time of the second cutting. If the observed differences were caused by an allelochemical in soil, the toxin must not be readily broken down after eight weeks in a greenhouse experiment. No other differences appeared among the other species two months after planting. It is unlikely that the observed difference in plant growth was caused by a toxin released by leafy spurge since the growth

of *Alopecurus arundinaceus* was not reduced when the plant was grown in soil from Vaughn. The growth reduction of this plant in infested soil from Missoula must have been a result of an unknown variable.

Selleck (1974) observed allelopathic responses from soil extracts by using soil directly associated with leafy spurge roots. The soil from Missoula and Vaughn was sieved to remove plant debris. Since growth of four species was reduced in infested soil at the first cutting, a toxin may have been present initially, but without continuous release from leafy spurge roots the allelopathic effects were not maintained. Under field conditions root and foliar debris would be present in soil or on the soil surface. Steenhagen and Zimdahl (1979) observed inhibition of tomato and *Digitaria sanguinalis* only when leafy spurge litter was incorporated in the soil.

The time of year of soil collection may have affected the results. If leafy spurge produces an allelopathic toxin it may not have been present in sufficient quantity in October to produce growth inhibition of the grass species tested.

CHAPTER ELEVEN

SUMMARY

Leafy spurge infests grazing land and will become the dominate vegetation over time. Several *Euphorbia* species exhibit allelopathic effects on plant species in old field succession. This study examined possible allelopathic soil residues from leafy spurge and their effect on grass species.

Soil was excavated from a dense stand of leafy spurge and from an uninfested area several meters away. Twelve grass species were grown in each soil. Plant height and dry matter accumulation were measured.

Several grass species showed decreased growth when grown in leafy spurge infested soil from one location. The effect on growth was not consistent between infested soils from two locations. Confirmation trials did not support the initial data. If leafy spurge produces allelopathic substances they do not remain in the soil at effective concentrations when plant debris is removed.

Results from this study indicate that soil from a dense stand of leafy spurge does not contain toxins in sufficient quantities to inhibit growth of native or introduced grass species when grown under greenhouse and growth chamber conditions.

Further studies in a controlled situation are needed. Native and introduced grass species should be observed when grown in association with intact leafy spurge roots. Growth of these species should also be monitored when natural litter is present. These studies may indicate which species would be useful in reseeding areas where leafy spurge is controlled.

SUMMARY

Leafy spurge is a serious weed problem in Montana, infesting over one half million acres. A three part program developed an education program on leafy spurge, analyzed the hydrocarbon of the weed and examined the allelopathic soil residues of leafy spurge.

The education program utilized newspaper articles, a leafy spurge newsletter, summer field tours and slide sets to increase awareness and knowledge of leafy spurge. The articles, summer tours and slide sets provided background information and the newsletters continue to update the information. Many people are still unaware of leafy spurge, the threat it presents and control methods. County agents and local weed personnel need to continue the program through utilization of the chemical control demonstration sites and incorporation of the educational materials into their existing programs.

Annual *Euphorbia* species have been examined as possible sources of hydrocarbons. In this study, 12 ecotypes of a perennial species, *Euphorbia esula*, were grown and harvested. Samples were harvested on three dates during the growing season and extracted for hydrocarbons. No ecotypes produced exceptionally high levels of hydrocarbons.

Leafy spurge regrowth was a problem. Extensive regrowth after cutting was expected but did not occur possibly due to restricted root growth. Low rates of fertilizer did not increase hydrocarbon content. Effects of heavier applications of fertilizer and irrigation on hydrocarbon content need to be researched. Additional research in plant breeding and soil fertility is needed to determine if leafy spurge has potential as a source of hydrocarbons.

Infestations of leafy spurge tend to dominate vegetation on grazing land. The effect of possible allelopathic soil residues from leafy spurge on grass species was studied.

Soil was excavated from a dense stand of leafy spurge and from an uninfested area several meters away. Native and introduced grass species were grown in the soils. Plant height and dry matter accumulation was measured.

Several grass species showed decreased plant dry matter when grown in infested soil. This effect was inconsistent between infested soils from two locations. The results from confirmation trials did not agree with results from the original experiment.

Results from this study indicate that soil from a dense stand of leafy spurge does not contain toxins in sufficient quantities to inhibit growth of certain grass species when grown under greenhouse or growth chamber conditions.

Leafy spurge research needs to be continued. Mechanisms of root bud activity need to be understood in order to control plant growth. Less expensive means of control must be found before leafy spurge acreage will decrease. Even though research has not developed a perfect control, an education program on leafy spurge should not be de-emphasized. People need to be aware of the weed, why it spreads, and controls presently available. While research is being continued, education of the public about leafy spurge is essential.

A wide array of personnel and media are available to disseminate information. Television, radio, slides, newspapers and special publications can be utilized by teachers, county agents, vocational agriculture instructors and weed district personnel to disperse information. Unless people are aware of leafy spurge, its problems and ongoing research, they will not initiate a control program.

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APPENDICES

APPENDIX A

LEAFY SPURGE ARTICLES

LEAFY SPURGE: WHEN DID IT ARRIVE AND WHERE IS IT NOW?

(This is the first of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a serious weed problem; presently ASCS estimates that 543,000 acres in Montana are infested with leafy spurge.)

Leafy spurge crept slowly west after being found in Massachusetts in 1827. For a while it was known in no other locations and when collected in New York in 1876 was noted as a rare plant. Five years later it was growing sporadically in Michigan and by 1913 it extended westward into Ontario, Canada. By 1921 leafy spurge had made such an impact by its weediness and the difficulty in controlling it that an editorial was written in the New York Herald. Leafy spurge was recognized in western Canada in the early 1900's.

The earliest date it was recognized in Montana appears to be in 1917 in a hayfield south of Lolo in Missoula County. Old-time farmers say this infestation and others were believed to have been brought in with hay or seed from North Dakota. Leafy spurge found in Judith Basin County supposedly was introduced with some alfalfa seed brought in from "somewhere in Asia."

Once an infestation had been established, waterways and machinery helped spread it from field to field and county to county. The first collected specimen of leafy spurge in the Montana State University Herbarium is dated 1924 and was collected from Paradise Valley in Park County.

// Leafy spurge is found worldwide with the exception of Australia. It is believed to have originated in Asia near Caucasus; presently in Europe it grows as far north as the Scandinavian countries and as far south as Italy and Spain. In Canada it is found in every province except Newfound-

land. United States infestations are found in all the northern states and extend as far south as Iowa.¹¹

// Leafy spurge is found statewide in Montana with the large majority of the acreage in non-cultivated land. According to ASCS figures over 543,000 acres are infested with leafy spurge in Montana. Counties of heavy infestations include Missoula, Fergus and Judith Basin.¹¹

LEAFY SPURGE: MORE SPURGE FROM SEED

(This is the second of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a serious weed problem.)

// Leafy spurge has several means of reproduction that enable it to invade new land, maintain its hold and spread to nearby areas. The two primary means are shoot buds on the roots that emerge after the parent plant has become established, and seeds that are in the soil and subject to germination. This article will describe seed germination and the next article will discuss leafy spurge roots and the growth of shoot buds.

The seeds are formed in a three-lobed capsule which explodes when dry, projecting the seeds as far away as 15 feet. Once out of the capsule, the seeds can be transported to other locations, remain dormant, or germinate the same season.

The most mature seeds are mottled brown in color. During the maturation process in the capsule the seeds change from yellow to brown to gray and finally mottled brown. Ripened seeds capable of germination include both gray and mottled seeds. The seed is approximately 2 millimeters long and oblong in shape.

Various factors influence leafy spurge germination, including age of seed, temperature and light. One-year-old seeds usually have a better germination rate than newly harvested or 2-year-old seed. Leafy spurge seeds will last longer under cool, dry conditions than under warm, moist conditions. Between the 2nd and 8th years after seed formation, germination rate can still be as high as 10 percent. After this length of time some seeds are still viable, although germination rate drops below 10 percent.

Germination does not occur at extremely high temperatures and is minimal at low temperatures. Spring temperatures often determine the exact time of seed germination and maximum germination occurs after several days of high temperatures. Leafy spurge germination is delayed during long, cool springs, but seeds will germinate throughout the growing season if moisture is sufficient. Seeds can also float and germinate in water.

// The number of leafy spurge seed present in the soil in an established patch varies between 3,500 and 11,000 seeds per square foot. // The loss of seed from the soil is only 13 percent per year. This leaves a large reserve of viable seed in the soil that can help reestablish a stand after the topgrowth is killed with herbicides.

Leafy spurge seed cannot be overlooked as a way the weed spreads. Dormancy allows the seeds to remain in the soil for an indefinite length of time. When controlling leafy spurge, both the seed being produced and the seed in the ground should be considered.

LEAFY SPURGE: ROOTS AND BUDS ARE THE ANSWER

(This is the third of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a troublesome weed problem.

The root system of leafy spurge is a network of roots that spreads throughout and beyond an infested area. The main roots produce vegetative buds which form shoots that reestablish an infestation in the spring and increase the lateral spread of the plant.

Young seedlings develop an extensive root system in a fairly short period of time. When free of competition these developing roots can penetrate a depth of over 3 feet in 4 months and attain a lateral spread of 40 inches in the same period. Competition will reduce the survival of the seedlings.

Leafy spurge plants coming from vegetative shoots appear earlier in the spring than do seedlings. The shoots develop from buds (formed the previous fall) on the crown just below the soil surface. The buds remain dormant through the winter and resume growth in the spring.

The persistence of leafy spurge is usually attributed to the characteristics of the root system. The older roots have a thick inner core and a corky bark to give strength and insulation. This enables the plant to maintain normal activities during times of water stress. The roots also store a large food reserve for use in regeneration and survival when environmental conditions are poor.

Leafy spurge roots can grow as deep as 15 feet. The large majority of the roots are found in the top 4 feet of soil and can weigh over 8,000 pounds per acre in a dense stand. The density of the roots is highest in the top 6 inches and decreases with depth.

Vegetative buds on leafy spurge roots are believed to be a major factor in the spread and persistence of the weed. These buds develop from vertical roots and produce shoots. The number of buds is associated with the weight of the roots with the greatest number of buds being near the soil surface and decreasing with increasing depth. Preformed buds have been found on roots down to depths of 9 and 10 feet.

Experiments done in Canada demonstrated the ability of the buds to produce shoots through 3 feet of soil. After regrowth from buds 1 and 2 feet deep, new crowns were formed below the soil surface. Regrowth the following season came from the crown.

The capacity of the roots to produce new shoots does not depend on preformed buds being present. Studies have shown that roots 10 feet deep have the same reproductive capacity as those near the surface and will produce shoots when brought within a few inches of the soil surface. Small root fragments can be planted and new shoots will be produced. This partially explains the failure of digging or tillage as methods of eradication.

The extensive root system of leafy spurge is well adapted to crowd out neighboring species and to store large amounts of food reserve. Vegetative buds on the roots enable the plant to regenerate new growth and spread. The answer to controlling leafy spurge is in controlling the root spread and destroying the vegetative buds.

LEAFY SPURGE: FLOWERS AND SEEDS

(This is the fourth of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a serious weed problem.)

Leafy spurge begins to flower in May when the shoots are between 4 and 6 weeks old and approximately 10 inches tall. Usually the farther north the patch is located the later in the spring flowering will occur.

Flowering is usually finished by the middle of July. Seed development continues for several more weeks and ripe seed is produced 20 to 30 days after the flower appears. Good weather conditions will allow flowering and seed formation to continue until the first freeze kills the umbel-shaped inflorescence.

Leafy spurge is usually cross-pollinated. The timing and development of the female and male flowers are structured to reduce self-pollination. This proves beneficial since greater production of seed is possible when the flowers are cross-pollinated.

Insects appear to be the primary means of pollination. Nectar is readily available at the time of pollination and insects have been observed feeding on the nectar. Studies have shown that, if spurge plants are isolated from insects, seeds fail to appear. Ants, bees, flies and mosquitoes are believed to aid in pollination.

According to one study, flowering stalks produce from 10 to 50 three-lobed capsules, with each capsule usually having three seeds. The number of seed per stem varies within a patch. As many as 400 seeds have been counted on one stalk. Canadian researchers in Saskatchewan calculated the yield of leafy spurge seed to vary from 24 to 3,400 pounds per acre.

Animals, birds and insects help to disperse leafy spurge seeds. Some patches appear to have originated near rodent diggings. The mourning dove has been suggested as a distributor of leafy spurge seed, since it feeds heavily on the seed. However, no viable seed were found in the digestive tracts examined. Some viable seed were found in the crop of the bird and these could possibly act as a means of distribution when regurgitation is used to feed the young and seeds drop to the ground. Moving water can also serve as means of transportation for the seed.

Flowering, pollination and seed production of leafy spurge each have their characteristics that help the plant be the spreading, persistent weed that it is. Eliminating seed production is a start in controlling the spread of leafy spurge.

LEAFY SPURGE: CHEMICAL CONTROL

(This is the fifth of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a serious weed problem.)

Leafy spurge is a tough weed to kill. But, control methods are available.

The method used may depend on the size and location of the infested area. Small infestations may be eradicated in a year or two, but larger areas may require repeated, persistent control measures.

Chemical and cultural measures are currently available for control of leafy spurge. A combination of these methods is sometimes the best approach.

Chemical recommendations for control of leafy spurge currently include Tordon, Banvel and 2,4-D. Each of these has slightly different characteristics.

Picloram (Tordon) is used on rangeland and non-cropland. It is absorbed by the foliage and roots of leafy spurge and translocated up and down in the plant.

Tordon has been shown to persist for several years in the soil. It has a restricted use label in some states. Application can be any time during the growing season, with two pounds per acre the recommended rate for controlling leafy spurge. Precautions need to be taken when using Tordon around trees. The label should be checked for all limitations.

Dicamba (Banvel) is absorbed by the roots and foliage of leafy spurge. Applied at the rate of 6-8 pounds per acre, dicamba will control top growth and reduce growth the following year. The residual life of dicamba is shorter than Tordon, but it is not as effective as Tordon.

The herbicide 2,4-D is applied to growing leafy spurge. Two treatments a year, in the spring and fall, are needed to control leafy spurge with 2,4-D. Many years of spring and fall treatments are required to use up stored root reserves and to kill emerging seedlings. The recommended rate for each treatment is two pounds per acre.

Of the chemical controls available, Tordon is the most expensive but also the most effective. Two, four-D is used for top growth control and as a follow-up treatment. Early treatment of new infestations and persistence in treating older stands are necessary for control of leafy spurge.

LEAFY SPURGE: CULTURAL CONTROL

(This is the sixth of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a serious weed problem.)

Leafy spurge is difficult to control. Often a combination of treatments has to be applied to leafy spurge before the spread can be checked. The previous article dealt with chemical control. This article describes cultural control and the next one will discuss biological control.

Included under cultural control are cultivation, cropping and grazing. For some infested areas it may be possible to use several of these methods. For other areas, chemicals may be the only feasible answer.

Cultivation must be intensive to control leafy spurge. A duckfoot cultivator tilling to a depth of 4 inches is usually recommended. Treatments must begin early in the spring, 2 to 4 weeks after the weeds emerge. Cultivation should continue every 3 weeks until fall freeze-up. The cultivation schedule should not be interrupted since leafy spurge can rapidly recover from the effects of cultivation.

Perennial sod-forming grasses and winter wheat are fairly competitive against leafy spurge, but must be managed properly to maintain vigorous growth. Alternate years of intensive cultivation and small grains sprayed with 2,4-D have proved effective.

In areas not suitable to cultivation or crops, sheep can be grazed on the leafy spurge to prevent seed set and reduce lateral spread of the plant. Several Montana ranchers are currently using sheep as an effective means of controlling leafy spurge. When using sheep to control spurge,

grazing should be started early in the spring before there is much growth. Sheep appear to prefer the younger plants and often refuse to eat the older plants. The sheep should be in sufficient numbers to keep the spurge closely cropped since control of the spurge is attained through depleting the carbohydrate reserves in the roots by forcing the plant to constantly put out new shoots. If too much foliage is allowed to grow, the root reserves can be replenished. If rotation grazing is used, it may be necessary to treat with 2,4-D to keep the top growth controlled.

Crested wheatgrass appears to be a beneficial grass in combination with leafy spurge and sheep grazing. In one study, crested wheatgrass was seeded into an area infested with leafy spurge. Twelve years later the stand was in good condition but it did not control the leafy spurge. After 5 years of grazing by sheep, the crested wheatgrass stand was much improved and leafy spurge was present in only small amounts.

// If a grazing program or some type of management is not maintained after control is achieved, the leafy spurge can return to the original level of infestation. //

Because of the high cost of fuel and the possibility of wind erosion when using cultivation, other means of control may be more desirable. In areas where it is feasible, sheep may be the best answer for now to the spurge problem.

LEAFY SPURGE: BIOLOGICAL CONTROL

(This is the seventh of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a serious weed problem.)

A large number of insects in Europe feed on leafy spurge. Several of these show some potential as biological control agents. Also, these insects are from an area of Europe with a climate similar to northern United States and many of these insects feed only on leafy spurge. For these reasons leafy spurge is a promising candidate for biological control.

The fact that an insect attacks a weed does not necessarily mean the weed will be controlled or eradicated. The insect-plant relationship has a balance and the level of weed control obtained once the insects have been established may not offer the level of control needed. Several species of insects may need to be released to attack the weed, or competitive grasses could be used to supplement the biological control to achieve the desired control of the weed.

Currently, about 25 insects may have the potential of attacking leafy spurge. Years of work lie ahead in order to screen and test these insects.

So far, three insects have been released on leafy surge. The spurge hawkmoth was released in 1965 in Canada and the United States. Most of the larvae released disappeared rapidly partly because of predation by ants and beetles.

The second insect released was also a moth, known by its scientific name of Chamaesphecia tenthredin-informis. Eggs and larvae were transferred to the field along with some adult moths. Most of the larvae died without feeding on the spurge.

One of the most hopeful insects is a root boring beetle that has been approved for release in Canada and the U.S. Initial releases of the beetle were made in 1979 in Saskatchewan and in 1980 in Canada, Wyoming and Oregon. This beetle does attack the leafy spurge in North America but it will be some time before its level of success can be determined.

Biological control is not an instant cure for leafy spurge. It takes many years to screen and isolate the insects and many more for the successful insects to begin to control the weed. Biological control is best viewed as a control method to be used in conjunction with other means of weed control.

LEAFY SPURGE: ECONOMIC IMPACT

(This is the eighth of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a serious weed problem.)

// Leafy spurge is stealing money from your pocket and grass from your cattle. //

// Weed district supervisors estimated that private landowners in Montana are spending more than \$2½ million each year in an attempt to control leafy spurge. They also report that weed control expenses for a number of ranchers in Montana counties exceed their annual land payments. Ranchers often have to spend \$75 to \$100 an acre to control spurge on land that is worth only \$200 to \$300 an acre. //

Nationwide the economic impact of leafy spurge was estimated at \$10.5 million in 1978.

// Leafy spurge causes significant production losses on Montana rangeland. Larry Baker, assistant professor of agronomy at Montana State University, reports his study in the Gallatin Valley showed leafy spurge infestations caused rangeland carrying capacity losses of up to 75 percent. Approximately 50 percent is from yield reduction in rangeland production. The remaining 25 percent is a loss in utilization of existing grasses from intermixing with leafy spurge which is not palatable to cattle. //

// A 1979 Montana weed survey conducted by Peter Fay, assistant professor of agronomy at Montana State University, indicated leafy spurge is the second worst weed in dryland pasture and on rangeland. //

" Leafy spurge continues to spread, resulting in more dollars being spent to control it while increasing the dollars lost by the reduction in grazing land.ⁿ Controlling the spread of leafy spurge should help control the loss of dollars.

LEAFY SPURGE: WHAT'S IN A NAME?

(This is the ninth of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a serious weed problem.)

To the farmer or rancher with a leafy spurge infestation, leafy spurge is leafy spurge. But, since the early 1930s, taxonomists have disagreed on the classification of leafy spurge. Several species are very similar. Over the years, the same leafy spurge plant has been classified as several different species by different taxonomists.

To add to the confusion of the leafy spurge identity problem, characteristics of the same species can vary depending on environmental factors. In a study at Montana State University leafy spurge was collected from 12 different locations in 6 states and 2 Canadian provinces. These 12 different plants showed variation in leaf shapes and plant height when grown under the same conditions in Bozeman, Montana. Differences were also observed in the distance of lateral root spread, flower structures and tolerance to herbicides. In this same study the plants from different locations showed varying tolerances to Tordon and 2,4-D.

The lack of agreement on the identity of leafy spurge and the knowledge that ecotypes exist hinders various phases of research. Researchers need to know if results from one location are applicable to another. The uncertainty in leafy spurge classification is causing some problems with biological control. Insects effective on one plant in Europe are not surviving on what appears to be the same plant in the United States. This suggests the plants are not the same species.

The proper identity of leafy spurge is necessary for future work with biological control and in other areas of research. The correct classification is also important in exchange of information and developing consistent methods of control.

LEAFY SPURGE: WHAT'S IN THE FUTURE?

(This is the last of a 10-part series on leafy spurge. Leafy spurge is a perennial noxious weed found in the northern United States and southern Canada. An extensive root system and a very efficient means of vegetative reproduction make this plant difficult to eradicate. It spreads readily and has become a serious weed problem.)

Researchers are working on new and diverse tactics in the leafy spurge battle.

A graduate student at Montana State University is working on a study on preferential grazing of leafy spurge by sheep.

Researchers in Nebraska have gathered leafy spurge plants from over 40 locations in the United States and Canada. The collection is complete and taxonomists are examining the plants to identify which spurge is present in the United States and note distinctions between the species.

North Dakota is researching the use of wick and roller applicators for control of leafy spurge. Both of these applicators use only 10-20 percent of the herbicide used in a broadcast application and yet will obtain similar control of leafy spurge. Research is continuing to determine the best rates of various herbicides for these applicators.

Wyoming is also continuing herbicide research for leafy spurge control.

A regional committee to work on leafy spurge has been formed. Goals of the committee include promoting Extension and education efforts, increasing research on leafy spurge, and improving coordination among states and agencies.

If you would like to be placed on the Leafy Spurge Newsletter mailing list and receive quarterly updates on leafy spurge research, contact Claire Barreto at the Plant and Soil Science Department, Montana State University, Bozeman, MT, 59717.

APPENDIX B

LEAFY SPURGE NEWSLETTERS



Leafy Spurge News

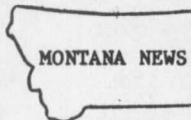
PLANT & SOIL SCIENCE DEPARTMENT
MONTANA STATE UNIVERSITY
BOZEMAN, MONTANA 59717

VOLUME I

April 1980

Issue 1

Hi! This is the first of the quarterly leafy spurge newsletters to be put out by the Plant and Soil Science Department at Montana State University. If you have any suggestions or contributions, please let me know.



Spring Work Has Started!

A new Dupont chemical is being tested by researchers at Montana State University for control of leafy spurge. A timing study is being conducted to test which stage of growth of leafy spurge is most susceptible to the chemical. An early spring treatment has been applied in Bozeman with three more treatments to be applied during the summer and fall.

More Help in the Battle

A new graduate student in Range Science at Montana State University, Barb Landgraf, is beginning her work on leafy spurge. Barb will be working on preferential grazing of leafy spurge by sheep.

Weed Maps

In a project initiated by Bill Reilly, Judith Basin Weed District Supervisor, and Howard Lyman, a rancher from Great Falls, each Montana county has compiled a map indicating acreages and locations of infestations for eight weeds including leafy spurge, wild oats, Canada thistle and five others. The county maps are being transferred to a large state map by Phil Smith of MSU. With the use of computer data on soil types and crop areas, the next probable areas of infestation can be approximated. This should aid in preventative control measures of leafy spurge and other weeds.

Spurge Blossom Specials

To start off the summer, leafy spurge tours will be held around the state the first few weeks of June. Most of the tours will be conducted at demonstration plots showing various levels of control obtained with different chemical treatments. Refreshments will be provided along with displays and discussions on the biology of the plant, dollar losses due to leafy spurge and the rope and wick applicators. The tours should be informative, fun and offer a break from summer work. A tentative schedule has been set up as follows:

June 3 Fallon County (Baker)
 June 4 Yellowstone County
 (Billings)
 June 9 Blaine County
 June 10 Hill County (Havre)
 June 11 Cascade Co. (Vaughn)
 June 12 Judith Basin Co. (Geyser)
 June ? Missoula Co. (Missoula)

Local papers and radio stations will have details regarding locations and times in late May.

NEBRASKA NEWSLeafy Spurge or ?

Much confusion exists about the true identity of leafy spurge species found in the United States. Several species are present in Europe and researchers disagree on the American species. To help solve the confusion, the University of Nebraska has started a collection of leafy spurge plants from the U.S., Canada, and Europe. When complete, the collection will have specimens from 40 locations. Detailed taxonomic studies will be conducted to establish distinctions between species.

NORTH DAKOTANew Application Method

Rod Lym and Calvin Messersmith at NDSU-Fargo are studying alternative herbicide application techniques. The roller applicator is a rotating metal cylinder covered with a carpet-like material that wipes the herbicide on the plant as it is pulled forward. Another applicator being experimented with is the wick. It is comparable to the rope-wick applicator, but in place of a rope a fabric is used. Both of these techniques use only 10-20% of the herbicide used in a broadcast application and yet obtain similar control of the leafy spurge. Research will continue to determine the best rates of various herbicides for the roller and wick, to determine exactly how much herbicide is applied with these techniques and whether or not surfactants increase control.

SOUTH DAKOTAGetting the Information Out

Drs. Bjugstad and Nobel reported developments of a research and management program for leafy spurge to the Pennington (South Dakota) County Weed Board. The researchers also presented an illustrated talk on leafy spurge to the Black Hills Resource Conservation and Development Area Council.

WYOMING NEWS

 WYOMING NEWS
Making Progress

Since 1978, over 18,000 acres of leafy spurge have been treated in Wyoming using monies provided by the State of Wyoming in addition to landowner and county funds. Ron Vore and Harold Alley at the University of Wyoming are developing a comprehensive chemical control research program to understand the plant's initial response to herbicide treatments and the need for retreatment to contain and/or eliminate leafy spurge infestations.

MEETINGS

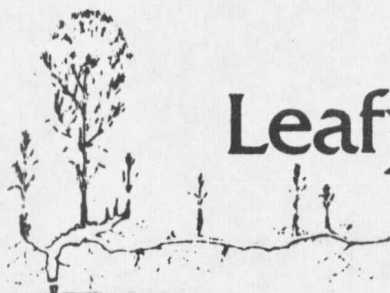
A leafy spurge symposium was held in Billings, MT in December, 1979. As a result of the symposium, it was determined that we need better education and extension of available information, better coordination of efforts between agencies and accelerated research.

A Pro Tem Steering Committee, set up at the Billings symposium, met in March in Billings. A Blueprint Committee (Regional Leafy Spurge Working Committee) was set up at this meeting with two purposes. The first goal is to develop a program package for an accelerated attack on leafy spurge. The package will consist of 1) extension and education efforts, 2) research and 3) improved coordination among states and across agencies. The second goal is to recommend the structure and functions of the Steering Committee (Standing Regional Leafy Spurge Steering Committee).

The Pro Tem Committee will continue to operate until the Steering Committee has been established.

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

Claire Barreto
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Leafy Spurge News

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

VOLUME I

July 1980

Issue 2

MONTANA NEWS

Tour Results

Approximately 250 people attended the eight leafy spurge tours that were held across the state from Ekalaka to Havre to Missoula. The turnout was excellent and it was encouraging to see so much interest in and concern about leafy spurge. A big "thank you" goes to all the county agents and weed district supervisors who helped put on the tours and also thanks to all the people who braved the mosquitoes, rain and thunderstorms to come to the tours. Dow Chemical Company funded the tours and we appreciated their support.

A New Source of Fuel?

The latex in leafy spurge may be a source of a petroleum fuel substitute. Leafy spurge is related to the rubber tree, but due to plant differences the latex in other Euphorbias tested remains a liquid after processing. Depending on the species, latex-bearing Euphorbia may be able to produce from 50 to 20 barrels of oil per

acre per year. Research at Montana State University is currently studying the latex content of leafy spurge.

In the News

Paul Kessler, a writer for the John Deere Furrow magazine, was in Montana in early June gathering information for a possible future article on leafy spurge.

Wick Applicator Contest

The Montana Agricultural Experiment Station is sponsoring a wick-applicator contest, with a \$500 prize donated by a chemical company, going to the best designed applicator for Montana uses. Farmers and ranchers are encouraged to design applicators suitable for use in Montana, especially range and pasture. Further details and applications are available from your county agent.

 NEBRASKA NEWS
Another Spurge

Dr. McCarty of the University of Nebraska says that the presence of an additional species of Euphorbia not previously reported in Nebraska has been found. The plant, Euphorbia agraria, is not found elsewhere in North America and has infested several acres in Nebraska. It is very similar to leafy spurge, Euphorbia esula and is often referred as such.

 NORTH DAKOTA NEWS
More Wick Work

Calvin Messersmith and other weed researchers at NDSU-Fargo are continuing their work on the wick and roller applicators. In a dense stand (75% to 199% spurge) the wick used approximately one-fourth the amount of herbicide used in a broadcast application. Areas treated with the roller used 30% to 50% of that used in a broadcast application. The treatments applied last year with the wick applicator look good and will be re-evaluated next year.

 SOUTH DAKOTA NEWS
Aerial Views

The Rocky Mountain Experiment Station in Rapid City has completed the first half of the field sampling on their feasibility study using remote sensing to detect leafy

spurge. They are looking to improve present techniques and offer a choice to the producer on the type of sensing device used. The study is expected to wind up this year.

 WYOMING NEWS
The Problem Goes Deep

Research in Wyoming is examining the effect of the original treatment and retreatment on the roots of leafy spurge. Harold Alley reports that although the control ranged from 98% to 100% on all but one treatment area, the maximum depth of root kill was only 16 inches. Below this depth new shoot growth originated from live roots. Their observations show that young shoots may be coming from roots killed to a depth of only two to four inches. Dr. Alley encourages an evaluation of depth of root kill on leafy spurge.

Studies similar to the ones described above, established in Crook County are planned for Fremont, Sheridan and Johnson counties this summer, with greater emphasis and study of the root system.

MEETINGS

The Regional Leafy Spurge Working Committee was set up with Russ Lorenz, SEA-AR, Mandan, North Dakota as the general chairman. Peter Fay from Montana State University is in charge of research. George Hittle, Wyoming, was selected chairman of Coordination and Larry Mitich, NDSU is chairman of Extension and Education. Each of the chairmen will be supported by four to five committee members from various states and agencies.

A meeting of the chairmen in Bismarck in June was videotaped and aired several times on TV and radio. Much interest has been demonstrated since the broadcasts and Dr. Lorenz has received many comments and questions.

If you have any suggestions, contributions or would like 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 I

October 1980

Issue 3

The mailing list for the Leafy Spurge News continues to grow. We are pleased to see this; it means more people are aware of what is going on in the world of leafy spurge research and extension activities. Although the newsletter comes from Montana State University, it is a regional newsletter for the north central states. A few copies are sent to other parts of the country and Europe to people involved with leafy spurge work.



MONTANA NEWS

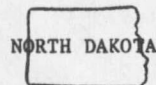
Tours of '81

The 1980 tours were a success and 7 more are being planned for June, 1981. Plots have been put out in Livingston, Broadus, Lewistown, Malta and Galen. Tours will also be held in Columbus and Culbertson. Reports have been received of farmers finding leafy spurge on their farm after attending this year's tours. This demonstrates the increasing awareness of the leafy spurge problem, and as a result, more efforts are being taken to control the weed. We hope the tours will continue to increase the concern about leafy spurge.

Weeds Go to the Legislature

Farmers and ranchers in Montana rate weeds as their number one problem. Because weeds are such a problem, a weed bill is to be introduced to the legislature this year in an effort to obtain funding for weed research and education. This bill, if passed, will

"establish a weed research and education commission, administratively assigned to the Department of Agriculture, to provide for a levy of \$.01/A on lands owned by any person for the purpose of funding research and education to improve weed control and management in Montana".



NORTH DAKOTA

Spurge in Shelter Belts

The controlled droplet applicator may be the answer for leafy spurge in shelter belts. Standard chemical treatments for spurge may be damaging to the trees. Since picloram (Tordon) is not harmful to grass at rates up to 2 lb/A, a controlled droplet applicator has been used to apply picloram at low rates. Herbicide: water volume ratios of 1:1 to 1:15 give an actual rate of picloram applied of 0.12 to 0.96 lb/A when walking at a normal pace. The unit is compact, light in

weight and easy to handle. Preliminary results show excellent topgrowth control the first year. Since low rates of picloram are being used, it is hoped the leafy spurge will be controlled without harming the trees.

SOUTH DAKOTA

Regional Directory

A regional leafy spurge directory has been compiled by personnel of the Rocky Mountain Forest and Range Experiment Station at Rapid City. The directory has over 750 listings of names, addresses and phone numbers of people involved with leafy spurge through research, extension, farming, ranching or administrative activities. This publication should prove to be a valuable tool for those involved with leafy spurge control.

WYOMING

Forage Increases

Wyoming researchers report that leafy spurge infestations treated in May 1978 supported an increase in forage production compared to the untreated check. Increases ranged from 218 to 724 lb/A. Utilization is expected to be nearly complete in areas where leafy spurge has been controlled. Forage production measurements will be continued.

Original and Retreatments

Leafy spurge test plots treated with Tordon 22K and Tordon 2K at 2.0 lb/A are maintaining 96 and 95% topgrowth control 24 months after treatment. Retreatments of Tordon 22K at .5 and 1.0 lb/A demonstrate the ability to either maintain control or

improve the control of original treatments. In looking at original/retreatment combination, percent topgrowth control is dependent on that combination's ability to suppress leafy spurge. Combinations which include highly effective original treatments and/or retreatments maintain a higher percent control than combinations which include less effective original treatments and/or retreatments.

Root Reduction Important

Root excavation data of treated and untreated areas showed all original/retreatment combinations reduced the root numbers and weight as compared to the untreated area. Evaluation of perennial weed control through root reduction is important. Several noted weed scientists feel that evaluating only topgrowth control does not give the true picture of control obtained. Work is currently being done to establish correct sampling procedures to determine root reduction.

CANADA

Insects

Canadian researchers released a root boring beetle, *Oberea erythrocephala*, on leafy spurge in Saskatchewan in October 1979. The insects, released by transplanting infested plants, survived the winter and have produced offspring.

A large number of adult beetles were released in July at 3 sites. Good oviposition (laying of eggs) was observed at all sites, but the success of the larvae to bore to the roots differed between locations. At one site, a large percentage of stems tested contained larvae while at another site no larvae were found in the roots.

More Insects

Two additional insects are being screened for possible use on leafy spurge. The Canadian government is funding the Commonwealth Institute of Biological Control to examine a defoliating moth and a bud gall midge. Canadian researchers are currently establishing colonies of these insects in quarantine for specificity tests.

Soil Made the Difference?

Dr. Peter Harris from the Agricultural Research Station in Canada reports that in comparing spurge infested acres in 1960 with today's acreages, some eradication of the weed has been obtained. Preliminary observations show that eradication was obtained in areas having heavier clay soils. The chemicals did not eradicate spurge on the sandy soils. Early indications may be that biological control should be directed to areas where chemicals do not work very well.

BIOLOGICAL CONTROL - U.S.

Wyoming

The root boring beetle, Oberea erythrocephala, was released in Wyoming by the USDA, Biological Control of Weeds Laboratory in Albany, CA in cooperation with Dr. Robert Lavigne, Dept. of Entomology, University of Wyoming, Laramie. Two releases were made, one at Sundance near the Devils Tower National Monument, and the second release at Lander. These insects must now survive the Wyoming winter.

Oregon

In August release of Oberea was made in Klamath County, Oregon near Bonanza. This was a cooperative release with Klamath County Weed and

Pest District, Oregon Dept. of Agriculture and the USDA all participating.

MEETINGS

Spurge Symposium

A leafy spurge symposium is being planned for June 29 and 30, 1981 in Fargo, ND. The agenda will include progress reports on leafy spurge research and extension education programs. A tour of several research sites will be conducted to view demonstration plots of leafy spurge treated with picloram using the roller, wick and controlled droplet applicator.

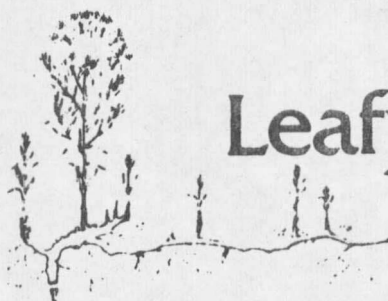
Spurge Proposal

The Extension and Education Subcommittee met in Rapid City, South Dakota in early August to put together a proposal on the extension and education needs regarding leafy spurge. The use of films, tapes, circulars, resource materials and newsletters were discussed. Subcommittee Chairman Rod Lym drafted the proposal and it was submitted to Dr. Russell Lorenz, chairman of the Leafy Spurge Pro Tem Steering Committee.

Dr. Lorenz reports he has received all 3 proposals from the chairmen of the Extension and Education Research and Coordination Committees. Dr. Lorenz will compile the three proposals into the final document to be submitted for funding.

If anyone would like extra copies of the 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

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NEBRASKA

Problems in Identity

The identity of leafy spurge, Euphorbia esula L. has been disputed since its discovery in the United States. A nursery has been set up in Lincoln, Nebraska containing leafy spurge plants from 36 locations across the northern United States and Canada and two from Austria. D.H. Ebke and Dr. M.K. McCarty of the University of Nebraska examined these plants for 28 morphological characteristics. Although many of the characteristics studied show some variability, a recent key developed by A. Radcliffe-Smith separates most of the nursery material except the Austrian plants into E. x pseudovirgata, a hybrid of E. esula and E. virgata. The Austrian material keys to E. esula.

NORTH DAKOTA

Weed Bill

The Legislative Council is introducing a bill for an act relating to, among other things, establishment and funding of a leafy spurge control program and a mill levy assessment for a leafy spurge control program.

The bill states that the control program would be funded by the landowner, county weed board and the state. The board of county commissioners in each county would be able to levy a tax, not to exceed one mill on the net assessed valuation of all taxable property within the county.

WYOMING

Residue Study

Ron Vore, University of Wyoming, is studying herbicide residues in the soil after treatment of leafy spurge with picloram and dicamba. Literature reviews show that picloram residue is highest in soils high in organic matter and it leaches more in sandy soils than clay soils. Dicamba residues tend to reduce 1 to 2 months after application while picloram persists from 3 to 15 months.

The Wyoming experiment took samples from three depths down to 24 inches over a 16 week period at four locations. Their results showed that the concentration of picloram and dicamba decreased with depth. Over the 16 week period the concentration of picloram changed little but in areas that received over 1" of precipitation the dicamba concentrations decreased between 4 and 16 weeks after treatment.

Data will also be collected 1 year after treatment to determine residues at the four locations. Hopefully this will aid in answering questions dealing with herbicide persistence and timing of retreatments.



Bill Passes Step 1

The weed bill to establish a weed research and education program within the Agricultural Experiment Station and the Cooperative Extension Service of Montana State University passed the Senate Agriculture Committee with three amendments being added to it. The bill will now go to the Senate floor and if approved there, will go to the House Agriculture Committee for consideration.

BIOLOGICAL CONTROL

A New Insect for Spurge

Permission was given by APHIS to bring a lacebug Oncochila simplex into quarantine at Albany, California for final testing. This insect is found on both leafy and cypress spurge in Europe. The first insects will come from the colony maintained at the USDA Rome Laboratory in February 1981 and in April additional field-collected insects will be sent. If the final testing goes well, the insects could possibly be released in 1982.

Dunn Transferred

Paul Dunn, Research Entomologist at the USDA Biological Control of Weeds Laboratory, Albany, California, will be transferred to the USDA Biological Control of Weeds Lab in Rome, Italy about April 1, 1981. In Rome he will concentrate on the foreign aspects of biological control of leafy spurge and the knapweeds. Responsibility for the spurge work at Albany will be assumed by Dr. Robert Pemberton who has recently been working on the biological control of Russian thistle at the Albany laboratory.

WYOMING

A survey was made in late August of leafy spurge plants in the area where the insect Oberia erythrocephala was released earlier in the summer. Some of the plants were infested but it will be spring before the adults emerge and survival rates can be determined.

MEETINGS

Old West Funding

A five-state project proposal entitled "Leafy spurge control utilizing integrated management systems" was approved by the Old West Regional Commission in December. The proposal was submitted by the North Dakota Agricultural Experiment Station in cooperation with Experiment Stations at the University of Nebraska-Lincoln, Montana State University, South Dakota State University and the University of Wyoming. The objectives of the proposal are three-fold: 1)

to develop and evaluate techniques for weed and land management to control leafy spurge in the field, 2) to demonstrate methods of leafy spurge control and land management and, 3) to increase the knowledge of the leafy spurge biology and physiology. Funding will be effective March, 1981 through February 1982.

Fargo in January

The Great Plains Ad Hoc Committee on leafy spurge control will meet Jan. 20 in Fargo, North Dakota to discuss ongoing research and the need for leafy spurge research. This meeting is following a suggestion of the leafy spurge steering committee set up following the Fargo and Billings symposiums.

Leafy Spurge Book

Dr. Alan Watson, MacDonald Campus of McGill University, Quebec, is editing a book on leafy spurge. Contributing authors are writing chapters dealing with various aspects of leafy spurge and will have their chapters to Dr. Watson by the end of January. The final manuscript should be together sometime in the coming months.

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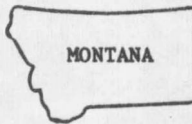
Leafy Spurge News

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ISSUE 2



Additional information will be available from the county agent or weed district supervisor in each county.

Spurge Specials 1981

Leafy spurge tours will again be held around the state during June. Most of the tours will be conducted at demonstration plots showing various levels of control obtained with different chemical treatments. Refreshments will be provided along with displays and discussions on the biology of the plant, dollar losses and some new application techniques. The tours should be fun, informative and offer a break from summer work. A tentative schedule has been set up as follows:

- June 1 or 3 Lake County
- 4 Park County (Clyde Park)
- 5 Silver Bow County (Butte)
- 9 Hill County (Havre)
- 10 Phillips County (Saco)
- 11 Sheridan County (Plentywood)
- 12 Roosevelt County (Bainville)
- 15 Stillwater County (Columbus)
- 16 Powder River County (Broadus)
- 17 Deer Lodge County (Galen)
- 22 Fergus County (Lewistown)
- 26 Judith Basin County (Geyser)

Sheep on Spurge

Barb Landgraf, a graduate student in Range Science, will begin field trials on preferential grazing of leafy spurge by sheep. The sheep have been on a winter spurge-hay trial for the last 3 months and will be moved to the field in May. The grazing trials will be in Geyser, MT at the location of the June leafy spurge tour.

Weed Bill Fails

The weed bill to establish a weed research & education program within the Agricultural Experiment Station and the Cooperative Extension Service of Montana State University was defeated by the Montana legislature in early April.

NORTH DAKOTA

Cell Culture Studies

Plant cell cultures are being used in the study of herbicide metabolism at the USDA Metabolism & Radiation Research Laboratory in Fargo, North Dakota. Donald Galitz, Botany Dept., NDSU-Fargo, is working on projects that include the establishment of cultures of leafy spurge and other weed species and the control of leafy spurge bud development.

Weed Bill

The bill introduced in the North Dakota legislature to, among other things, establish and fund a leafy spurge control program was voted on the end of March. The leafy spurge cost-share program was reduced from \$1 million to \$250,000. The bill also established county weed supervisors, trained by the Extension Service, to oversee the weed control programs in each county.

WYOMING

Spurge Observations

Wyoming researcher Ron Vore made some observations on leafy spurge throughout the 1980 summer season. Although these are only observations with no experimental data to support them, the measurements are reliable. In late April, plants 6-8 inches tall showed flower formation and seed pod development. At the same time seed germination was noted to depths of 6 inches. Seeds were expelled from the capsules as early as mid-July.

In areas of limited soil moisture, the roots at 7-8 feet depths appeared to contain less latex than the more shallow depths. Preformed leaves were noted on new shoot regrowth arising from roots and on the newly formed shoots produced from the seed, each 6-10" below the soil surface.

Regrowth of leafy spurge in areas treated the previous year with Tordon 2K at 2 lb ai/A began showing herbicidal effect upon reaching 8 to 12". Regrowth was sparse compared to untreated areas and was somewhat of a uniform distribution over the treatment areas. The literature seems to indicate that in Europe native populations of leafy spurge are observed to be sparse and uniformly distributed over the area of infestation.

MEETINGS

Spreading the Information

A Forest and Range Pest Management workshop was held in Kalispell, Montana in March. Representatives from the Forest Service, private timber companies, and Burlington Northern attended the meeting which covered pesticide toxicology, weeds, insects and diseases. The workshop included a presentation on leafy spurge, after which several people expressed appreciation for obtaining information about the weed. Various requests were received regarding educational material and the leafy spurge newsletter.

Spurge Symposium

A leafy spurge research, extension and coordination conference will be held June 29 and 30 in Fargo, North Dakota. The primary emphasis will be for research scientists and extension specialists to exchange information developed in the last 2 years and to coordinate future work.

OTHER

Leafy Spurge Specialist

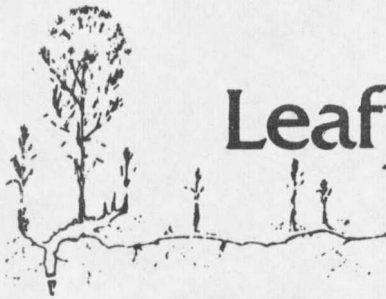
Dr. A. Radcliffe-Smith, a world specialist on the genus Euphorbia, will be visiting the United States and Canada from Kew, England during June and July. The U.S. Dept. of Agriculture and the Canadian Dept. of Agriculture invited Dr. Radcliffe-Smith to study the leafy spurge complex in North America. He will be visiting Eastern herbaria to study collection material before going to Lincoln, Nebraska to examine the leafy spurge nursery and visit field sites in the north central region.

Leafy Spurge Articles

A 10-part series of newspaper articles on leafy spurge is available to extension or research personnel who would like to have the articles printed in their area newspaper. Please contact Claire Barreto for the articles.

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

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Leafy Spurge News

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Issue 3

MONTANA

Leafy Spurge Tours Results

Ten of the original 12 leafy spurge tours were held as scheduled in June. Lewistown and Galen had to be postponed until summer arrived and the plot sites dried out. In spite of the mosquitoes being hungry, the weather threatening and several people not being able to find the sites, attendance was good. Over 280 people attended nine of the tours. A big "thank you" goes to all the county agents and weed district supervisors who helped put on the tours. Dow Chemical Company and Velsicol Chemical Corporation funded the tours and we appreciate their support.

Geyser Weed Fair

The first Montana Weed Fair was held in June in Geyser, Montana at the Roy Baxter Ranch. A crowd of 400 showed up to participate in the Weed ID contest, learn about sheep on leafy spurge and pick up some weed information. Several weed displays were set up at the fair and speakers from different state agencies were present. Already, plans and improvements are being made for next year.

NEBRASKA

Control Work

Dr. Alex Martin, University of Nebraska, is working with various chemical combinations to increase the control of leafy spurge. He is applying herbicides with growth regulators and using herbicides in conjunction with nitrogen fertilizer. Preliminary results show that a spring application of the herbicide plus a growth regulator gives improved control over those applied with no growth regulator. An increased control of leafy spurge topgrowth was also noted when using high rates of nitrogen fertilizer.

NORTH DAKOTA

Applicators

Dr. Rod Lym, NDSU, reports that the roller applicator using a 1:7 solution of picloram to water could save 50% of the cost of a broadcast treatment. The wick applicator using a 1:3 solution of picloram to water would save 70%. Research is continuing on different types of applicators and the use of different additives.

 SOUTH DAKOTA

We regret the loss of Dr. Dan Noble formerly of the Rocky Mountain Experiment Station, Rapid City, South Dakota. Dr. Noble has taken a new position in Main. We wish him the best of luck.

 WYOMING

Soil and Herbicide

Leafy spurge research being conducted at University of Wyoming is examining shoot and root control in treated areas. Soil analysis in the treated areas show that 16 weeks after treatment, the herbicide is concentrated in the top eight inches of the soil profile. Their work indicates that percent clay and percent organic matter are the major factors affecting the herbicide residue in that soil layer. Precipitation is a secondary factor.

Retreatment Control

Ron Vore, extension agronomist at University of Wyoming, evaluated topgrowth control of leafy spurge and concluded that two annual retreatments increased control of leafy spurge topgrowth as compared with original treatment control after three years. Two annual applications of Tordon 22K at 1 lb/A over all original treatments gave excellent results. All retreatments managed to maintain regrowth control to a good or excellent level if the original treatment control was high. A retreatment providing good to excellent control is needed to improve or maintain regrowth if the original treatment was poor to fair.

CANADA

Spurge Identity

P. Harris reports that most Canadian leafy spurge appears to be Euphorbia virgata Waldst. + Kit. and E. psuedovirgata (Schur.) Soo rather than E. esula. However a gradation of morphological characters and possibly hybridization exists between the different spurges so insect preferences must still be determined by feeding tests.

BIOLOGICAL CONTROL

Wyoming

Dr. Robert LaVigne reports that no adult Oberea had emerged from the infested leafy spurge plants at Lander as of the end of June. Eggs were laid in the plants last summer and after hatching, the larvae moved down through the stem, feeding on the pith. The insects over winter as larvae, pupate in the spring, and emerge as adults. The absence of adults this summer may be due to winter kill despite the mild winter in Wyoming. He feels that when eggs are laid late in the season, the larvae may require two seasons to mature and it may be next year before the adults are observed. The insects released at Devil's Tower, Wyoming survived for only 3 days due to extreme temperatures.

Conflicts?

The Biological Weed Control Newsletter states that a possible conflict of interest is shaping up in the biological control of leafy spurge because of interest in other related

spurges as a source of an agriculturally produced petroleum substitute using a plant which is closely related to leafy spurge.

OTHER

Visit Cancelled

Dr. A. Radcliffe-Smith, a Euphorbia specialist from Kew, England, was unable to visit the United States in June as previously planned due to a sudden illness. We wish him a speedy recovery and hope he will be able to visit in the future.

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More Oberea in Oregon

Bob Pemberton, USDA Biological Control Lab, Albany, California, released 124 Oberea in southern Oregon in late June. Fifty-eight of these insects were female and good feeding, mating and ovipositing was observed. Although the majority of the insects were released in small enclosures, a limited number of insects were free released and good ovipositing was observed with these also.

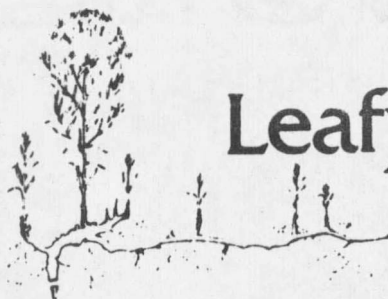
There was, as yet, no evidence of establishment of Oberea at the site where the larvae were released last year.

MEETINGS

Fargo

Officers were elected for the newly formed GPAC Research Committee on Leafy Spurge at the leafy spurge research and extension meeting held in Fargo, North Dakota, the end of June. Cal Messersmith, NDSU is the new chairman, vice chairman is Harold Alley, University of Wyoming, and Russell Lorenz, ARS-USDA, Mandan is the secretary. The next meeting is tentatively planned for June 1982 in Bozeman, Montana.

At the meeting reports were given from each of the states on their current research and participants had the opportunity to look at some North Dakota field sites where the roller and wick applicators had been used to control leafy spurge.



Leafy Spurge News

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MONTANA

DNRC Tours

The Montana Department of Natural Resources and Conservation has funded a leafy spurge program in Montana that pays for chemical treatment for 2 years. Quite a few counties expressed interest in the program but only 12 could be funded with the available money. The program will be continued for another 5 years by a cooperative effort between the county Soil Conservation Service, Weed District and the land owner. Field days were held at the time of the fall applications this year with a representative from Montana State University being present to explain and demonstrate proper field sprayer calibration. Retreatments will be applied as needed for the next 6 years.

Sheep on Spurge

A field study using sheep on leafy spurge was completed this summer in central Montana. Esophageal fistulated ewes (ewes with openings in their esophagi) were grazed on three densities of leafy spurge. After an initial adjustment period, all three groups increased their spurge intake to 40-50% of their diet when there was still plenty of grass left. The sheep on the leafy spurge areas showed a weight gain similar to ewes being grazed on grass in the same area.

NEBRASKA

Research Notes

Alex Martin and his workers are continuing their work in several areas of leafy spurge research. Initial work done with ropewick applicators indicates leafy spurge control may be obtained with 50-75% less herbicide than required for sprayer applications.

Growth regulators were used in conjunction with herbicides applied to leafy spurge. Several of these, especially 'Maintain', showed promise for improved leafy spurge control. Applying nitrogen to stimulate growth before applying the herbicide has also shown potential for increasing the control of leafy spurge.

Researchers at the University of Nebraska are involved with an extensive study on the biology and taxonomy of leafy spurge.

NORTH DAKOTA

Forage vs. \$

Researchers at NDSU-Fargo are looking at a long-term management study on pastures infested with leafy spurge. Forage data from four sites are being looked at to compare the forage increase on treated areas to the treatment cost. This long-term

study should give a breakdown on the costs and returns involved with treating leafy spurge in a pasture situation.

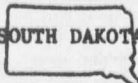
Roller and Wick

Roller and wick research is continuing on North Dakota leafy spurge. Experiments have demonstrated that the roller applicator needs to be lower than what was used previously in order to treat the smaller plants. Additives such as foam, oil or surfactants do not increase the control with the roller or wick. The herbicide:water ratio has been narrowed down to three concentrations that seem to be effective, depending on the leafy spurge density. Ratios of 1:7, 1:4 and 1:3 are being used with the 1:4 ratio most often used.

More Research . . .

Other NDSU research is looking at the carbohydrate movement from the leaves to the roots in leafy spurge.

Plant growth regulators are being applied to spurge before herbicide application in an attempt to stimulate growth of vegetative buds in order to increase the number of leafy spurge shoots at the time of spraying.

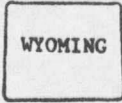
 SOUTH DAKOTA

Site and Soil

Over the past several years the Rocky Mtn. Experiment Station has been looking at leafy spurge infestations and the soils where the infestations are. This summer was the final season to gather data. The data will now be examined to see if there are relationships between the infestations and the soil characteristics.

Spurge in the Woods

Portions of the Black Hills National Forest have been treated with a combination of high rates of 2,4-D ester and diesel fuel in water to control leafy spurge. The control has been excellent according to Dr. Leon Wrage of the South Dakota Cooperative extension. Dr. Wrage feels the control achieved in the forest may be partially due to site characteristics which may be unique to that area.

 WYOMING

SULV for Spurge?

Efforts are continuing to evaluate new herbicides and/or new formulations of herbicides that may be more effective and economical for the control of leafy spurge. One of the new formulations of 2,4-D which is being marketed is "DED-WEED SULV amine". Data are unavailable on this herbicide for control of perennial weeds in this area. Extensive aerial and/or ground-applied plots have been established this year in Wyoming on leafy spurge, Canada thistle, field bindweed, sagebrush, greasewood and spreading wild buckwheat. All of the treatments had regular 2,4-D amine formulations applied next to the SULV amine for direct comparisons.

Evaluation of the 1981 plots indicate no visual differences in vegetative topgrowth control of leafy spurge between common 2,4-D formulations and SULV. Regular 2,4-D appeared to have greater root activity. However, actual kill or control of perennial weeds cannot be evaluated until one year after application. It remains until the 1982 season before the true value of SULV amine can be understood. Chemical dealers in several states are promoting "DED-WEED SULV amine" for leafy spurge

control. No research data, by either the manufacturer of the product or universities, have been provided which substantiates the claims for "DED-WEED SULV".

BIOLOGICAL CONTROL

Oberea Update

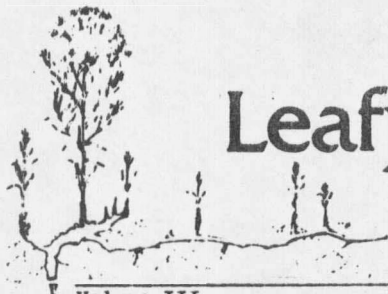
Robert Pemberton of the USDA Biological Control Laboratory in Albany, California reports that they are continuing to monitor the Oberea release in Oregon. A number of insects released this year have gone through the stems and roots indicating that the plants are acceptable. The success of establishment will be assessed after the insects have overwintered. Some eggs that were laid in the stems did not hatch which may indicate ovipositioning (how the eggs are laid) problems. Researchers will continue to monitor this insect.

New Release

Two species of beetles from the genus Apthona will be released on leafy spurge in 1982. These insects feed on the crown area of the plant and are currently undergoing testing in Europe.

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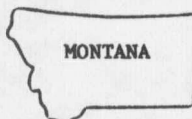
Leafy Spurge News

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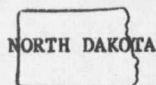


Pathogens on Spurge

Scientists are working with pathogens to aid in control of leafy spurge. Sherry Turner, after receiving her Master of Science in Plant Pathology from Montana State University, is in Frederick, Maryland screening pathogens for use on leafy spurge. Sherry's work will involve feeding studies to determine what other plants the pathogens will attack. She will also study the effectiveness of the pathogens on leafy spurge.

Fungi Toxins

Plant pathologists at Montana State University are examining toxins from the fungus Alternaria to see if they can be used to kill leafy spurge. The toxins are being identified to see how active, effective and important they are on leafy spurge. The pathologists also need to find out if the toxins affect useful plants.



Forage Plus \$

Increased forage yields were obtained with 50 out of 59 herbicide treatments used on leafy spurge. The

most economical treatments with resulting high forage yields were a combination of 1 lb/A 2,4-D and .25 lb/A of Tordon or Tordon alone at .25 lb/A. Leafy spurge control by the end of summer was only 40 to 60% but if this treatment is applied yearly the infestation should gradually decrease and at the same time result in a \$20 to \$25 per acre per year profit because of increased production.

Spurge in Trees

Weed researchers at North Dakota State University are evaluating leafy spurge control in trees. Applications of picloram and dicamba with the controlled droplet applicator are being studied. It may be possible to apply these herbicides to control leafy spurge without damaging the trees due to the low output per acre of the controlled droplet applicator.

WYOMING

Program Update

Wyoming's leafy spurge program, implemented in 1978, is funded by landowners, weed districts and state appropriations. Over 1800 cooperators have initially treated 35,968 acres and have retreated 29,158 acres since

July, 1978 to December 31, 1981. Cooperators include private, state and federal landowners.

The program is on schedule and the effectiveness is projected at 75 to 90%. This means 10 to 25% of the original acres will have to be treated each year after the program ends in 1984 (this estimate would include new infestations, regrowth, new seedlings, etc.). Research studies by the University of Wyoming indicate that effectiveness of treatments on topgrowth is higher than projected.

A monitoring program for herbicide contamination was initiated in 1977. This involves collecting water, sediment and soil samples which are analyzed for herbicide contamination plus studying soil residues of various herbicides. During the last 5 years there were no indications of pesticides in streams at a level which would be harmful to the environment. Herbicide monitoring reports are available in the Wyoming Department of Agriculture Office.

BIOLOGICAL CONTROL

Canadian Research

Three new insects may be released on leafy spurge this summer. Dr. Peter Harris, Agriculture Canada, expects the screening reports on Lobesia euphorbiana and two Apthona species to be completed this winter. The reports must be approved by the committee before release of the insects. Lobesia euphorbiana reduces seed production and the Apthona species are root-feeding flea beetles.

Dr. Harris reports that Oberia is surviving in small numbers at the Canadian release sites.

Bio Control Program

Directors from the Agricultural Experiment Stations in North Dakota, South Dakota and Montana and Experiment Station representatives from Wyoming and Idaho met in Rapid City, South Dakota in January. The major thrust of the meeting was to outline a program of receiving biological control agents from Canada. Each director will assess what his university has in terms of money, manpower and space to assist the biological control efforts. The insects being brought in will be a diverse group, some of which will be for release on leafy spurge.

The directors from the five states hope to develop a coordinated program on biological control. The program will allow for division of responsibilities between the states and facilitate interaction with the Canadian and U.S. quarantine systems. The group of directors will meet again in Bozeman, Montana on June 22, 1982.

OTHER

Leafy spurge is not the only spurge being studied. Dr. A. G. Wheeler, Pennsylvania Department of Agriculture, studied spotted spurge (Euphorbia maculata) and several other spurges and the insects associated with the plants. Spotted spurge is an occasional weed in home lawns and becomes a major pest only in localized areas such as western New York's onion-growing region. Dr. Wheeler concluded that native spurges, such as spotted spurge, host few chewing insects that might help limit infestations of introduced, weedy spurges.

USDA Money

The USDA has given a \$200,000 grant to North Dakota, Montana and Wyoming for research on control of leafy spurge. The grant extends to 1984.

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

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Plant and Soil Science Dept.
Montana State University
Bozeman, MT 59717

APPENDIX C

PLANT GROWTH CURVES

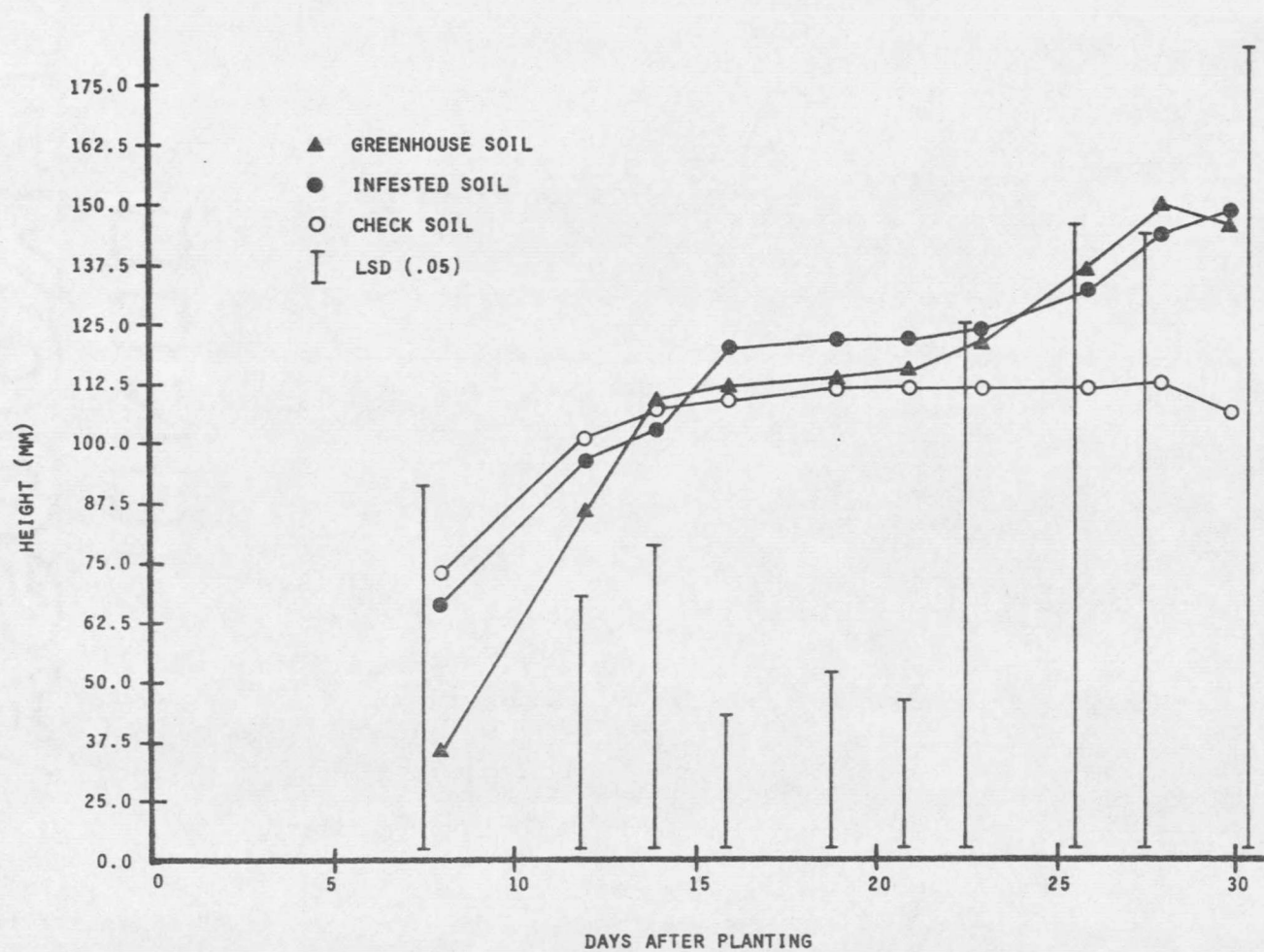


Figure 11. Growth curve of *Agropyron spicatum* in three soils.

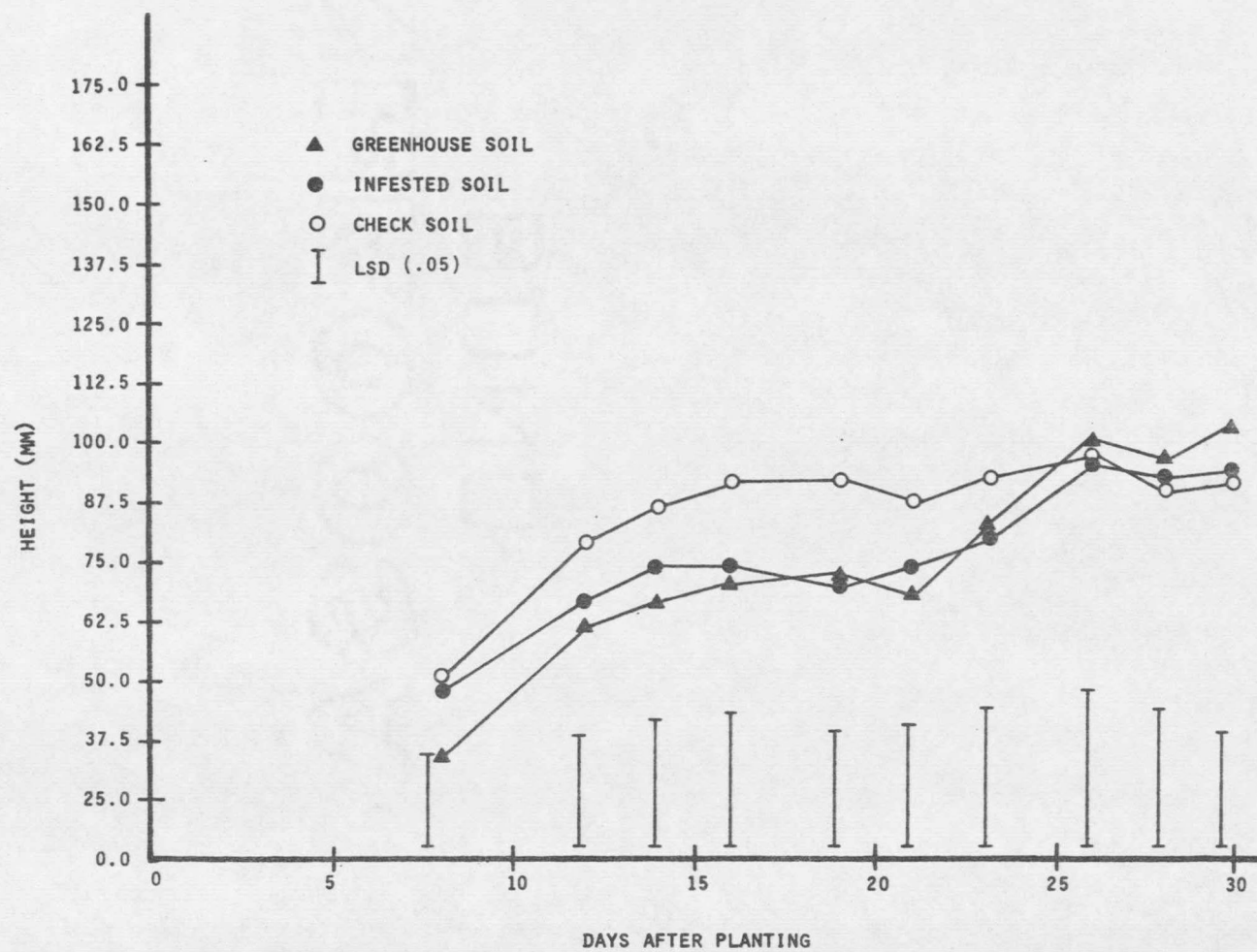


Figure 12. Growth curve of *Bromus inermis* in three soils.

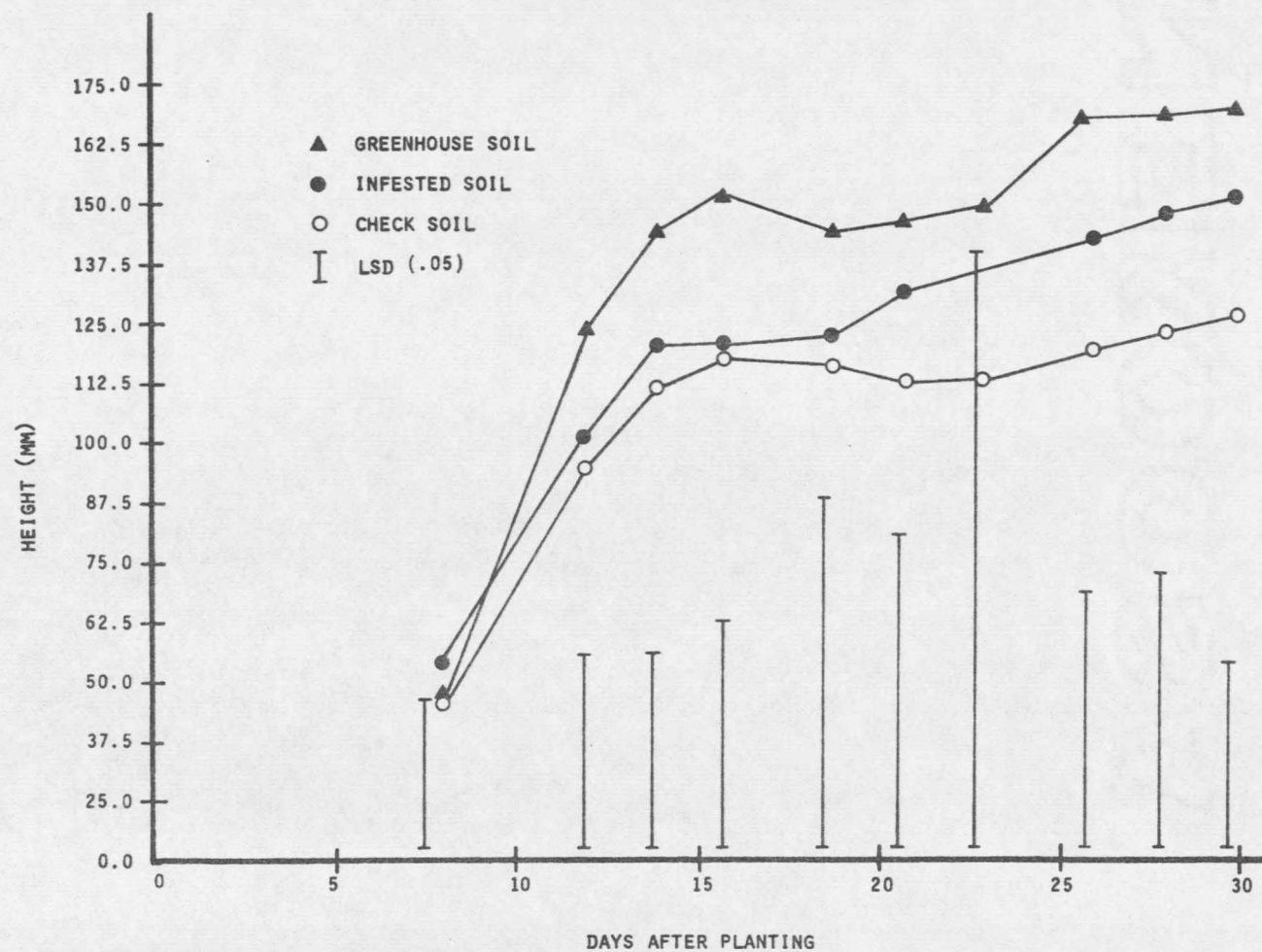


Figure 13. Growth curve of *Elymus angustus* in three soils.

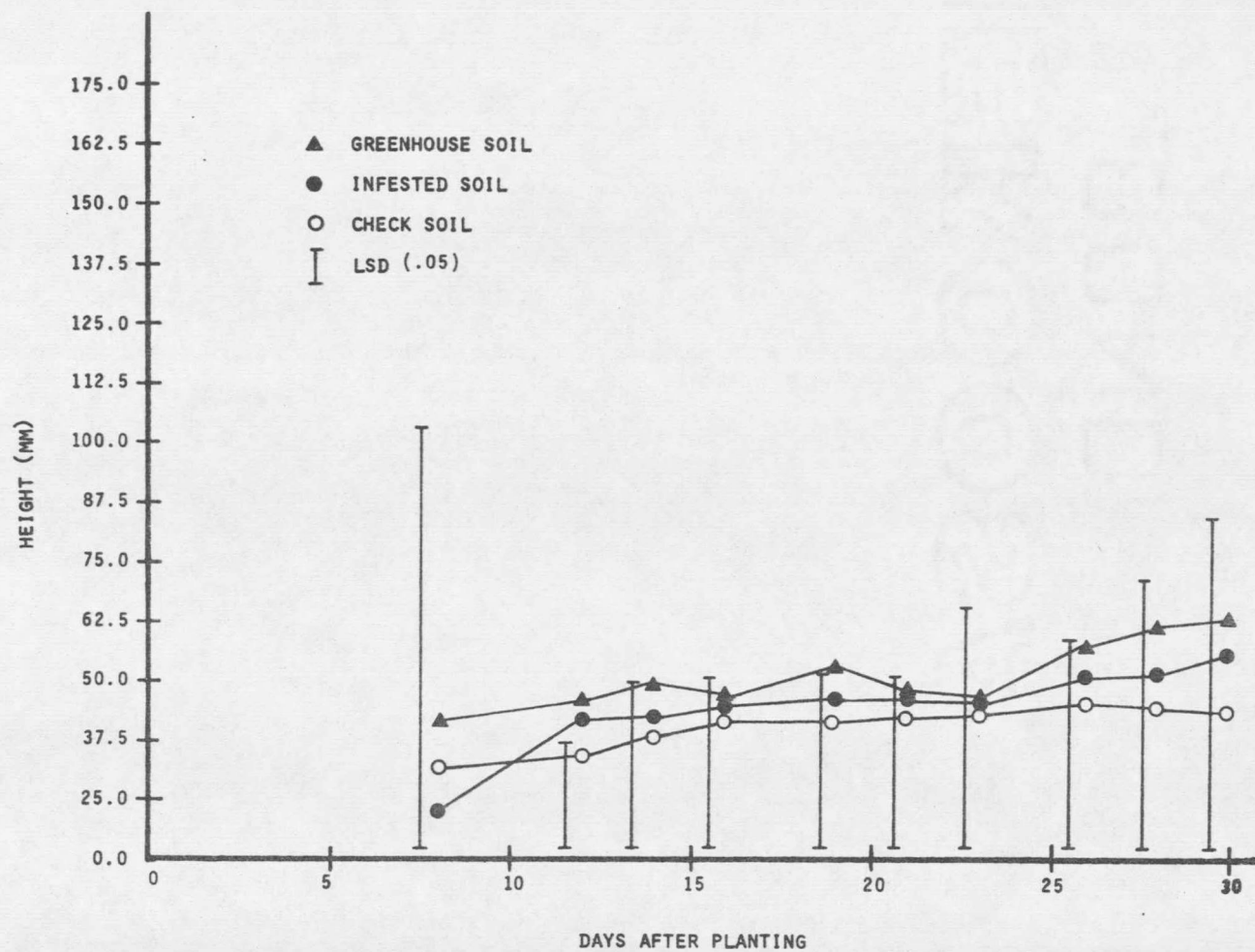


Figure 14. Growth curve of *Alopecurus arundinaceus* in three soils.

APPENDIX D

REGRESSION LINES FOR PLANT GROWTH

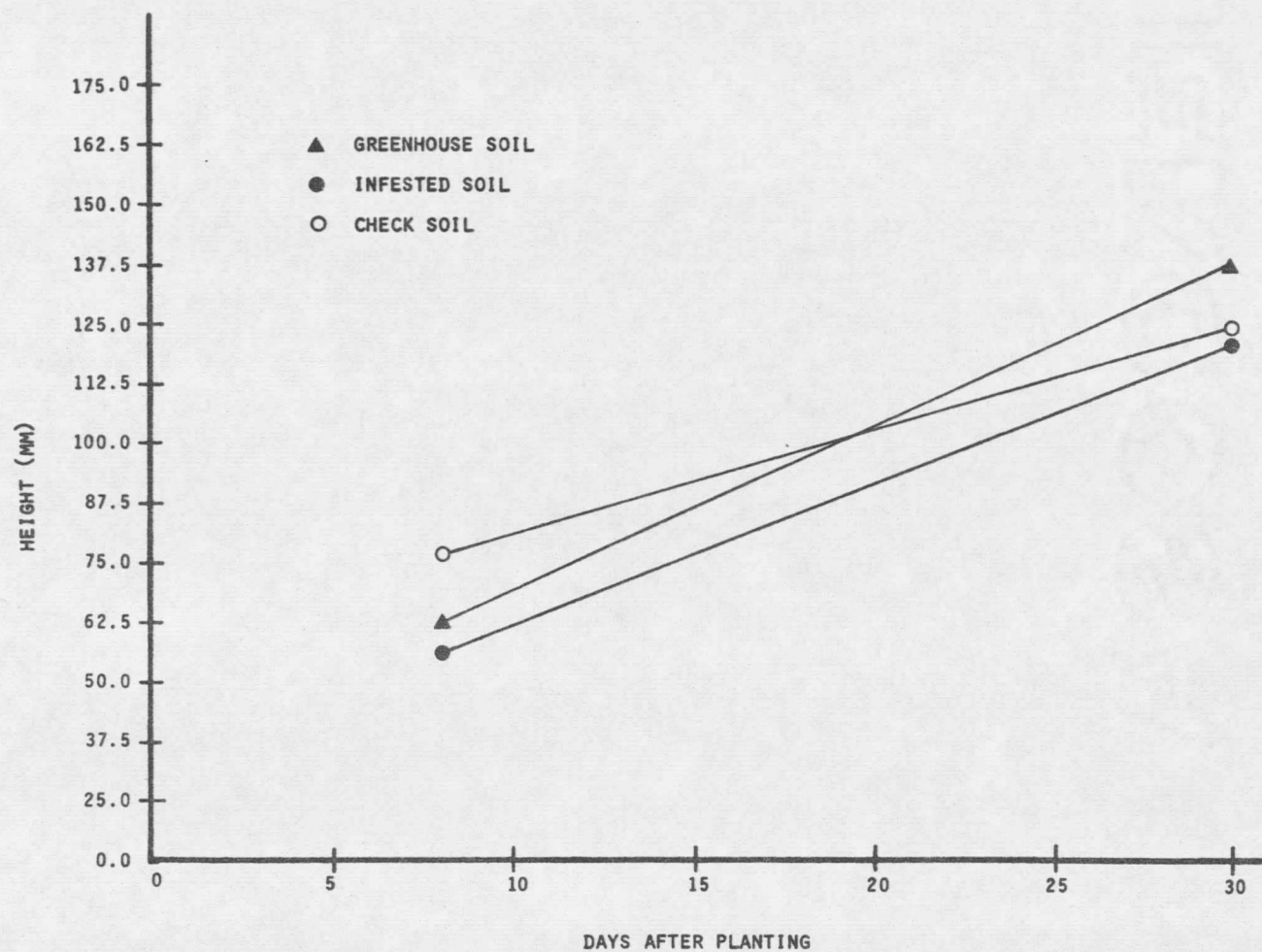


Figure 15. Regression lines for growth of *Agropyron trachycaulum* in three soils.

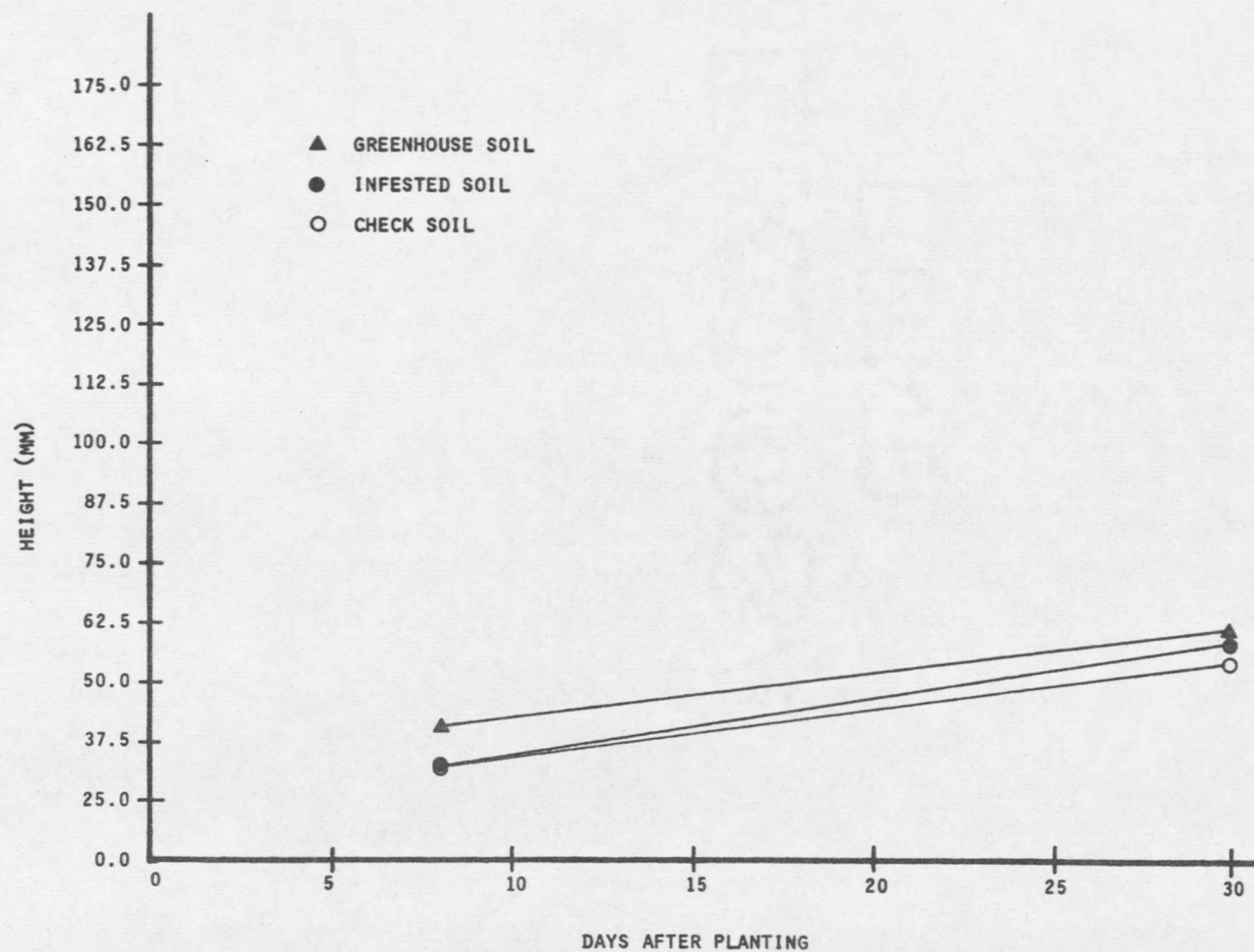


Figure 16. Regression lines for growth of *Alopecurus arundinaceus* in three soils.

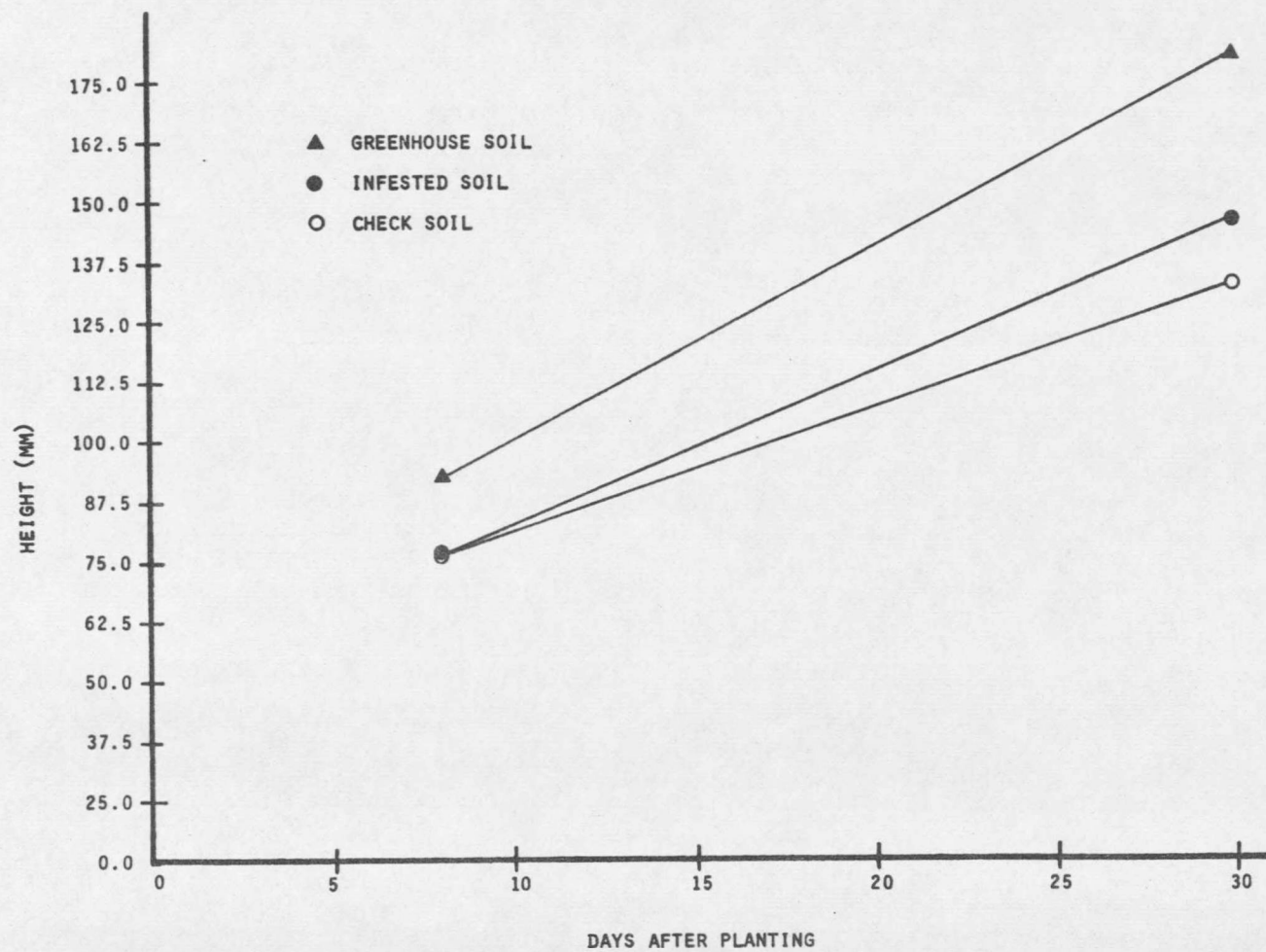


Figure 17. Regression lines for growth of *Elymus angustus* in three soils.

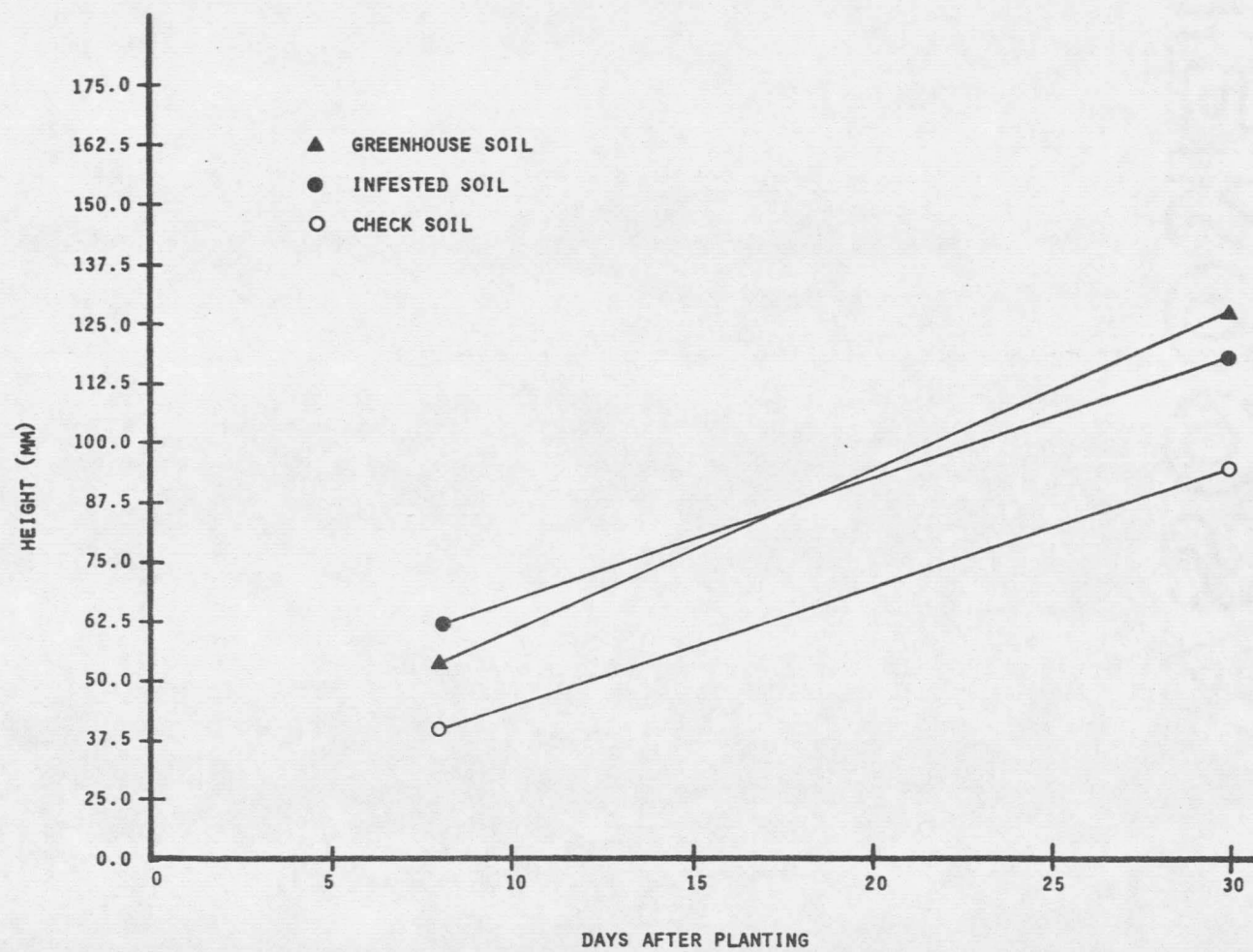


Figure 18. Regression lines for growth of *Elymus cinereus* in three soils.

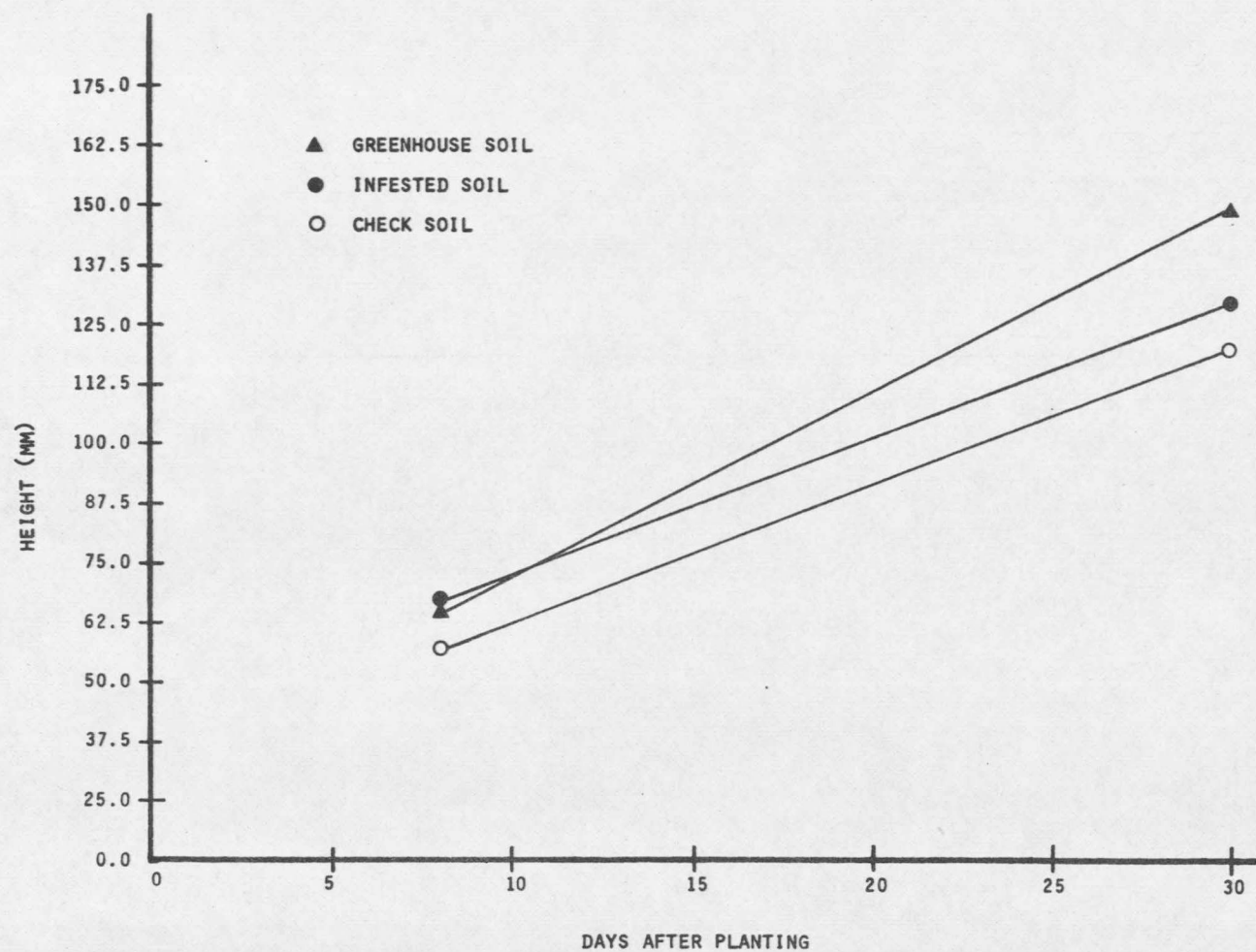


Figure 19. Regression lines for growth of *Agropyron smithii* in three soils.

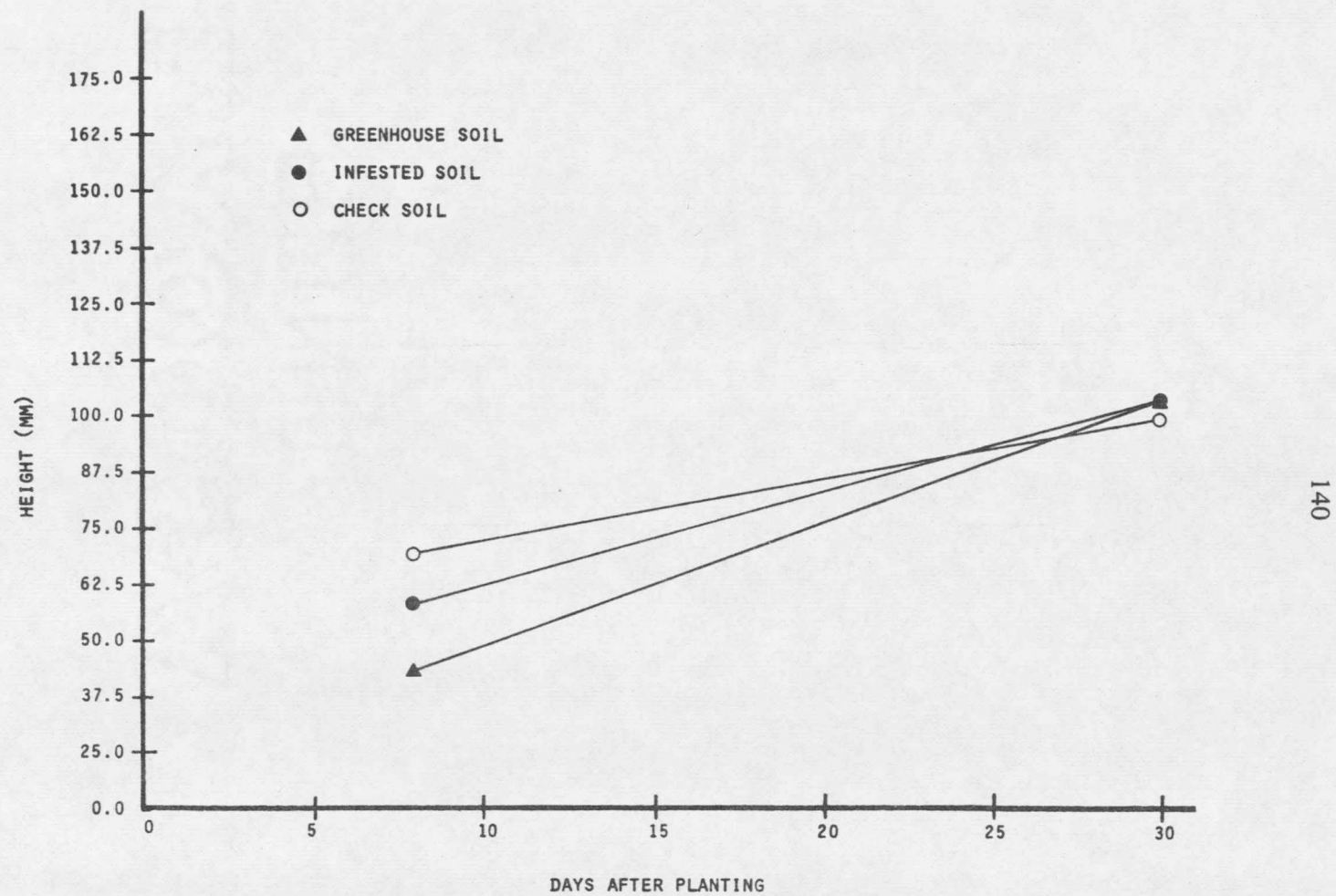


Figure 20. Regression lines for growth of *Bromus inermis* in three soils.

